Nov. 16, 1971 S. A. PARKER 3,619,959

CONCRETE BUILDING

Filed July 7, 1969 2 Sheets-Sheet 1

Fig. 1

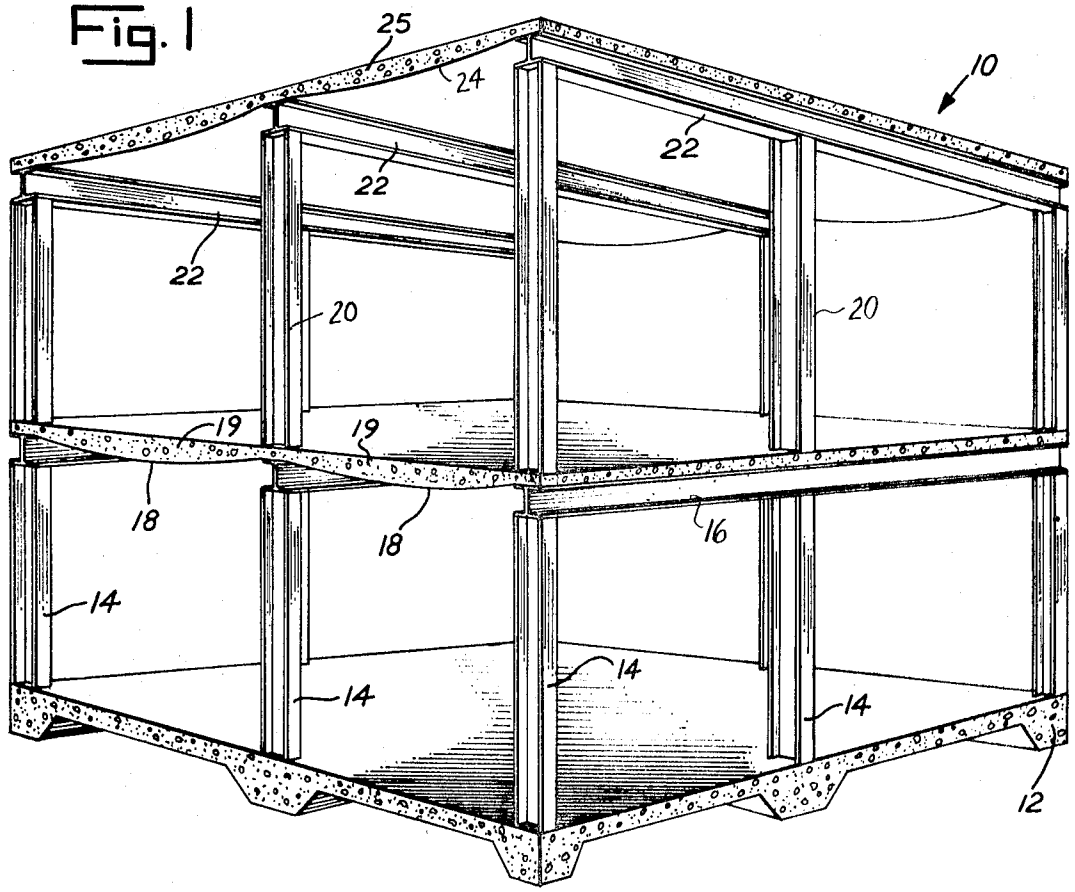


Fig. 2

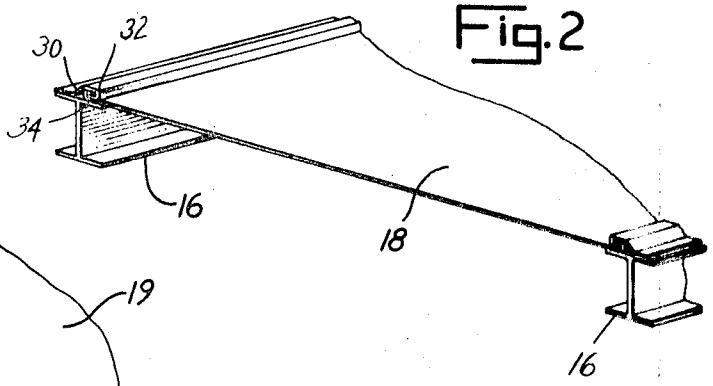
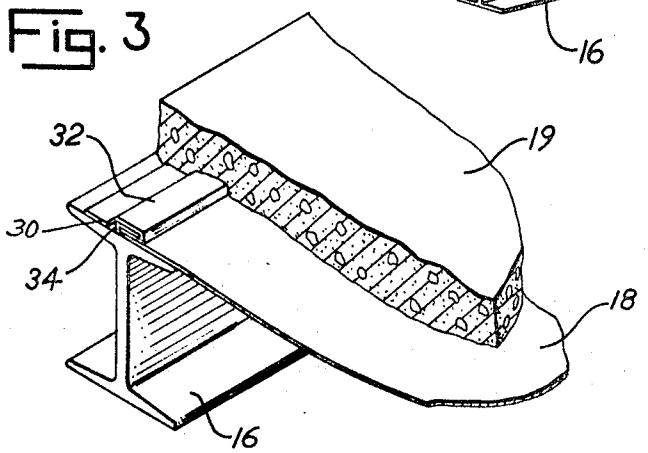


Fig. 3



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Nov. 16, 1971 S. A. PARKER 3,619,959

CONCRETE BUILDING

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Fig. 4

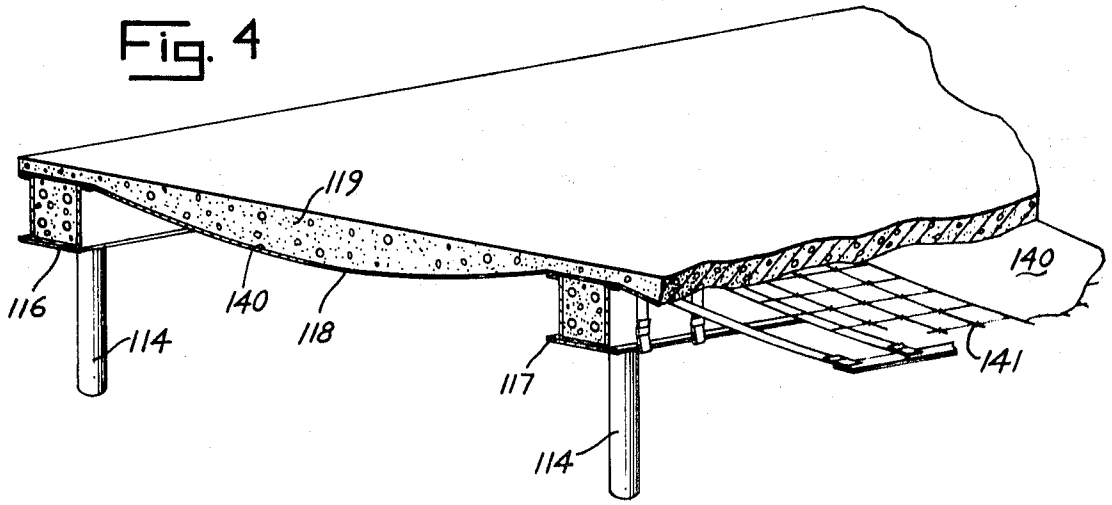


Fig. 5

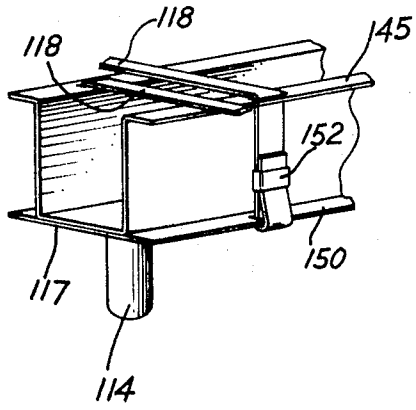


Fig. 7

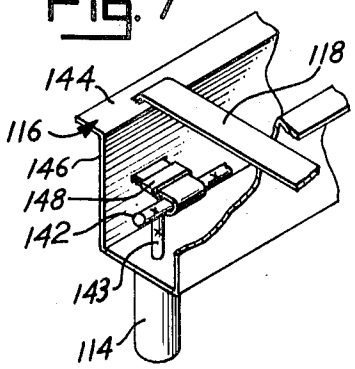


Fig. 8

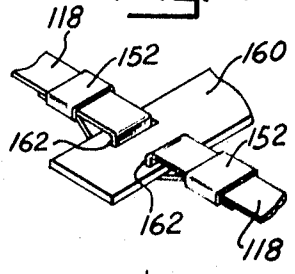


Fig. 9

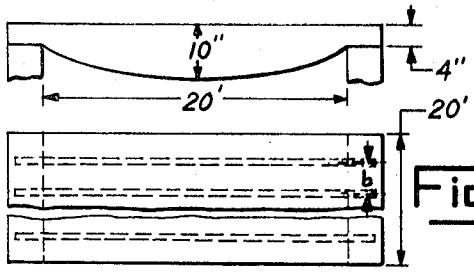


Fig. 10

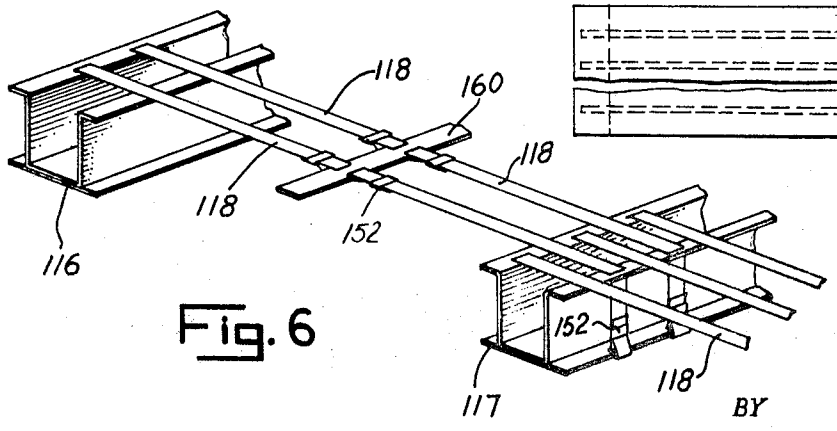


Fig. 6

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United States Patent Office 3,619,959 Patented Nov. 16, 1971

3,619,959

CONCRETE BUILDING

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Filed July 7, 1969, Ser. No. 839,194
Int. Cl. E04b 1/24
U.S. Cl. 52—223 1 Claim

ABSTRACT OF THE DISCLOSURE

An improved elongated concrete member and a method for fabricating improved elongated prestressed or nonprestressed concrete members in situ and without form work comprising stretching a support comprising a sheet or a plurality of bands between spaced end supports, applying wet concrete onto said support, and curing the concrete to form a prestressed or nonprestressed concrete member having a flat top surface and a generally parabolic bottom surface between the end supports.

BACKGROUND OF THE INVENTION

This invention relates to concrete structures and to methods of fabricating concrete structures, and more particularly, this invention relates to prestressed and nonprestressed concrete beams, floors or ceilings of novel design and to a method of making such beam, floor or ceiling.

Multifloor concrete buildings are conventionally made by forming one story at a time. In a typical structure, the foundation is formed below ground level and wooden forms or like form work for the walls are set in place. Reinforcing rods may be tied to the foundation and are disposed between the spaced wooden forms. Wet concrete is poured between the wooden forms. After the concrete has set, the wooden forms, typically plywood panels suitably fastened to one another and retained in position, are removed and by means of scaffolding the wooden forms for the column supports and floor for the next story are positioned. The floor of the next story, which is also the ceiling of the story below, is formed by providing wooden forms beneath the desired floor, positioning reinforcing rod where desired, and then pouring concrete onto the wooden form to form the floor, which may be of the flat slab or two-way slab types. The wooden forms are removed after the concrete has set and can be reused for the next floor above. However, the wooden forms have only limited life because the use is so hard. It is known from the literature available in the trade that the cost of form work is a major factor in reinforced concrete construction. See, for example, "Formwork for Modern Structures," by Sir Frederick Snow, Chapman & Hill 1965.

Notwithstanding improvements in concrete, fabrication of buildings in the fashion stated above is slow, requires much labor and is relatively expensive. For some applications, it has been suggested that the floors which are in the nature of slabs be formed at the site, one atop the other, and then elevated into position by large power rams. The size of the power rams limits this method. Lift slab construction is slow and very hazardous. Slabs have fallen due to either power ram failure or weight distribution being such that slab failure occurred.

Another suggestion (see Chiado Pat. 3,090,165) has been to precast floor sections at a plant and then ship them to the site for assembly. Due to bulk and weight, shipping of large and heavy sections for large distances is not economically feasible. Formation of precast panels at the job site would save shipping costs, but would then require large expenditures for equipment to raise the slabs to the desired elevations.

Yet another method used in buildings is steel deck flooring where approximately 2" of concrete is poured over corrugated steel decking. This system is used primarily in steel buildings to form the floors or ceilings. This system has only been successful with spans up to 5 or 6 feet between expensive steel truss sections. This system is quite expensive and requires a heavy use of steel, and will only stand light floor loading.

Thus, an object of this invention is to provide an improved concrete floor or ceiling structure and a method for fabricating same in situ wherein deficiencies and disadvantages in prior structures and methods are obviated.

Another object of this invention is to provide an improved concrete floor or ceiling that can be formed in situ in a simple manner without the necessity for wooden forms or similar scaffolding.

A further object of this invention is to provide an improved elongated beam or floor or ceiling which can be supported only at its ends for relatively great lengths and without the number of support columns or girders required in conventional concrete structures.

Yet another object of this invention is to provide an improved method for forming a concrete member in situ without the necessity for wooden forms which comprises securing a support member at its ends in desired position, applying a predetermined quantity of wet concrete onto the support member to tension same to a predetermined value, and curing the concrete to form prestressed or non-prestressed concrete members having a generally parabolic bottom between its ends. Other objects and advantages of this invention will be made more apparent hereinafter.

BRIEF DESCRIPTION OF THE DRAWING

Preferred embodiments of the present invention are illustrated in the attached drawing wherein like numerals refer to like elements in the different figures, and wherein:

FIG. 1 is a skeleton of a concrete structure embodying the present invention;

FIG. 2 is a detail view illustrating a sheet-like support member in place between a pair of end supports;

FIG. 3 is a detail view of the connection of sheet-like support member to an end support, with concrete set in place thereabove;

FIG. 4 is a detail view of a concrete floor or ceiling structure illustrating the support member formed from a plurality of strap-like members;

FIG. 5 is a detail view on an enlarged scale of the end support shown at the right in FIG. 6;

FIG. 6 is a perspective view illustrating a plurality of strap-like members attached to end supports and to an intermediate support where larger spacings are required between end supports;

FIG. 7 is a detail view on an enlarged scale of a modified manner of securing the end of a strap-like member to an end support;

FIG. 8 is a perspective view on an enlarged scale illustrating the connection of the strap-like members to an intermediate member;

FIG. 9 is a cross-sectional view of a concrete member formed in accordance with the principles of the present invention; and

FIG. 10 is a plan view of the concrete member of FIG. 9, illustrating the spacing of bands.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

Concrete is in many areas the cheapest material available for carrying compressive loads. Though its compressive strength is high, its tensile strength is only about 10 to 15 percent of its compressive strength and this

value is often further reduced to zero by shrinkage cracks which occur during curing.

One prior method of increasing the tensile strength of a concrete member was to incorporate reinforcing rods on the tension side to carry the entire tensile load. The addition of reinforcing bars, made, for example, from steel, gave a member with a low cost material to carry compressive stresses plus steel with a minimum amount of fabrication to carry the tensile stresses. However, a disadvantage of the concrete reinforced with steel bars was that all of the concrete on the tensile side of the neutral axis was useless dead weight, other than serving as a connection between the compressive concrete and the steel. Typically, the reinforcing steel bars have a tensile property of 30,000 p.s.i.

A further improvement in concrete construction was prestressed concrete which goes beyond reinforced concrete. In prestressed concrete structures, all of the concrete on the tensile side of the neutral axis is put under an initial compressive stress of such a magnitude that all design loads which are to be applied to the structure in the future can reduce the stress, but will not put the concrete in tension. Further, the prestress is applied in such a manner that it creates a moment of opposite sign to those which will be produced by applied dead and live loads. In the ideal design, this negative moment carries all the dead load and creates the maximum allowable compressive stress in the concrete on the tensile side of the member. As far as the stresses in the prestressed member itself are concerned, it is then a weightless structure with all its moment-carrying capacity available for live load. Typically, these cables are of high strength steel and are round in configuration, and buried in the center or just off center of the concrete flat slab.

The present invention is concerned with a concrete member, as particularly applied to an elongated beam or an extended ceiling or floor structure. Referring to FIG. 1, there is illustrated a skeleton of a building **10** which incorporates the present invention. The foundation **12** is suitably formed in the ground and is of sufficient strength to support the maximum design weight of the building structure. Upright columns **14** are provided to support the weight of the building and the tops of the columns **14** are connected by longitudinally extending beams or end supports **16**. The ceiling or floor is provided by the concrete member comprising support means **18** and cementitious material or concrete **19** formed in situ in accordance with the present invention without need for form work.

A second story may be provided in the building structure by extending columns or beams **20** upwardly from the floor defined by the concrete **19** and support means **18**. Securing the tops of the columns **20** to one another are the elongated beams or end supports **22**. The second floor ceiling or roof in the case of a two-story building is comprised of support means **24** disposed between the adjacent end supports **22** and concrete **25** poured onto the support means and permitted to cure. It should be noted that the ceiling of the first and second floors could be poured simultaneously since no vertical scaffolding is required.

Referring now to FIGS. 2 and 3, there is illustrated a method of securing a support means, for example, sheet **18** to the end supports **16**. As shown, the end supports **16** may comprise an I-beam. Secured to each I-beam **16** or formed integrally therewith is a retainer **30** which comprises an elongated channel-like member having a bent-over portion **32** which is adapted to receive and cooperate with the complementary elongated bent-over portion **34** on the sheet **18**. The sheet **18** may be joined to the end supports **16** so that there is no prestressing of the sheet **18**. However, if it is preferred that a predetermined prestressing be applied to the sheet **18**, the specific manner of calculating the degree of prestressing will be considered hereinafter.

Suffice it to say that preseressing of the sheet **18** to a predetermined value prior to adding the wet concrete will permit a resultant beam or floor or ceiling structure that has a flat top with parabolic contour beneath of predetermined center thickness after the concrete is set.

It is readily apparent from the foregoing explanation as to FIGS. 1–3 that fabrication of a concrete building structure in accordance with the present invention will obviate the need for form work for the floor or ceiling structure. Thus, there are very significant savings in the cost of the material that normally goes into the wooden form work set in place before pouring the concrete and in the labor in setting up the form work and then removing same after the concrete has cured. Furthermore, there is a savings in concrete by use of the present invention, for in normal practice it is an economical necessity to utilize a constant cross-section the full span distance in order to gain the desired thickness in the center of the span. This is because of the extreme cost of contour carpenter work. In the present invention it will be noted that the top of the span of the floor will be flat, whereas the bottom thereof will be generally parabolic. There is less dead weight concrete in a beam or floor or ceiling structure made in accordance with the present invention. Since it will be apparent that a floor of one-story is also the ceiling of the story below, these terms may hereinafter be used interchangeably. Further, a floor is an extended beam and therefore in considering any cross-section or portion of a floor, the term beam will be used interchangeably.

Turning now to FIGS. 4, 5, 6, 7 and 8, there are illustrated modifications of the present invention, wherein the support means is comprised of a plurality of separate straps or bands, rather than a single sheet. In FIG. 4 it is seen that the upright columns **114** are adapted to support beams or end supports **116**, **117**. The lower ends of the upright columns **114** are adapted to be secured to the foundation or to a floor below. The end supports **116**, **117** are supported on the top of the columns **114**, as, for example, by having projections or reinforcing rods extend upwardly from the columns **114** through openings in the end supports **116**, **117** into the end supports **116**, **117**. Secured to the end supports **116**, **117** are a plurality of straps or bands **118**. Concrete **119** is carried on top of the bands **118** with the result that a floor structure having a parabolic bottom results in a manner similar to that of FIGS. 1, 2 and 3. Since the bands **118** are spaced laterally from one another, a filler material **140** such as a film or sheet of wood, or plastic, for example, polyethylene may be placed over the bands **118** in order to cooperate with the bands **118** to retain the wet concrete during the curing process.

The bands **118** are preferably fabricated from a material having very high tensile strength, for example, a hardened strip steel with a bainitic structure made by Sandvik and sold under the trade name Hardflex.

FIGS. 5 and 7 illustrate details of the end supports. The end support **116**, as shown in FIG. 7, is provided with a reinforcing rod **142** positioned longitudinally thereof and secured in place by means of the upwardly extending reinforcing rods **143** from the columns **114**. A strap **118** is adapted to pass through an opening in the flange **144** of the end support **116** and then through the end wall **146** of the end support **116** over and about the extended reinforcing rod **142** and then clamped in place by a band or retaining member **148**. It will be appreciated that each of the bands **118** are spaced along the length of the end support **116** in generally parallel relationship to one another. These bands **118** are generally transverse to the end support and extend through openings in the flange **144** and openings in the side **146** and are secured to the reinforcing rod **142** by means of retaining members or clamps **148**. A basket weave design (not shown) could be used, with sets of parallel bands **118** crossing each other at approximately 90°.

The support **117**, as shown in FIG. 5, is of the type adapted to be disposed centrally of a wall member. Spe-

cificially, it is intended that there be an end support **116** to the left and to the right of the intermediate beam **117**, as shown in FIG. 4. The strap **118** extending from the left and secured to the end support **116**, as shown in FIG. 4 is adapted to pass over the intermediate supports **117** through an opening in the flange **145** and an opening in the flange **150** and be bent over on itself so as to be secured by a member or clamp **152**. The strap **118** from the right hand support (not shown) passes over the top of the intermediate end support or beam **117** and down through similar openings in flanges **145** and **150** and is likewise secured by a retaining member or clamp **152**. It is apparent from this arrangement that there is a balancing of the forces applied to the intermediate support **117** so that no undesirable moments are applied thereto.

In FIGS. 6 and 8, there is shown an alternate support arrangement for spanning between adjacent beams **116** and **117**. An intermediate member **160** is disposed between a pair of adjacent end supports and in generally parallel relationship thereto. The straps or belts **118** are adapted to be secured at one end to the member **160** in the fashion shown, for example, in FIGS. 6 and 8. The straps **118** extend through openings **162** in the elongated intermediate member **160** and are bent upon themselves and secured by means of a clamp **152**.

Briefly, in utilization of the present invention, the uprights or columns **114** are secured at the lower end to a foundation and extended upwardly in a vertical plane. The beams **116**, **117** are suitably affixed to the upright columns **114** and then the desired straps **118** are tensioned between the end supports. Since it is intended that the straps **118** be spaced from one another, a sheet filler as, for example, a film of plastic **140** is disposed on top of the straps and concrete is then poured onto the filler material. It may be desired to use a wire mesh **141** over straps if the strap spacing is such that too great a sag might develop by filler **140**. The weight of the concrete causes the straps **118** to deflect downwardly to a generally parabolic form as best seen in FIG. 4, resulting in a prestressed or non-prestressed concrete beam structure after the concrete cures. No distinction is intended between prestressed and non-prestressed concrete insofar as the invention is concerned.

Those persons skilled in the art will be familiar with texts describing the differences in prestress and non-prestress concrete, for example, "Modern Prestressed Concrete" by H. Kent Preston and Norman J. Sollenberger, McCraw-Hill 1967 and "Design of Prestressed Concrete Structure" by T. Y. Lin, John Wiley & Son, Inc., 1967. It is evident to those skilled in the art that structures made as shown in the drawings and description thereof will produce a non-prestressed structure. However, if temporary compression members or spreaders placed between beams **16** (FIG. 2) or **116** and **117** (FIGS. 4 and 6) are employed and then removed after the concrete has cured, then the horizontal structure will be prestressed. For high floor loading designs, strap **118** or sheet **18** may require pre-tensioning before the wet concrete is poured in place.

The roof of my new building structure may be formed from materials other than concrete, for example, the roof might be gypsum tarred to form an acceptable waterproof roof. Other lightweight roofing could be used.

Designers using the system of this invention have at their disposal many design flexibilities. The decision whether to use a non-prestressed system or a prestressed system will depend on the economics of the building under construction and the type of loading on the floor. Also the type of filler material such as high strength concrete, lightweight concrete, gypsum, etc., is a design consideration.

By use of this invention, there is no necessity for the normal wooden form work beneath the beam as utilized in conventional concrete construction. The amount of concrete utilized may be reduced considerably from the present practice of utilizing a constant cross-section the full distance in order to gain the desired thickness at the center of the expanse of beam or floor.

The concept of the present invention may best be understood from the following discussion. The variables that may be controlled for a desired contour of beam and center thickness of such beam are:

b—the center to center spacing of steel straps
F_1—tensile force, or preload applied to the straps before pouring wet concrete
Y_{max}—deflection of steel straps at center of span under the load of wet concrete. (This value makes up part of the desired section thickness.)
l—span of the straps between supports
A—cross-sectional area of straps
h_f—uniform height above original strap position. (This value is the section thickness at the supports. It also makes up the other part of the section thickness in the center of the span.)
ρ—density of wet concrete

By definition, the desired section thickness at the center of the span would be:

(1) Center section thickness $=Y_{max}+h_f$

For steel straps, the equation relating the above listed variables is as follows:

(2)
$$b=\frac{1.3333F_1\left(\frac{Y_{max}}{l}\right)^2+[53{,}000{,}000\ A-3.2F_1]\left(\frac{Y_{max}}{l}\right)^4}{0.3333\rho h_f Y_{max}+0.2667\rho Y^2_{max}}$$

The equation solves for strap spacing, b.
Strap tensile stress may be calculated as follows:

(3)
$$\text{Strap tensile stress}=\frac{F_1}{A}+E\left[2.667\left(\frac{Y_{max}}{l}\right)^2-6.4\left(\frac{Y_{max}}{l}\right)\right]$$

The formula, which might be modified slightly for practice allowances in a situation, may be used in the following manner. Assume a structure as depicted in FIG. 9. Straps will be made of steel having a yield strength of 100,000 p.s.i., and a stress of 80,000 p.s.i. will be applied. Assume further that the straps to be used are 1.0" wide by 0.062" thick-(0.062) in.^{2} area). Concrete density (wet) is 155 lb./ft.^{3} or 0.0897 lb./in.^{3}. It can be shown that for a problem as described, the volume of steel cannot be reduced or increased by merely changing strap dimensions, i.e. the stress values dictate a given volume of steel strap or sheet. The value for a given yield strength would be as follows:

$Y_{max}=10-4=6''$
$l=(20)(12)=240''$
$A=.062$ in.^{2}
$h_f=4''$
$\rho=.0897$ lb./in.^{3}

By use of Equation 3 the preload can be calculated:

$$\frac{F_1}{A}=\text{Total stress}-E\left[2.667\left(\frac{Y_{max}}{l}\right)^2-6.4\left(\frac{Y_{max}}{l}\right)^4\right]$$

$$\frac{F_1}{A}=80{,}000-30{,}000{,}000\left[2.667\left(\frac{6}{240}\right)^2-6.4\left(\frac{6}{240}\right)^4\right]$$

$$=80{,}000-50{,}000$$

$$\frac{F_1}{A}=30{,}000 \text{ p.s.i.}$$

thus

* $F_1=(30{,}000)(.062)=1860$ lb.

Finally, the computation of strap spacing is as follows using Equation 2.

$$b=\frac{1.3333(1860)\left(\frac{6}{240}\right)^2+[53{,}000{,}000(.062)-3.2(1860)]\left(\frac{6}{240}\right)^4}{.3333(.0897)(4)(6)+(.2667)(.0897)(6)^2}$$

and

**$b=1.793$ inches

Since the strap spacing is larger than strap width the arrangement will function. The volumes and weight of steel straps for costing purposes can be calculated as follows:

$$\text{No. of straps}=\frac{\text{Width of Structure}}{b}=\frac{240}{1.793}=134$$

$$\text{Volume}=AlN=(.062)(240)(134)=1993.92 \text{ in.}^3$$

$$\text{Weight}=(1993.92 \text{ in.}^3)(.283 \text{ lb/in.}^3)$$
$$=564.28 \text{ lbs. steel (100,000 p.s.i. yield strength)}$$

The 564.28 lbs. of steel required is the result of a fixed contour and the choice of a relatively low strength steel strapping material. Suppose that a high strength bainitic steel (yield strength of 200,000 p.s.i.) were used instead and our working stress was to be 160,000 p.s.i. If these straps were, say 1.0" wire x .024" thick (.024" sq. in. area), the amount of steel required would be computed as follows:

F_1=Total stress−50,000

A=160,000−50,000=110,000 p.s.i.

and

*$F_1=(110{,}000)(.024)=2{,}640$ lb.

$$b=\frac{1.3333(2640)\left(\frac{6}{240}\right)^2+[53{,}000{,}000(.024)-3.2(2640)]\left(\frac{6}{240}\right)^4}{.3333(.0897)(4)(6)+(.2667)(.0897)(6)^2}$$

and

**$b=1.706$ inches

Again, the strap spacing is larger than strap width.

No. of straps=240/1.706=141

Volume=(.024)(240)(141)=813 in.^{3}

Weight=(813)(.283)=230 lbs. steel (200,000 p.s.i. yield strength)

The savings in concrete used between supports in the improvement of this application and prior constructions having a constant cross-section is determined as follows: The parabolic section below supports in FIG. 9 has a cross-sectional area (A_p):

$$A_p=\frac{2}{3}(Y_{max})l=\frac{2}{3}(6)(240)=960 \text{ in.}^2$$

Above the supports, the area (A_r) is:

$$A_r=h_f l=(4)(240)=960 \text{ in.}^2$$

and Total Cross-sectional area=960+960=1920 in.^{2}

Total Volume (V_p) is:

$$V_p=\frac{(1920)(240)}{(1728)(27)}=9.89 \text{ cubic yards}$$

Volume with a constant thickness of 10" would be:

$$V_c=\frac{(10)(240)(240)}{(1728)(27)}=12.36 \text{ cubic yards}$$

The concrete savings for the illustrated structure as compared to prior known constructions would be:

** 12.36−9.89=2.47 cubic yards

There is a 20 percent savings in concrete resulting from

use of the present invention for the specific example given.

The present invention has widespread applicability in the building industry. It can be effectively used for the ceilings of single story structures wherein extended beam lengths may be desired without intermediate column support, as well as in multi-story buildings. Much of the interior column supports for carrying the load of the floor above in a multi-story building are obviated by use of the concept of the present invention, providing increased usable floor space. There is no need for the form work commonly made of wood used to form a slab floor and the savings in material costs is substantial. Furthermore, there are large labor savings since there are no wooden forms to be set up and then taken down. As pointed out above, the concrete beam is not uniform in cross-section, but rather is contoured to the most desirable form (a flat top with a parabolic bottom between supports). This results in a savings in concrete costs.

There has been provided a novel method for forming a concrete beam in place in a building which is relatively inexpensive as compared with comparable known methods. The resultant beam structure contains less concrete since it is automatically contoured to an optimum design profile and it is prestressed or non-prestressed for providing maximum economy and all the other advantages as described earlier.

It will be obvious to those skilled in the art that changes may be made in the method and beam structure without departing from the true spirit and scope of my invention, and it is not my intention to limit the invention to the specific form shown and described other than as necessitated by the scope of the claims.

I claim:

1. A concrete member comprising a support means made at least in part from a material having a high tensile strength and a cementitious material carried on top thereof, the top of the concrete member being flat and the bottom of the concrete member being parabolic as viewed in cross-section, the support means comprising a plurality of bands made of high tensile strength steel and spaced from one another in accordance with the following formula:

$$b=\frac{1.3333F_1\left(\frac{Y_{max}}{l}\right)^2+[53{,}000{,}000A-3.2F_1]\left(\frac{Y_{max}}{l}\right)^4}{0.3333\rho h_f Y_{max}+0.2667\rho Y_{max}^2}$$

b is the center to center spacing between the straps

F_1 is the tensile force applied to the straps before pouring

Y_{max} is the deflection of the steel straps at the center of the span under load of wet concrete

l is the span of the straps between the end of supports

A is the cross-sectional area of the straps

h_f is the uniform height above the original strap position; and

ρ is the density of wet concrete

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FRANK L. ABBOTT, Primary Examiner

H. G. SUTHERLAND, Assistant Examiner

U.S. Cl. X.R.

52—326, 327, 335

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,619,959 Dated November 16, 1971

Inventor(s) Sidney A. Parker

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 7, line 28, "wire" should read -- wide --; same column 7, lines 31 and 32, the two top lines of the computation should read

$$\frac{F_1}{A} = \text{Total stress-50,000}$$

$$= 160,000\text{-}50,000\text{=}110,000 \text{ PSI}$$

Signed and sealed this 2nd day of May 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

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Commissioner of Patents

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