

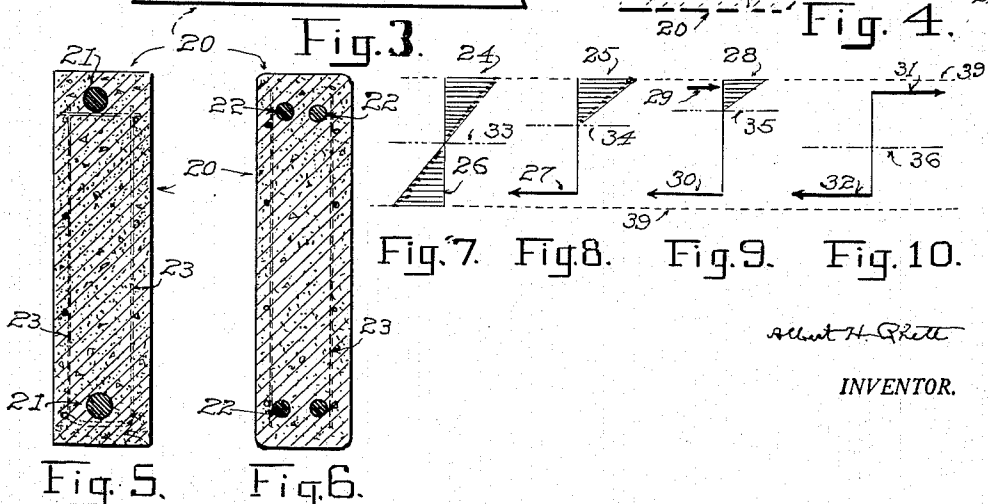
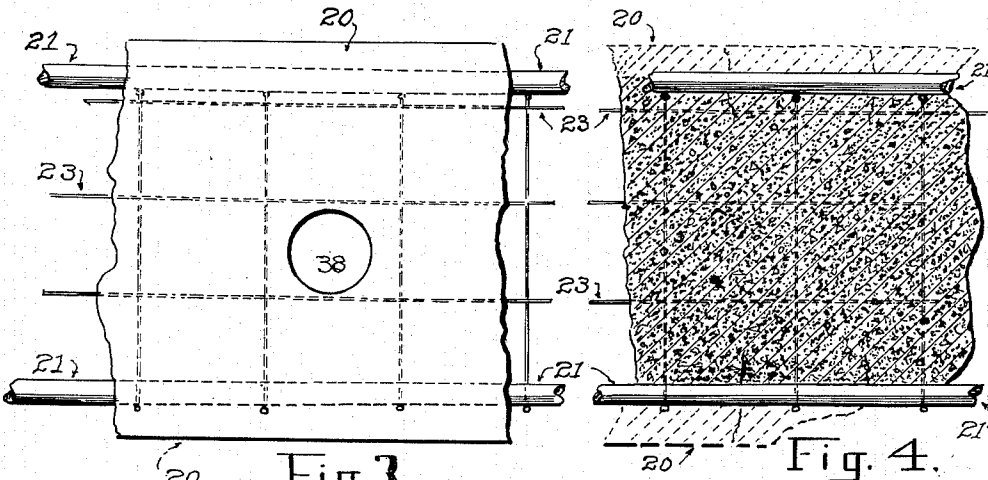
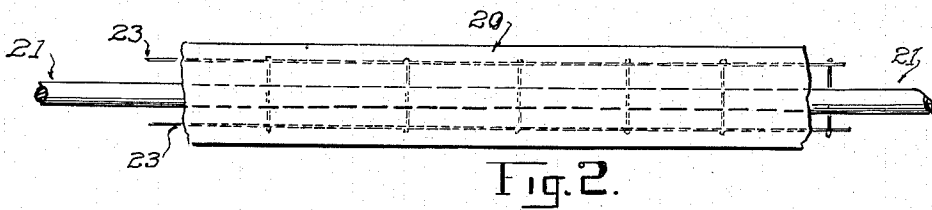
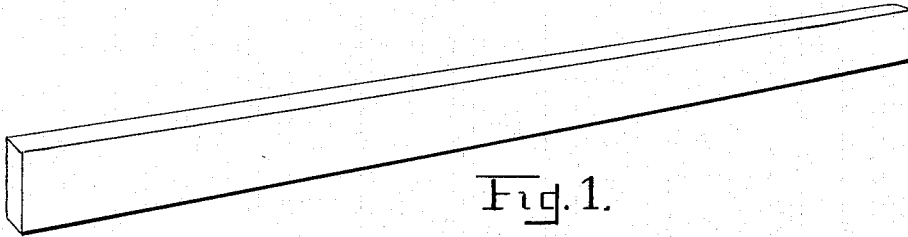
Aug. 19, 1941.

A. H. RHETT

2,252,980

CONCRETE FLOOR AND ROOF JOIST

Filed Dec. 8, 1937



A. H. RHETT
INVENTOR.

UNITED STATES PATENT OFFICE

2,252,980

CONCRETE FLOOR AND ROOF JOIST

Albert Haskell Rhett, Summit, N. J.

Application December 8, 1937, Serial No. 178,635

2 Claims. (Cl. 72-61)

This invention relates to fire-proof building construction, with especial reference to the beams or joists that directly support the floor and/or roof sheathing slab.

In non-fireproof buildings, these joists are commonly composed of rectangular wooden beams spaced from 12" to 14" apart, to the top of which the wood planking is directly nailed. Due to the light weight of wood, its nailable and cuttable properties, its availability and adaptability, this makes an ideal form of floor and roof construction.

It has, however, one great defect. It is combustible and, therefore, can not be used when fire-proof construction is desired or required.

Many efforts have been made to duplicate, or imitate, with fireproof materials, this very desirable form of floor and roof construction, through the development of various forms of fire-proof joists, but with only partial success in each of the proposed substitutes.

Steel joists have been produced in both open and solid web beam form and have been widely used, but because of the thin metal used are not fire-proof and can not be nailed to or cut as applied.

Further efforts have been made to produce fire-proof joists, pre-fabricated, with concrete and many types of these have been developed. Their chief merit is that they are fire-proof, in fact, and so rated. They are, further, less flexible and more indestructible than steel joists.

Their chief demerit is their great weight. They weigh several times more than an equivalent wooden or steel joist. In order to reduce their weight as far as possible, the very desirable rectangular cross section of the wooden joist is usually abandoned and more or less fanciful flanged or hollow shapes resorted to. This eventuates in increased cost in fabrication and impractical framing conditions.

Their second demerit is hardness. If concrete is to possess high compressive strength, it must be dense, hard concrete, but dense, hard concrete can not be nailed to, or field cut or manipulated. Consequently, as heretofore produced, concrete joists had also to be pre-detailed and exactly pre-fabricated.

The object of this invention is to produce an improved joist that will retain the advantages of each of these types of joist, while, at the same time eliminating their objectionable features. That is, to produce a joist that will be light in weight, nailable, cuttable, adaptable and of rectangular cross section, like a wooden joist; have

the strength and structural homogeneity of a steel joist; be as fireproof and indestructible as a concrete joist.

The first condition to be met is, therefore, that if this joist is to possess the maximum of fire-proofness and permanence, it must, almost of necessity, be composed of Portland cement concrete, because it possesses these qualities to a greater degree than other possible material.

If, however, concrete is to be used, then, in order to fulfill the requirements, both weight and hardness must be eliminated and eliminated in some manner that will not sacrifice strength. This immediately imposes as a primary condition, a result, which it has not been possible to achieve successfully, heretofore in the production of concrete products.

Weight and hardness can be eliminated by resort to some of the accepted forms of lightweight concrete, which are made light in weight, however, through the use of weak, soft, light aggregates, aeration or a combination of both. The value of concrete, though, as a structural material, rests mainly on its great compressive strength, and unfortunately, this is directly proportional to weight and hardness. Decreasing the latter, also decreases the former. Consequently, if compressive strength has to be furnished by weak light concrete, so much volume is required, that the finished product composed of light weight concrete may weigh even more than if produced in heavy concrete.

This naturally leads to the thought of resort to reinforcement, but, on the basis of formerly accepted concepts with regard to compressive reinforcement, only leads to further difficulties, cause of the converse strength characteristics of concrete, very strong in compression, but very weak in tension.

As is well known, tensile reinforcement is provided on the theory that the concrete breaks from tensile stress and thus shifts or unloads all of this stress on the encased reinforcement.

On the other hand, compressive reinforcement has, heretofore, been used in exceptional cases to boost the already possessed great compressive strength of the concrete and in order to do this must deform with it. As it deforms more than the concrete for respective economic strength values, more steel than is required for strength must be used to give equal deformations. This is not only uneconomical, but results in unequal amounts of tensile and compressive reinforcements, and a slab or beam, so reinforced, can not be reversed as regards strength capacity. Where

weak concrete is used the amount of compressive reinforcement required by deformation may exceed that required for strength by six or seven times. Consequently this generally accepted method of compressive reinforcement will not apply.

The applicant has discovered, however, if the concrete matrix of a joist or beam is purposely made so weak that it can not furnish the strength required to sustain a demanded loading compressive stress, while the encased reinforcement is proportioned to sustain all of it without regard to deformation, that the faster rate of deformation of the metal will crush the concrete and thereby cause the reinforcement to assume its full true strength capacity. Also, contrary to previous ideas, this does not cause the beam to fail.

By means of this device, a strength condition is thus artificially created in the compressive side of the beam that is similar to that which naturally exists in the tensile side and strength homogeneity is thus artificially created, provided the strengths of the compressive reinforcements are made sufficient which is a further necessary condition. With this method of related proportions, the strength of the joists becomes that of an all metal couple, as many tests have proven, and is so determined.

As such, the strength can be varied by merely varying the strength of the reinforcements, without change of depth as is required in reinforced concrete beams when the concrete sustains the compressive stress.

It also permits for use as matrix, lightweight weak mixtures which are cheap and whose composition and texture can be adapted to provide easy nailing and cutting properties without sacrifice of strength, as has, heretofore, been necessary.

However, one other factor of device is needed to make this possibility a reality. In order that the two equal reinforcements, now become replacements, or flanges, may act as flanges and accept the duty imposed upon them, they must be supplemented by a web.

Fortunately, tests have proven, that while the weak, lightweight concrete matrix may be artificially deprived of its normal compressive stress bearing function, it can be so compounded, that it will, nevertheless, retain sufficient shearing and gripping strength to fulfill the web function.

It is essentially important, however, in fabricating a joist in this manner, that this web capacity shall maintain, not only initially, but in the presence of anticipated destructive influences, such as fire and water. Properly compounded Portland cement compositions are even more resistive to high temperatures than steel and are actually improved by water. On the other hand a cementitious plastic might be used for the matrix, which might initially perform the web function, but would lose this capacity in the presence of fire and/or water and fail at a load less than its designed or initial capacity.

The weakening of the compressive strength of the matrix, introduces one other factor which should receive consideration. This is stress induced in the lateral faces from unavoidable or accidental thrusts or loads. The compressive stress induced in the joist from vertical loading, develops a tendency in long members, particularly, to buckle or deflect laterally. Handling or other causes may also cause such stresses.

In order to provide for such conditions, there-

fore, layers of wire mesh or the like, are inserted in the matrix in planes parallel to and adjacent to the lateral faces.

By means, therefore, of these especial devices of combination, the pre-designated requirements of the type of joist desired have been produced.

The joist is light in weight, nailable, cuttable and adaptable like a wooden joist and can, likewise, be economically produced with a rectangular cross section; it is as strong as a steel joist with same effective depth and flange area, is more rigid, more indestructible and is cheaper to produce; it weighs about half as much as concrete joist composed in accordance with previously used methods, is easier to handle, frame and adapt and is just as fire-proof and permanent, because it is concrete. It can, furthermore, be inverted with impunity, or sustain reversal of stress if used with cantilever or continuous method of support.

A further economic advantage also accrues from this method of design. As heretofore designed, the strength of a concrete joist varied directly with the depth and strength of the concrete matrix. With the applicant's device, the strength can be varied at will by merely changing the strength or area of the steel flanges, without altering the depth of concrete mix. Consequently many strength sizes can be produced from one mold.

Fig. 1 shows a perspective view of a joist as it would appear for common or standard usage. Its preferable dimensions are, from 2" to 4" in width; 6" to 16" in depth, while the lengths required for normal usage would run from about 10 ft. to 24 ft.

The cross section is, preferably, substantially rectangular in form, as further illustrated in Figs. 5 and 6, to a larger scale. This is to be desired because the rectangular form is the easiest and most economical to fabricate, reinforce, handle, erect and frame. With a lightweight concrete matrix, the increased amount of material thus used, as compared with the flanged or hollow forms, is insignificant from both a weight and cost standpoint. However, the principle of design would not be vitiated if depressions were placed in the lateral faces approximating the flanged form. Further, the edges are usually rounded or beveled to prevent disfigurement in handling.

Figs. 2, 3, and 4 show, respectively, a top plan view, a side elevation and a longitudinal section of a segment of a joist. The matrix is preferably composed of lightweight Portland cement concrete weighing not more than 125 lbs. per cubic foot, whose aggregate consists of substantially soft and penetrable materials, such as cinders, asbestos fibre, saw dust or the like, or finely particled materials such as fine sand, the mixture being, preferably further aerated to decrease weight and increase nailing and cutting properties. The matrix may also be compounded with aggregates of cellular texture such as slag and heydite.

It should, however, be so compounded, of whatever material mixture used, that its ultimate compressive strength should not, preferably, be greater than 1500 lbs. per square inch, nor less than 600 lbs. per square inch. This is easily controlled and determined by testing sample mixes.

The metal flanges, 21, are shown in their normal or preferable positions in Figs. 2, 3, 4, 5, and 6, imbedded in the matrix, adjacent to and sub-

stantially parallel to the upper and lower surfaces of the joist. They are composed, preferably, of commercially standard steel rods or bars or the like, and may be used in one section, as shown in Fig. 5, or in several, as shown in Fig. 6. They may be used in one length, substantially that of the joist, or in shorter segments lapped or spliced.

The principle of the determination of the proper areas to give these flanges, for designated joist loadings, is an essential factor in this novel method of constructing joists, particularly as it controverts previous practice.

In order to illustrate its evolution and application for purposes of design, Figs. 7, 8, 9, and 10 are given to show, if plotted, the internal stress distribution as it occurs from bending moment, on a transverse cross section of four types of joist or beam. The dotted lines, 39, indicate the top and bottom surface outlines of the joist.

Fig. 7 shows the distribution that occurs in a beam of homogeneous texture and symmetrical form as, for instance, a rectangular wooden joist. The intensities of the stresses, both compressive 24 and tensile 26 vary as the ordinates of a triangle. The areas of the triangles are equal and their apices meet on the neutral axis plane 33. The internal bending moment would be indicated by the area of each triangle by the distance of its center of gravity from the neutral axis.

Fig. 8 shows a similar diagram for a concrete beam, reinforced in the usual manner for tension only, in the lower side. As it is assumed that the concrete has no tensile strength, the tensile force triangle, 26, as it appeared in Fig. 7, ceases to exist and is replaced by a single line force representing the tensile strength of the reinforcing rod 27. The compressive stress distribution 25 in the concrete, remains, however, triangular in form, as that (24) of Fig. 7. The neutral axis plane shifts from the center line of beam. The internal bending moment is represented by the product of the force 27 and its distance from the neutral axis, plus the area of the triangle 25 by the distance of its center of gravity from the neutral axis.

Fig. 9 shows what happens when the normally reinforced beam as illustrated in Fig. 8, has reinforcement added on the compressive side to eke out or supplement the already existing compressive strength. The single line tensile force 30 conforms to that (27) of Fig. 8, and the compressive triangle in the concrete 28 conforms to that (25) of Fig. 8, but there appears in addition, on the compressive side, a single force line 29, and also an additional moment represented by the product of this line 29 and its distance from the neutral plane. The neutral plane has, also, again shifted.

Fig. 10 shows the radical change in stress distribution that has been brought into effect through application of the petitioner's discovery. The compressive stress triangle, 24, 25, 28, as it appeared in Figs. 7, 8, and 9 has now been artificially destroyed and eliminated, and is replaced by the single line compressive force, 31, equal to the single line tensile force, 32. This forces the neutral plane back to the center line and invokes homogeneity and symmetry as far as stress bearing capacity is concerned, after the concrete matrix has broken from compression, which it should be made weak enough to do, under a stress which is a fraction of the capacity which would be required of it from ultimate loading if it were strong enough to sustain it. Under these condi-

tions the internal bending moment at ultimate load is simply the product of one of the duplicate forces by the distance between them.

The required area of each of the flanges is then determined by dividing the required ultimate bending moment by the product of the distance between the flanges and their ultimate unit strength. Much simpler than by means of the heretofore complex reinforced concrete formulae based on assumed values of the unknown compressive strength and position of the neutral axis, and much more accurate. Repeated tests have shown that slabs or beams reinforced and combined in this manner break within 1% to 5% of the computed maximum load, which is as it should be, because the manufacture of steel is refined to the point where the strength of the product is predetermined to this degree of accuracy.

On the other hand the strength of concrete is so variable and unpredictable that many building codes require factors of safety as high as eight.

In Figs. 3, 4, 5 and 6, the lateral reinforcing sheets, 23, are shown in their preferable normal positions. These sheets are, preferably, composed of wire mesh, because the longitudinal strands do, in fact, also assist the main flanges in resisting bending moment from vertical loading and may be, similarly, so computed, while the vertical strands assist in sustaining web shear.

This mesh also performs a further useful function in framing holes 38 that may be required to be cut or cast in the web of the joist to permit the passage of pipes or conduits, or cast in it, to reduce weight. These sheets, 23, may be placed in the mold in single layers, as shown in Fig. 6, but if preformed to the shape of the joist with lesser dimensions and so inserted, as shown in Fig. 5, they will act as a spacer and support for the main flanges. In short joists it is more convenient to insert them in one piece of a length substantially equal to that of the joist, while in long joists, it is more convenient to insert them in shorter overlapping segments. Except for convenience, expanded metal mesh can be used and even single strands.

Figs. 5 and 6, show, in cross section, the preferable rectangular form. This form is preferred above flanged or hollow fanciful forms, because it is the easiest to mold, handle, erect, frame and invert. Actually the edges are rounded, usually, to prevent defacement from handling. While holes, or lateral depressions may be cast in the web to save weight, without vitiating the novel design device, the lightweight concrete is already so light and also so cheap, that the savings in weight and cost would not compensate to any degree for the increased difficulties involved in the molding. This constitutes, therefore, one of the utilitarian advantages of this joist.

A further utilitarian advantage is achieved through imbuing the matrix of the joist with a nailable property in conjunction with the elimination of the stress bearing function from it. This is, that pre-cast floor and roof sheathings, ceiling board and lath can be nailed directly to it, which is not possible with hard concrete or steel joists.

While this improved type of joist construction presents especial advantages for pre-fabricated units, its principle and many of its valuable assets would maintain, even if the joists were molded in place on the structure to which they would apply and it is not intended to exclude this application.

Fig. 4 represents a longitudinal cross section

of a segment of the joist. In order to further indicate the principle involved the portions of the matrix, 20, above and below the metal flanges 21 are shown dotted to indicate their elimination from stress bearing function, while the portion between the flanges is shown in solid lines to indicate the retention of the web function.

It will be noted that the computations are based on ultimate maximum loading and unit strength values, not, as has been the custom, heretofore, on so called, safe values, arrived at by the assumedly necessary applications of factors of safety of from four to eight. Until the concrete subject to compressive stress has been prematurely crushed, the desired and artificially created stress relationship, required for heavy or maximum loading, has not materialised and the beam retains its composite character and complex, indeterminate internal stress relationship. This really makes no practical difference, however, but is merely done to accord with the actual established fact that the beam breaks almost exactly as figured, thus permitting of a more intelligent use of the factor of safety.

Having thus described my invention, I claim as new and desire to secure by Letters Patent:

1. A combination of materials adapted to form a strong, lightweight, nailable, equivalently invertible and reversible reinforced concrete joist beam of substantially solid symmetrical cross section of optionally selected depth which exceeds its width, by means of so compounding Portland cement and lightweight aggregates, that the weight of this matrix per cubic foot, shall be less than 120 pounds; its ultimate maximum compressive strength less than 1500 pounds per square inch; its texture penetrable; encasing within and throughout the length of said matrix

a primary substantially vertical stress couple composed of metal rods, whose vertical, internal moment of resistance is sufficient, determined as an all metal couple independent of the strength of the concrete matrix, to sustain the ultimate, maximum primary loading in direct or inverted position and with any method of support; and a secondary stress couple composed of metal mesh or the like, extending lengthwise and so placed that its axis is transverse to that of the primary couple, to sustain secondary lateral strains.

2. A combination of materials adapted to form a strong, lightweight, nailable, equivalently invertible and reversible joist beam for building construction, of a substantially solid rectangular cross section whose depth is optionally selected and exceeds its width, by means of so compounding Portland cement and lightweight aggregates that the weight of this matrix per cubic foot is less than 120 pounds; its ultimate maximum compressive strength less than 1500 pounds per square inch; its texture penetrable and cellular; encasing within and throughout the length of said matrix a primary, substantially vertical stress couple composed of metal rods placed adjacent and substantially parallel to the upper and lower surfaces respectively, whose moment of resistance determined as an all metal couple independent of the strength of the enveloping concrete matrix, is sufficient to support, in direct or inverted position and with any method of support the ultimate, maximum designated loading; and a secondary transverse stress couple composed of two layers of metal mesh or the like, extending throughout the length and adjacent each lateral face, to sustain secondary lateral bending strains.

ALBERT HASKELL RHETT.