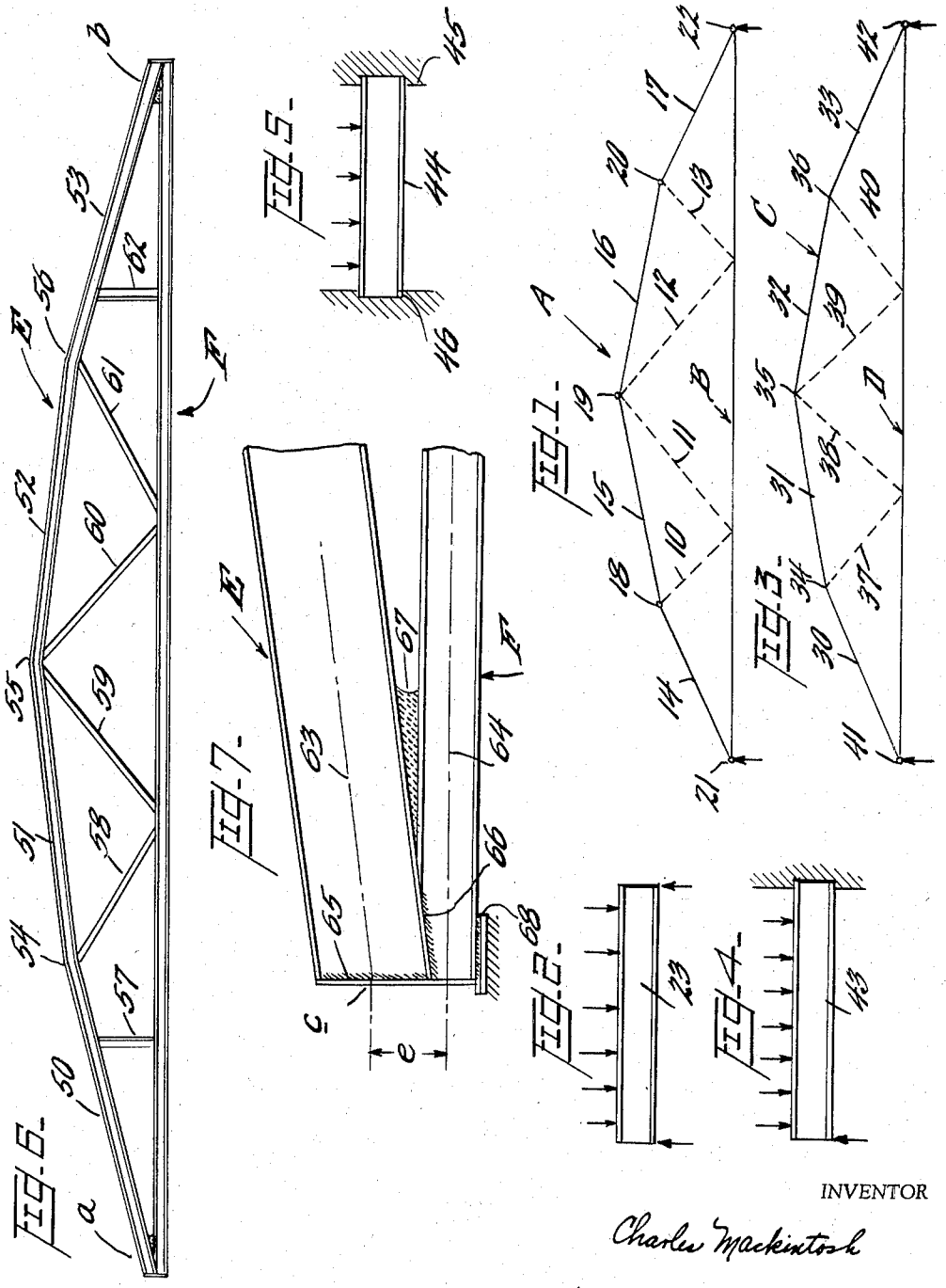
March 3, 1959 C. MACKINTOSH 2,875,711

BEAM OR TRUSS ARCH CONSTRUCTIONS

Filed Sept. 21, 1953 2 Sheets-Sheet 1



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BEAM OR TRUSS ARCH CONSTRUCTIONS

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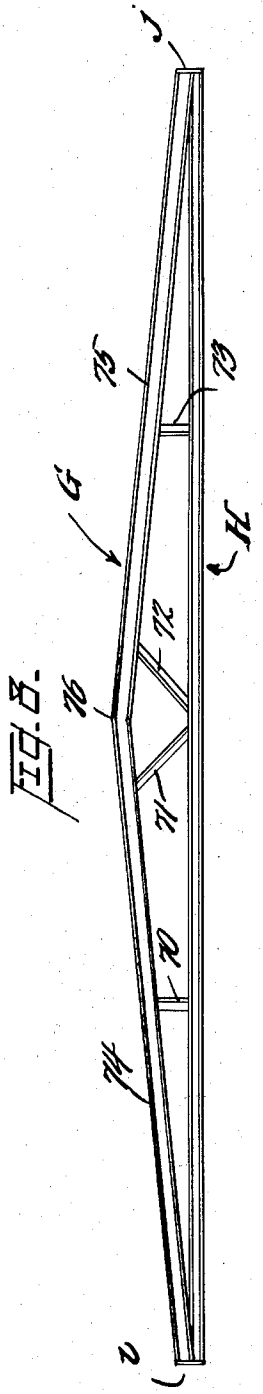


FIG. 8.

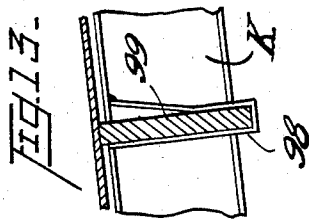


FIG. 13.

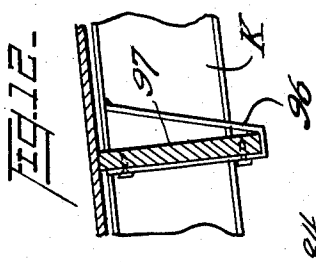


FIG. 12.

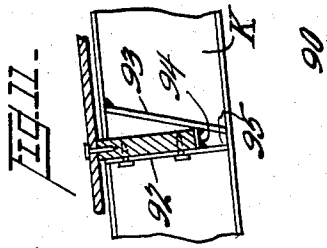


FIG. 11.

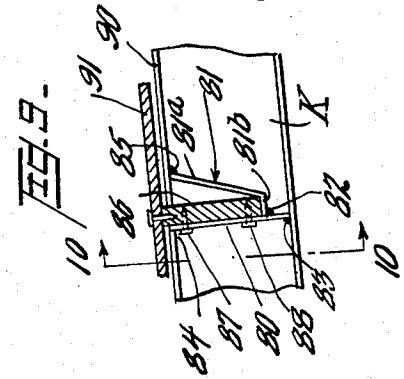


FIG. 9.

FIG. 10.

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BEAM OR TRUSS ARCH CONSTRUCTIONS

Charles Mackintosh, Los Angeles, Calif.

Application September 21, 1953, Serial No. 381,193

2 Claims. (Cl. 108—23)

This invention relates to improvements in structural spans.

More specifically it relates to a class of structure which I have chosen to designate as a beam or truss arch in order to distinguish it from conventional beam and truss structures which my invention is designed to replace.

It has long been the practice in the structural field to use straight or tapered I beams (having upper and lower flange members joined by an intermediate solid web) to support loads of short span. Where a load supporting member is required having a relatively long span, a high over-all height is necessitated, and it has been the practice to provide truss structures having upper and lower chords joined by intermediate web members. Beam members have been found objectionable because of their excessive weight and reduced load handling capacity. Conventional truss structures have also been found objectionable because secondary stresses are set up therein, in a number of cases greatly reducing the factor of safety for the structure. In addition, it has been necessary that the chord members of such trusses be heavy to compensate for the high bending moments inherent in such structure.

Accordingly it is an object of this invention to provide a structural span characterized by fixity of joints and heel eccentricities to eliminate all secondary stresses and accomplish a marked saving in material because of reduced bending moments.

It is also an object of this invention to provide a span of the character described which effects a marked saving in weight over conventional straight or tapered beam constructions.

I accomplish these objects by providing a structural span having longitudinally extending upper and lower unitary chord members and web members intermediate the chord ends. I fix the chord members together at their heel ends eccentrically so that bending moments in the span are offset by load tension in the lower chord to produce a condition of non-rotation at the ends of the upper chord. By placing the chord ends in a condition of non-rotation, bending moments are greatly reduced. Secondary stresses are eliminated by providing unitary chord members, the segmental portions of such chords being welded to one another so that there is no rotation of segments about the welded joints.

It is another object of my invention to provide novel joist and hanger means integral with my aforementioned truss or beam arch to insure that the arch is stayed against lateral bucking phenomena peculiar to said truss or beam arch.

These and further objects, features, and advantages will be apparent from the description which follows, read in connection with the accompanying drawings in which:

Figure 1 is a diagrammatic illustration of a well known type roof truss;

Figure 2 is a diagrammatic representation of one known type of beam support;

Figure 3 is a diagrammatic illustration of a second well known type roof truss;

Figures 4 and 5 are diagrammatic illustrations of known type beam supports;

In Figure 6 is shown a truss-arch type span which is one embodiment of my invention;

Figure 7 is a detail of the heel construction in my truss-arch of Figure 6;

Figure 8 is a beam-arch type span which is a second embodiment of my invention;

Figure 9 is a cross-sectional view through a roof construction employing the principles of my invention and showing one embodiment of my improved joist hanger;

Figure 10 is a cross-sectional view taken along line 10—10 of Figure 9;

Figures 11, 12 and 13 are cross-sectional views through roof constructions employing the principles of my invention and showing further embodiments of my improved joist hanger.

In order to facilitate an understanding of the invention, reference is made to the embodiments thereof shown in the accompanying drawings and detailed descriptive language is employed. It will nevertheless be understood that no limitation of the invention is thereby intended and that various changes and alterations are contemplated such as would ordinarily occur to one skilled in the art to which the invention relates.

Referring to the drawings, in Figure 1 is shown a well known type roof truss having an upper chord A—the segmental joints **18**, **19** and **20** of which lie upon a parabolic curve—and a lower chord B, between which are fixed intermediate web members **10**, **11**, **12** and **13**. The upper chord comprises four segments **14**, **15**, **16** and **17** pivotally fixed together at pin points **18**, **19** and **20**. At the heel ends of the truss the centerlines of the upper and lower chords meet and are joined together at pin points **21** and **22**.

In the analysis of steel trusses, it is generally assumed that the joints of the trusses are all pin joints. It is upon this assumption that all stress diagrams are drawn in order to determine the primary stress in each member of the truss. In order to actually get the same stresses as are computed in the analysis, many trusses, as in Figure 1, have been built using pin connections as at **18**, **19**, **20**, **21** and **22**, in order that each member so joined may rotate about the pin thereby reducing secondary bending stresses in the member, but inducing primary stresses which tend to carry a fixed uniform load in the upper chord. In such a truss each segment of the upper chord may be considered supported at its ends as in the case of segment **23** of Figure 2. Under uniform loading of segment **23** the maximum bending moment is at its center and can be computed by the formula

$$M=\frac{WL}{8}$$

where W equals the uniform loading and L equals the length of the segment.

Pin joints, as in the truss of Figure 1, are expensive and inconvenient. Thus, trusses are often built avoiding the use of pin connections, the segments being fixed in their angular positions, but always the centerlines of each of the joined members must intersect at a single hinge point. This hinge location is the point at which a pin would be located if pin connections were used. Bolting at a plurality of points near the joint has been resorted to, but joint continuity is absent at such junctures. Recently welded segment connections have become popular, welded connections providing such complete continuity or unity of members that a segmental chord acts as a single unitary member rather than several segments.

Such a known truss is that roof type shown in Figure 3 with an upper chord C comprising segments **30**, **31**, **32** and **33** welded together and having hinge points **34**,

35 and 36. A lower chord D is provided together with intermediate web members 37, 38, 39 and 40. The centerlines of the upper and lower chords meet and are pivotally connected at the heel ends 41 and 42. In such a welded structure the upper chord is a continuous unitary member supported for angular movement at its ends similar to beam 23 in Figure 2. The bending moment of the chord at its apex 35 is computed by the formula

$$M=\frac{WL}{8}$$

Unitary chord segments 30 and 31, therefore, are fully fixed by welding at 35 so that this end 35 of the beam 30, 31 can neither move nor rotate. Such a fixed end beam is shown diagrammatically at 43 in Figure 4. At the center, corresponding to point 30 in Figure 3, of such a beam as 30 the bending moment is computed by the formula

$$(1) \qquad M=\frac{WL}{16}$$

Attention is directed to Figure 5 of the drawings wherein is diagrammatically shown a beam member 44 fully fixed at both ends so that they can neither move nor rotate. A marked reduction in bending moments is achieved in a beam so supported. Under uniform load the moment at either end 45 or 46 of such a structure may be computed by the following formula

$$M=\frac{WL}{12}$$

At the center of a beam supported as in Figure 5, the bending moment when the beam is under uniform load is computed by the formula

$$(2) \qquad M=\frac{WL}{24}$$

Thus, in any structural span which when assembled has unitary chord members having fully fixed ends equivalent to the beam of Figure 5, an optimum bending moment condition is reached.

Figures 6 and 7 of the drawings illustrate one embodiment of my invention in which the upper load bearing chord member is in a fully fixed end condition. Upper chord member E comprises four segments 50, 51, 52 and 53, the joints 54, 55 and 56 of which are welded together so that upper chord E is a unitary member and independent rotation of the segments about joints 54, 55 and 56 is impossible. Because of this fixity of joints, secondary stresses, under uniform load on equal length segments, are largely eliminated. Webbing members 57, 58, 59, 60, 61 and 62 are fixed between the upper and lower chords E and F as in the conventional roof-type truss.

In order that bending moments in the chords be reduced to the figures typified by the beam with fully fixed ends of Figure 5, I have found that fixed ends in the upper load supporting chord may be obtained at the heels *a* and *b* of the span by producing a condition of no rotation at the heel joints, assuming the span to be under a uniform load. I produce this condition by introducing an eccentricity *e* into the heel of the truss. By eccentricity is meant forces not meeting at a point. Therefore, I provide a heel construction as shown in Figure 7 in which the centerlines 63 and 64 of upper and lower chords E and F, respectively, do not intersect, but fall short of intersecting at the heel ends by an eccentricity distance *e*. The chord ends are welded to a butt plate 65, lower chord F being cut away and welded to the upper chord along 66 according to the designed angle of inclination of chord E. A filler plate 67 is welded between chords E and F at their junction, and a heel plate 68 is welded to the lower chord F.

Taking the point *c* (Figure 7) on the centerline of the upper chord member E and assuming there is no loading upon the lower chord member F except that of the negligible dead weight, it is seen that two moments are present tending to produce rotation at *c*. First, there is the downwardly acting bending moment on E to the right of point *c* directed clockwise of *c*. Further, there is a moment counter-clockwise of *c* which is produced by load tension in the lower chord F at a distance *e* from point C. This moment, therefore, tends to offset the bending moment on chord E to produce a condition of non-rotation at point *c*. As was pointed out in connection with Figure 5, a beam having fully fixed or non-rotating end characteristics has a bending moment at its end equal to

$$\frac{WL}{12}$$

Thus, to produce a condition of non-rotation in the upper chord at the heel of the span, it is necessary that the two moments about point *c* be equal and oppositely acting, or that

$$(3) \qquad T(e)=\frac{WL}{12}$$

where T equals the tension in lower chord F, W equals the uniform loading on chord E, and L the length of one of its segments. Therefore, the distance *e* may be calculated by solving the following algebraic expression:

$$(4) \qquad e=\frac{WL}{12T}$$

or

$$(5) \qquad e=\frac{M_u}{T}$$

where M_u equals the bending moment on upper chord E.

The above expression holds true only in the event that there is no loading upon lower chord member F. If the span were to be used in a building with the upper chord supporting a roof load and the lower chord supporting a ceiling load, a further bending moment would be produced in the structure due to the load on the lower chord. In such a case the bending moments on the two chord members would be additive and Formula 5 should be revised as follows:

$$(6) \qquad e=\frac{M_u+M_L}{T}$$

where M_L equals the bending moment taken from the end of the lower chord F.

Thus in my arch type span shown in Figure 6, there will be negligible stresses present in the web members 57, 58, 59, 60, 61 and 62. The only purpose such web members serve under conditions of balanced load is to act as hangers for the lower chord. In the event of unbalanced load, web members 58 and 61, which diverge upwardly of the lower chord, serve to minimize the tendency of peak joint 55 to rotate as they fix the peak joint in position, thereby greatly reducing the stresses inherent at unbalanced load.

Such a truss-arch structure as shown in Figure 6 is characterized by great economy, for the web members receive very little stress and consequently their size and number may be greatly reduced. In addition, the bending moments upon the upper chord are much smaller than in prior known structures because of the fully fixed chord ends. Consequently, size of the chord may be greatly reduced.

If desired the truss arch structure shown in Figure 6 could be inverted so that lower chord F becomes the upper chord, and upper chord E becomes the lower chord. In such event the formulae set out above are still applicable, tension of the member E being employed therein rather than that of the member F.

In Figure 8 is shown a second embodiment of my invention which is designed to replace conventional straight or tapered beam constructions. Accordingly, I call this embodiment a "beam arch." This span comprises an

upper chord G and a lower chord H fixed together at their heel ends *i* and *j*, eccentrically in the same manner as shown in Figure 7. Web members **70**, **71**, **72** and **73** are provided for joining the chord members intermediate heel ends *i* and *j*. The upper chord comprises the segments **74** and **75** welded together at their peak joint **76**. The same formulae set out at (5) and (6) are applicable to determine the required eccentricity. It is important to note that web members **71** and **72** diverge upwardly from the lower chord to the upper chord, thereby absolutely fixing joint **76** and prevening joint rotation even under unbalanced loads such as a load on **74** but not on **75**. In the event that the beam arch of Figure 8 is inverted so that chord H becomes the upper chord and chord G becomes the lower chord, it is necessary that webbing members **71** and **72** be rearranged to diverge upwardly from chord G, thereby preventing the tendency of chord H to rotate about its center.

In known truss structures, as disclosed in Figures 1 and 3, having an upper chord fabricated from the conventional I-beam it is noteworthy that the lower flange of the chord is in a state of tension while the upper flange is in a state of compression. In order to prevent lateral bucking of the upper flange under compression, it has been the practice to fix joist hangers to this flange for the reception of laterally extending joists, thereby staying the flange against lateral movement.

In my beam and arch constructions of Figures 6 and 8 it is to be noted that compression is produced in the lower flange of the upper chord. Thus, it becomes necessary that the lower flange, as well as the upper flange, be stayed against lateral bucking. I prevent such bucking by providing a joist hanger which is welded to both the upper and lower flanges. Wood joists may then be fixed within the hangers to stay the chord flanges against undesirable bucking.

Several embodiments of my improved joist hanger construction are set out in Figures 9 through 12.

In Figures 9 and 10 is shown a two-part hanger comprising joist confining members **80** and **81** welded together at **82**, and to the upper chord K of a span constructed according to the teachings of my invention at points **83**, **84**, and **85**. Member **80** and portion **81***a* of member **81** extend generally transverse to upper chord K, portion **81***b* of member **81** extending longitudinally of chord K to act as a joist seat. At the opposite side of the chord K an identical hanger L is welded as may be seen in Figure 10. A wood joist **86** is placed in the hanger and secured therein by bolts or nails **87** and **88**. As may be seen in Figure 10, the hanger member **80** has apertures for reception of the securing nails, the upper aperture **89** preferably being slotted vertically to compensate for shrinking or expansion of the wood joist. The joist seat portion of the hanger is dimensioned to such a depth that the joist **86** will project slightly above the upper flange **90** of upper chord K. In such a manner, diagonal roof sheathing **91**, or the like, may be nailed directly to the joist and the necessity for fixing blocking to upper flange **90** of chord member K is thereby eliminated.

In Figure 11 is shown a three-part hanger welded to an upper chord K and comprising members **92**, **93** and **94**. Members **92** and **93** are welded at **95**, seat member **94** being welded between members **92** and **93**. Nail apertures are formed in member **92** in the same manner as shown in Figure 10.

Figures 12 and 13 show a one-piece hanger welded to an upper chord K, the member **96** having nail receiving apertures similar to those in Figure 10 for fixing the joist **97** therein, while the member **98** has a joist receiving slot at its base for receiving a joist **90** snugly therein. The necessity for nail or bolt apertures in hanger **98** is thereby eliminated.

The truss and beam arch constructions illustrated and described above are by way of example only, and any changes which might occur to one skilled in the art are contemplated by the present invention, within the scope of the following claims.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. In a structural span, a longitudinally extending upper chord member comprising a plurality of segments which intersect upon a conic section and are fixed together by welding, a lower unitary chord member, web members fixed between said chord members intermediate the ends thereof, said chord members being fixed together at their ends and having their center lines at such ends spaced apart a distance *e* determined by the formula

$$e=\frac{WL}{12T}$$

where W is the load uniformly applied on the upper chord, L is the moment arm for the load W, and T is the load tension in the lower chord, whereby the bending moments in the span upon the application of a downwardly acting load to the upper chord are substantially off-set by a load tension in the lower chord to produce a condition of substantial non-rotation in the upper chord ends.

2. In a structural span, a longitudinally extending upper chord member comprising a plurality of segments which intersect upon a conic section and are fixed together by welding, a lower unitary chord member, web members fixed between said chord members intermediate the ends thereof and diverging upwardly from said lower chord and outwardly of the center of the span to prevent rotation of the upper chord about its center, said chord members being fixed together at their ends and having their center lines at such ends spaced apart a distance *e* determined by the formula

$$e=\frac{WL}{12T}$$

where W is the load uniformly applied on the upper chord, L is the moment arm for the load W, and T is the load tension in the lower chord, whereby the bending moments in the span upon the application of a downwardly acting load to the upper chord are substantially off-set by a load tension in the lower chord to produce a condition of substantial non-rotation in the upper chord ends.

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