Aug. 3, 1954 T. COLLINS 2,685,354

NAILABLE STRUCTURAL MEMBER

Filed Feb. 3, 1950

5 Sheets-Sheet 1

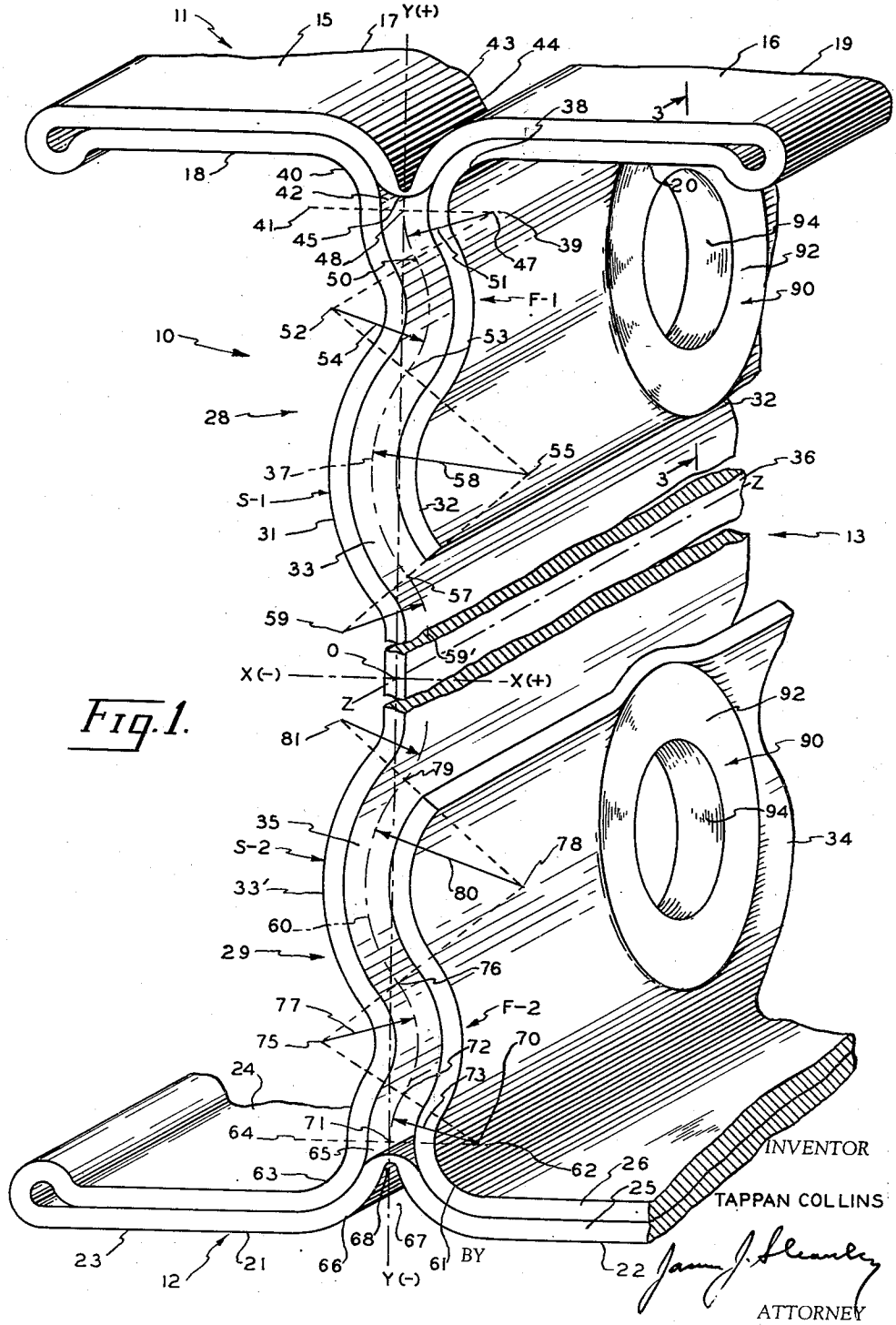


Fig. 1.

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5 Sheets-Sheet 2

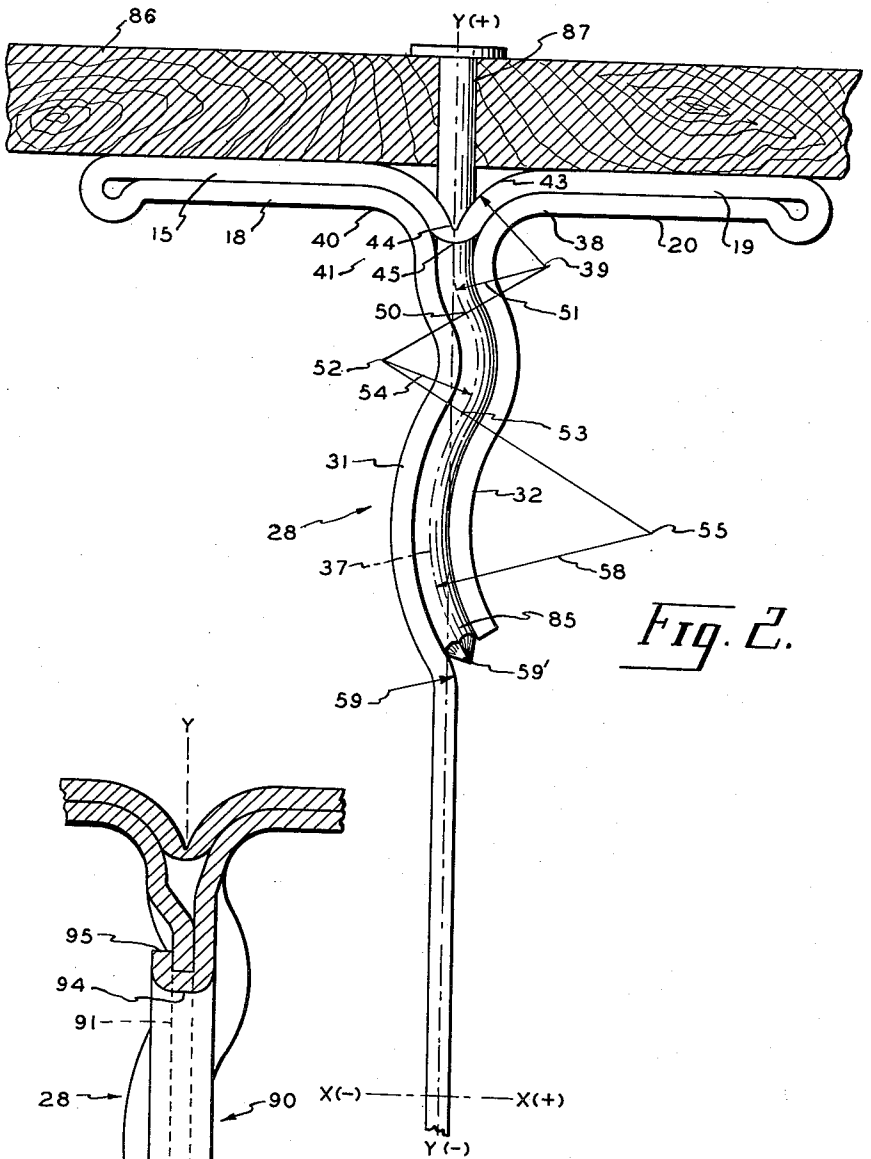


FIG. 2.

FIG. 3.

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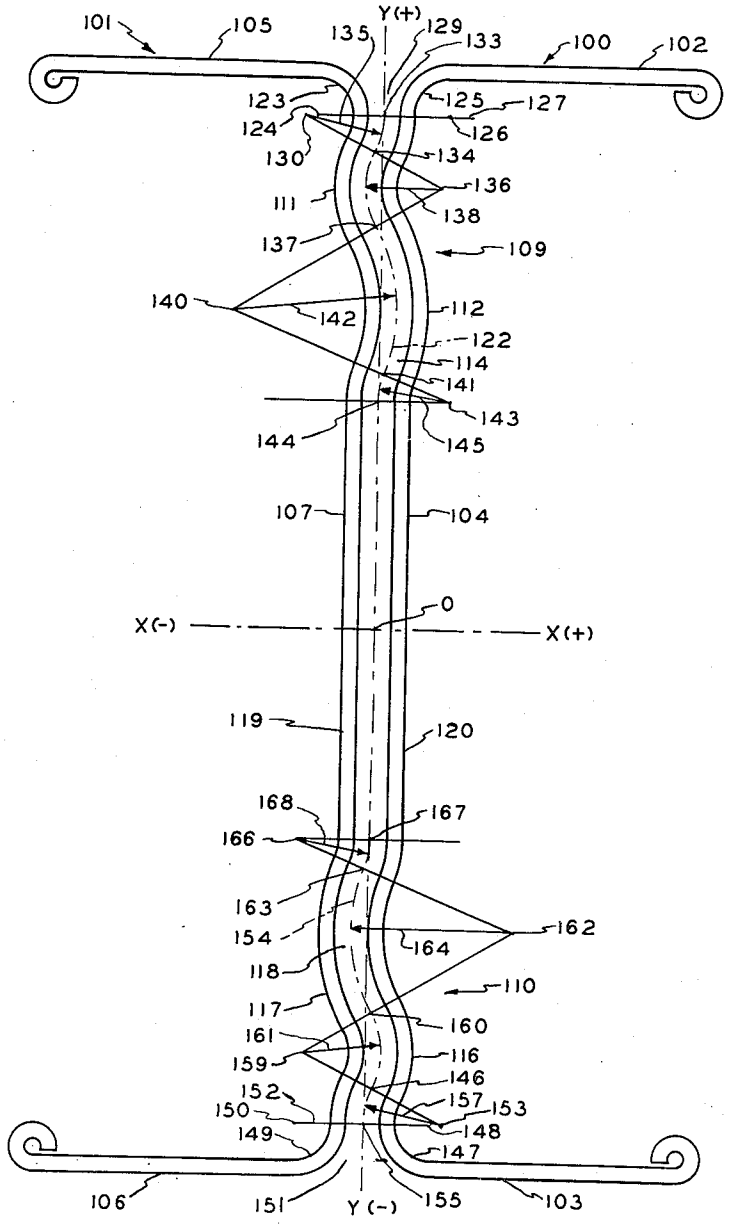


FIG. 4.

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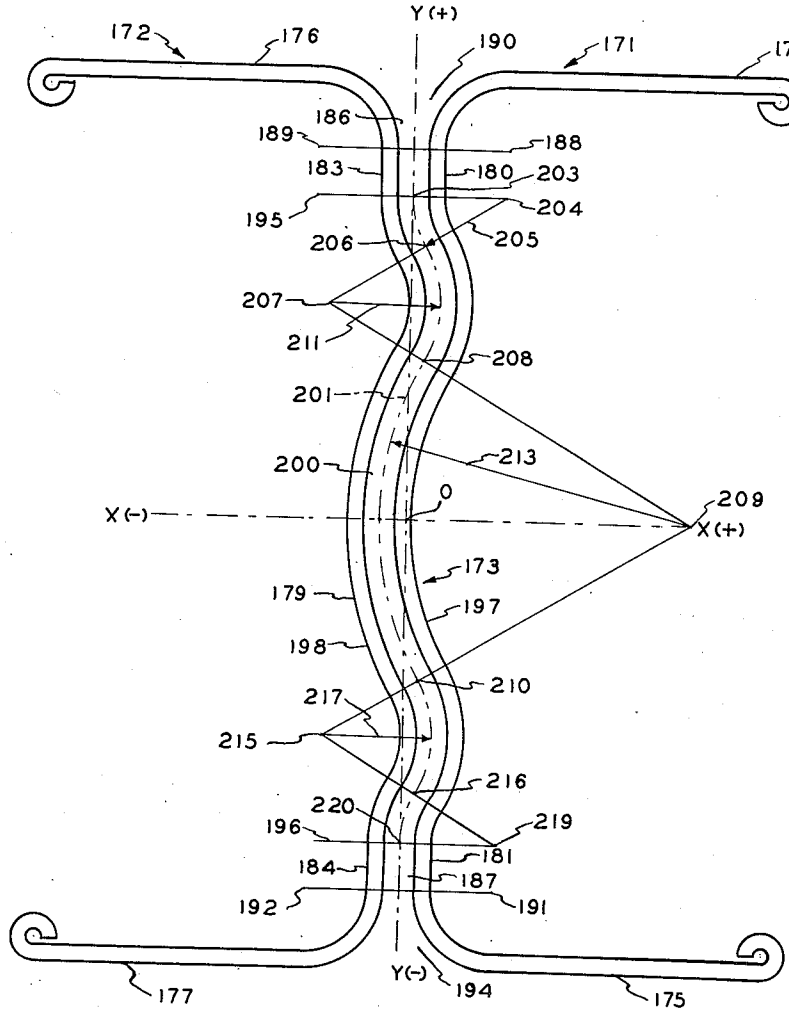


Fig. 5.

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NAILABLE STRUCTURAL MEMBER

Filed Feb. 3, 1950

5 Sheets-Sheet 5

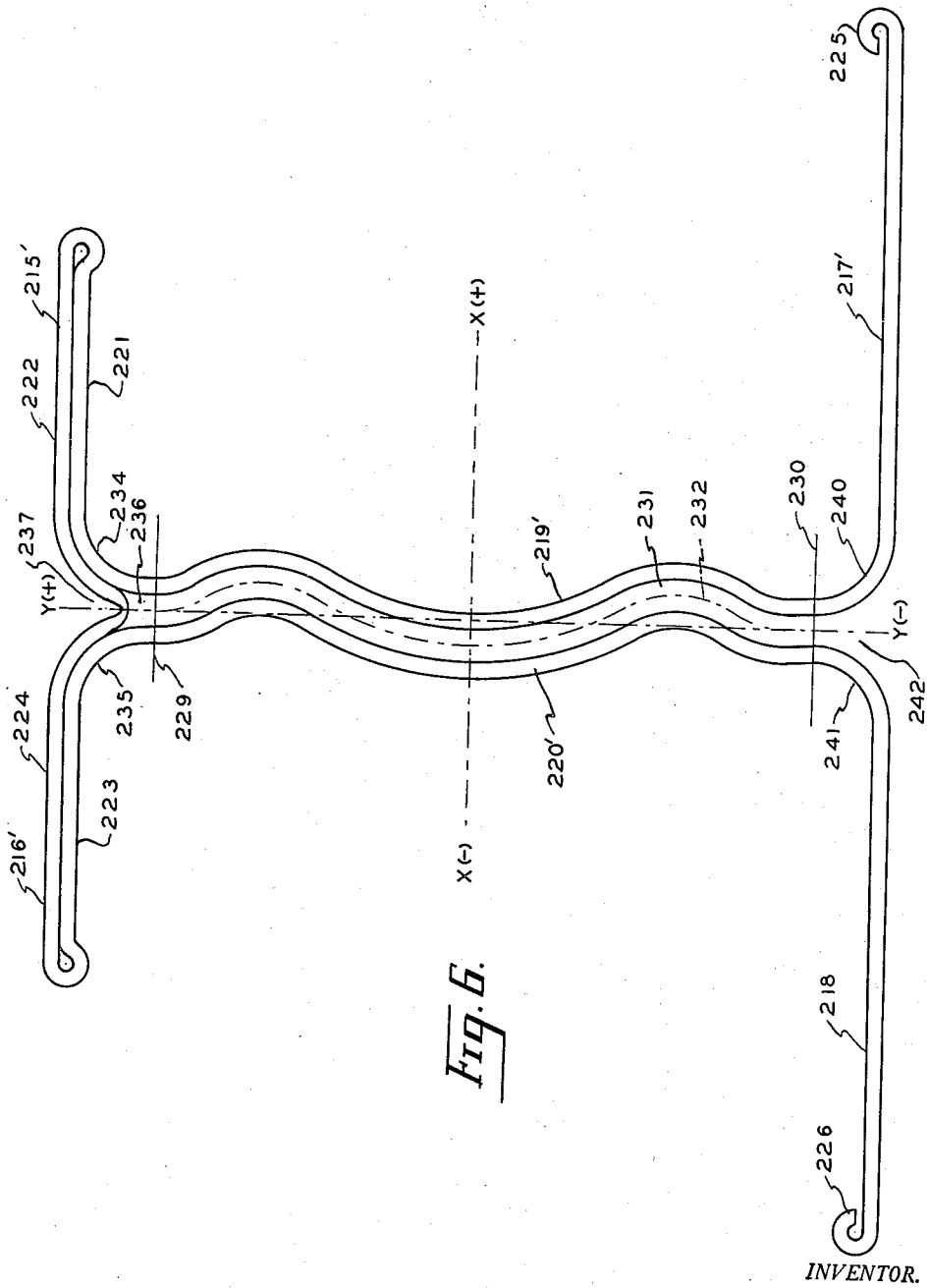


Fig. 6.

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Patented Aug. 3, 1954

2,685,354

UNITED STATES PATENT OFFICE

2,685,354

NAILABLE STRUCTURAL MEMBER

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Application February 3, 1950, Serial No. 142,171

13 Claims. (Cl. 189—37)

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The present invention relates to structural members and more particularly to nailable structural members formed of metal, such as steel sheet or strip, and adapted to receive and removably retain nails whereby boards or other collateral material may be attached to the structural members by means of nails and similar fastening elements.

It is an object of my invention to provide a nailable structural member that will securely retain nails and that will securely retain a nail subjected to a live load.

Another object of my invention is to provide an improved nailable structural member that will not be deformed by nails driven into the member.

Another object of my invention is to provide an improved nailable structural member formed of relatively thinner metal that is relatively stronger and more rigid than the nailable members heretofore provided.

Various types of metal nailable structural members have been proposed in the past. These nailable members have been intended to replace wooden members and have been intended to receive and retain driven nails while permitting the removal of the nails when desirable. Only a few of the proposed types have been accepted for commercial use. The nailable members which have received commercial acceptance have, in general, been of the type in which a nail is driven into a tortuous or sinuous slot or groove defined by parallel spaced apart webs. These webs are provided with a single corrugation so that the nail is bent first in one direction and then back in the opposite direction through a single reverse curve. These structural members are designed to be used with a nail having a diameter substantially equal to the width of the slot. It has been considered by designers that the nail is held in place by friction and by resistance of the nail to straightening. While nailable members of this particular type have received fairly wide acceptance for commercial use as beams, joists, columns, studs and the like, the members do have a number of drawbacks or deficiencies. One serious trouble encountered in using such a member is that while the nailable member may retain the nail against a constant withdrawal force applied in one direction, the nail is readily worked loose by a live load. For example, when the head of the nail is gripped and an attempt is made to pry the nail out of the groove by means of a suitable instrument, it may be found that it is quite difficult to withdraw the nail in this manner, and it has been considered that the nailable member will satisfactorily retain nails during use. A difficulty arises when the head portion of the nail is subjected to a weaving, bending, lunging load—that is, a live load—for the nail is "walked" out of engagement with the structural member. Each cycle of change in load application will pull the nail a short distance out of the nailing groove. Under nearly all conditions of commercial application, the nail is subjected to live load at least part of the time, and if the cycles are relatively rapid or if the live load is relatively great, the nail is quickly worked out of the nailing groove. Accordingly, the nailable members of the prior art have been characterized by relatively weak nail retaining qualities, especially when the nail is subjected to a live load.

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Another difficulty encountered with nailable structural members is the tendency of the nails to deform the walls of the nail receiving and bending slot. If the walls are materially deformed or spread, the ability of the member to retain nails is either lost or greatly reduced. To overcome or reduce this tendency, it has been the practice quite frequently to make the member of relatively thicker metal. This in turn increases the problems involved in forming the nailable member and increases the cost of the member. This is particularly undesirable as the users of such members are often quite cost conscious, particularly where the structural member is being substituted for a wooden member. In many instances, the nailable member is made heavier than is necessary to support the loads applied to the member when in use so that the nail will not deform the member. In other words, the thickness of the metal in a structural member, such as a beam, is determined by the forces set up by the driven nail and not by the load carrying capacity required of the beam.

In accordance with the present invention, the nail receiving and bending means of the nailable, metal structural member is constructed and arranged in a novel manner so that the nail is securely held in place when subjected to a live load and not readily "walked out" of the nail receiving slot. It has been discovered that bending or corrugating the webs which define therebetween the nail holding slot so that the slot extends through two reverse curves greatly increases the retention of nails, particularly nails subjected to live loads. The addition of the second reverse curve increases the retention of nails more than the increase in the length of the nail receiving slot, if there is any increase in the length of the slot.

The reason why a nail receiving means which bends a nail through two reverse curves will retain a nail subjected to a live load while a nail receiving means which bends a nail through a single reverse will not retain a nail subjected to a live load is not accounted for by merely multiplying the properties of a single reverse curve by the factor, two. In addition, and as will be more fully hereinafter described, the addition of more reverse curves or corrugations does not correspondingly increase the resistance of the nail to withdrawal by a live load.

Further, it has been found that the structural member can be constructed of thinner metal without having the nail spread or deform the walls or webs defining the nail receiving slot, if the second reverse curve is made larger than the first so that the nail is bent more gradually. In other words, for each unit of longitudinal advance, the nail is bent through fewer degrees when being driven through the second reverse curve than when being driven through the first reverse curve.

An unexpected advantage of the present invention has been in the discovery that the presence of the second relatively larger reverse curve enables the cross-sectional area to be proportioned so that the nailable structural members are now free or substantially free of any tendency to twist under loads tending to bend the members. Insofar as is known, the prior art nailable structural members and particularly those which have received commercial acceptance have been characterized by poor structural stability. When these members have been used as beams, joists, columns, studs, or other frame members, it has been necessary to brace the members quite extensively to prevent twisting or to use larger members or both.

These and other objects and advantages will become apparent when considering the following description, taken with the accompaying drawings, in which:

Figure 1 is a cabinet view of a structural member embodying the principles of the present invention;

Figure 2 is a fragmentary view of the member of Figure 1 and showing a nail driven into the member;

Figure 3 is a fragmentary sectional view taken along line 3—3 of Figure 1;

Figure 4 is an end view of another structural member embodying the principles of the present invention;

Figure 5 is an end view of another structural member embodying the principles of the present invention; and

Figure 6 is an end view of a different structural member embodying the principles of the present invention.

Referring to the drawings and particularly to Figure 1 which is a cabinet view of a structural member embodying the principles of the present invention, the elongated member 10 is formed by bending and shaping a single piece of steel sheet or strip. The present invention is not concerned with the particular manner in which member 10 is formed although the member is preferably formed by cold rolling steel strip. Metal other than steel may be used. The member 10 includes a first flange means 11, a second flange means 12 and a web means 13 connecting the flange means with the flange means 11 and 12 extending along opposite sides of the web means 13 so that the member 10 has substantially an I-shape in cross-section. The flange means 11 includes a pair of coplanar, equal flange portions 15 and 16. The flange portions are each made of two layers of metal with flange 15 having outer and inner layers 17 and 18 integrally joined along their outer edges and with flange 16 having outer and inner layers 19 and 20 also integrally joined along their outer edges. Flange means 12 similarly includes a pair of coplanar, equal flange portions 21 and 22 with flange portion 21 having outer and inner layers 23 and 24 integrally joined together along their outer edges and with flange portion 22, including outer and inner layers 25 and 26, also integrally joined together along their outer edges.

Adjacent each flange means 11 and 12, there is a nail receiving and bending means 28 and 29, respectively. The nail receiving means 28 includes a web or nail guiding portion 31 and a parallel nail guiding portion 32 adapted to receive a driven nail therebetween. The web and nail guiding portions 31 and 32 are spaced apart and define an elongated nail receiving slot or groove 33 having a constant width throughout its length. The nail receiving means 29 also includes a web portion 33' and a parallel nail guiding portion 34. The portions 33 and 34 are spaced apart and define therebetween an elongated nailing groove 35.

The flange means 11 and the nail receiving means 28 constitute a T-shape as does the flange means 12 and the corresponding nail receiving means 29. These two T-shapes are joined by a flat web portion 36 which is integrally joined along opposite edges to the web portions 31 and 33'. The web portions 31 and 33' constitute part of the nail receiving means as well as part of the web means joining the flanges 11 and 12. As shown, axes x—x and y—y are mutually perpendicular, coordinate axes of the cross-sectional area of the elongated member 10. These axes are located in a plane normal to the longitudinal axis z—z of the member. Axes x—x and y—y intersect at point O. The web portion 36 is symmetrical about axis y—y as is flange 11 and flange 12. Accordingly, the cross-sectional area of the structural member, except for the cross-sectional area of the two receiving and bending means 28 and 29, is symmetrical about axis y—y. The expression "cross-sectional area" means the area of metal measured in a plane normal to the longitudinal axis. Similarly, the cross-sectional area of the flanges 11 and 12 and web 36 is symmetrical about axis x—x. Accordingly, point "O" is the center of gravity for the cross-sectional area of the web 36 and flanges 11 and 12, and these axes are gravity axes for this portion of the member. Additionally, and for reasons more fully hereinafter pointed out, all values of "y" above axis x—x are positive, and all values of "y" below axis x—x are negative. All values of "x" to the right of axis y—y are positive, and all values of "x" to the left of axis y—y are negative as indicated on the drawings by the customary plus (+) and minus (—) signs.

In each of the nail receiving means 28 and 29, the parallel web and nail guiding portions are curved or corrugated through two reverse curves or two corrugations so that their axes curve in a particular novel manner for reasons more fully hereinafter set forth. Referring to the nail receiving means 28 and to Figures 1 and 2, the axis or center line 37 of the nail receiving slot 33 is midway between the opposed inner surfaces of the parallel pair of web and nail guiding portions

31, 32. The nail guiding portion 32 is integrally joined to flange portion 16, and at their juncture 38 the metal is curved about the center 39 which is to the right or one side of axis *y*—*y*. Similarly, the web portion 31 is integrally joined to the flange portion 15, and the metal at their juncture 40 is curved about center 41 which is on the left or opposite side of axis *y*—*y*. Points 39 and 41 are equally spaced from axis *y*—*y* and also from the coplanar flange portions 15 and 16. The portions of metal 38 and 40 at the juncture of the nail guiding and web portions with flange portions 16 and 15 define therebetween an entrance throat 42 and throat 42 is symmetrical about axis *y*—*y* Preferably, entrance throat or passage 42 has the outwardly diverging walls as shown so that the point of a nail will be guided into the nail receiving slot 33. The metal at 43, between flange portions 15 and 16, is depressed and extends into throat 42 to form a nail guiding entering groove 44 extending longitudinally of the member between flange portions 15 and 16. The metal at the bottom 45 of groove 44 may be thinned to facilitate penetration of a nail point. The metal of both the web portion 31 and web portion 32 is curved about point 47 disposed on one side of axis *y*—*y* so that axis 37 of the nail receiving slot, starting at point 48 where axis 37 coincides with and is tangent to axis *y*—*y*, curves to said one side of axis *y*—*y* to point 50, and the radius of curvature indicated by line 51 is relatively quite small. The radius of curvature 51 is equal to the horizontal distance of point 47 from axis *y*—*y* so that axis 37 is tangent to axis *y*—*y* at point 48. The web and nail guiding portions 31, 32 are next curved about point 52 disposed on the opposite side of axis *y*—*y* so that axis 37 from point 50 curves away from axis *y*—*y* and then curves back toward axis *y*—*y* to point 53 through a radius of curvature indicated by line 54. Point 50 is the point at which a line drawn between centers 52 and 47 would intersect center line 37. Thus, axis 37 curves away from and to said one side of axis *y*—*y* and then back toward axis *y*—*y* through a reverse curve. The web and nail guiding portions 31 and 32 are thereafter curved about center 55 disposed on said one side of axis *y*—*y*. The axis 37 is curved from point 53 across axis *y*—*y* to said opposite side of axis *y*—*y* and then back toward and across axis *y*—*y* to point 57 through a radius of curvature indicated by line 58. Point 53 is the point at which a line drawn between centers 52 and 55 would intersect center line 37 and point 57 is the point at which a line drawn from center 55 to center 59 would intersect center line 37. Thus, that portion of axis 37 which extends from point 48 to a point between points 50 and 53 is curved or bent through a reverse curve and the remaining length of axis 37 which extends to point 57 is curved through a second reverse curve. While the length of axis 37 which is curved about center 52 forms part of the first reverse curve and also part of the second reverse curve, the tortuous nail receiving slot 33 does contain two reverse curves, and the web portions 31 and nail guiding portion 32 each contains two corrugations with the corrugations of one portion parallel with the corresponding corrugations of the other portion. The radius of curvature 54 is equal to and may be longer than 51 but is shorter than 58 so that the first reverse curve is relatively sharper and the second or final reverse curve is relatively larger and more gradual.

The web portion 31 is curved about center 59 through an arc of relatively short radius so that the web portion 31 joins the web portion 36. The nail guiding portion 32 is not curved around center 59 for the reason that the groove 33 at its inner end preferably should direct the point of the nail away from the web portion 36. If the inner edge portion of portion 32 were curved about center 59, then the point of a long nail would tend to curve into the web portion 36. With the arrangement shown, the point is directed away from the web 36. It will be noted that the inner surface of the web portion 31 curved about point 59 joins the inner surface of web portion 36 at a point that is tangent to a line parallel to axis *y*—*y*. If axis 37 were extended as shown, the axis 37 would intersect a horizontal line at a point 59' spaced from axis *y*—*y* a distance equal to one-half (the thickness of the metal plus the width of slot 33). Thus, the lower end of axis 37 is shifted to the right of the upper end of axis 37. This is done to bring the center of web portion 31 over to axis *y*—*y*.

The web and nail guiding portions 33', 34 of the nail guiding means 29 are curved through two reverse curves and contain two corrugations so that the axis 60 of nailing groove 35 also is curved in a particular manner. The nail guiding portion 34 is integrally joined to flange portion 22 and at their juncture 61 the metal is curved about the center 62 which is to the right or on said one side of axis *y*—*y*. Similarly, the web portion 33' is integrally joined to the flange portion 21, and the metal at their juncture 63 is curved about point 64 which is on the left or on the said opposite side of axis *y*—*y*. Centers 62 and 64 are equally, oppositely spaced from axis *y*—*y* and are also equally spaced inwardly from the outer face of the coplanar flange portions 21 and 22. The portions of metal 61, 63 define therebetween a nail entering throat 65 which is symmetrical about axis *y*—*y*. Preferably, the nail entering throat 65 or passage has outwardly diverging walls so that the entering point of the nail will be guided into the nail receiving slot 35. The metal at 66 between the flange portions 21 and 22 and more particularly between the outer layers of flange metal 23 and 25 is depressed and extends into throat 65 to form a nail guiding entering groove 67 which extends longitudinally of the member between the flange portions 21 and 22. The metal at the bottom 68 of groove 67 is thinned out to facilitate penetration of a nail point. The metal of both the web portion 33' and the nail guiding portion 34 is curved about a center 70 disposed on said one side of axis *y*—*y* so that axis 60 starting at point 71 where axis 60 meets or coincides with axis *y*—*y* curves to said one side of axis *y*—*y* to a point 72 and the radius of curvature indicated by line 73 is relatively short. The radius of curvature 73 is equal to the distance of point 70 from axis *y*—*y* so that axis 60 is tangent to axis *y*—*y* at point 71. The web and nail guiding portions 33' and 34 are next curved about a point 75 disposed on said opposite side of axis *y*—*y* so that the axis 60 curves from point 72 back toward axis *y*—*y* to point 76 through a radius of curvature indicated by line 77. Thus, axis 60 curves away from and to said one side of axis *y*—*y* and then back toward axis *y*—*y* through a single reverse curve. The web and nail guiding portions 33' and 34 are thereafter curved about center 70 disposed on said one side of axis *y*—*y*. The axis 60 is curved from point 76 across axis *y*—*y* to said opposite side of axis *y*—*y* and then back toward axis *y*—*y* to point

79. Thus, that portion of axis 60 which extends from the point 71 to a point between point 72 and 76 is curved or bent through a reverse curve, and the remaining length of axis 60 which extends to point 79 is curved through a second reverse curve. As stated in connection with the first nailing means 28, the length of axis 60 which is curved about the center 75 forms part of the first reverse curve and also part of the second reverse curve, and the tortuous nail receiving slot 35 does contain two reverse curves and the web portion 33' and nail guiding portion 34 each contains two corrugations with the corrugations of one portion parallel with the corresponding corrugations of the other portion. The radius of curvature 77 is equal to the radius of curvature 73 but is shorter than the radius of curvature 80 so that the first reverse curve is relatively sharper and the second or final reverse curve is relatively larger or more gradual. The web portion 33' is curved about center 81 through an arc having a relatively short radius of curvature which brings the web portion 33' into web portion 36. The nail holding portion 28 which extends from point 42 to 59' and the nail bending and holding portion 29 which extends from a horizontal line drawn through point 70 to a horizontal line drawn through center 81 are symmetrical about axis x—x.

I have discovered that the addition of the second corrugation or second reverse curve greatly increases the ability of the nailing member to retain a nail driven into the nail receiving slot, particularly when the nail is subjected to a live load. I also have discovered that having the second reverse curve larger than the first reverse curve produces certain important advantages in addition to greatly increasing the ability of the nailing beam to retain a nail subjected to live load. While I do not want to be limited to any particular theories, it is believed that the addition of the second reverse curve greatly increases the ability of the member to retain a nail subjected to live load because of a difference in the manner in which the nail is gripped. This will be more readily understood by considering the difference between a nail holding means having a single corrugation and a double corrugation. Referring more particularly to Figure 2, assuming that the nail receiving means 28 is constructed in the manner heretofore used by the prior art, particularly in the members which have received commercial acceptance, the nail receiving means 28 has been constructed as though it were severed at about the point 53. The addition of web and nail guiding portions below point 53, which additional portions are parallel to the axis y—y, did not and will not materially alter the problem or prevent the nail from being walked out of the groove by a live load. The nail which is driven into the nail receiving groove is substantially the same width as the nail receiving groove so that it engages the interior surfaces of the web and nail guiding portions throughout the reverse curve. Thus, the nail apparently is held in place both by frictional engagement with the walls of the tortuous nail receiving slot and by the resistance of the nail to being straightened. I believe and results confirm my belief that this is somewhat misleading, particularly when the nail is subjected to a live load. When a nail is subjected to a static load, the holding ability of the nail is, in practice, quite different. For example, if a force is applied to the head of the nail in a direction parallel to the axis y—y tending to pull the nail out of the slot, a relatively large force will be required to remove the nail. While the nail may be removed when desirable by applying a sufficiently great force, the nail will be relatively securely held in place when subjected only to a static load.

I believe that the forces retaining the nail in place when subjected to a live load are different than those retaining the nail in place when subjected to a static load. When a nail is subjected to a live load, it is not only subjected to a force tending to pull the nail out of the groove but is subjected to forces tending to bend the head portion of the nail first in one direction and then in the opposite direction. These cycles of load application upset or alter the nail holding characteristics of the beam. Before discussing this point, it is to be noted that if a force is applied to the nail and the nail starts to move, the frictional force resisting movement of the nail is reduced. The force necessary to overcome friction between two stationary parts is greater than the force required to maintain movement. The starting friction is always greater than the moving friction. As a result, once the nail starts to move, friction alone can not stop movement of the nail.

Once the nail starts to move or moves a very short distance, the nail tends to straighten out so that it is no longer accurate to consider the nail as being engaged throughout its length. The nail in the prior art structures acts as though it were engaged only at two points along its length. When a live load is applied to the head portion of the nail, the head portion is bent back and forth and these points of engagement change. The head portion of the nail is relatively easily bent and particularly after the nail is once started the live load apparently shifts the points of engagement between the nail and the walls of the slot. This rocking or shifting of the nail walks the nail out of the slot. In other words, each time the direction of load changes, the nail is moved outwardly a short distance. While under some conditions this distance may be very slight, the nail will not support live loads indefinitely, and if the live load changes cycles rapidly or if the live load is relatively great the nail will be quickly walked out of the slot.

In contradistinction, when a nail 85 is driven through a board 86 into slot 37 and bent through two reverse curves, the nail is held at a plurality of points of engagement along its double corrugated length. When a live load tends to shift board 86 back and forth and tends to bend the head portion 87 of the nail 85 back and forth, at least two of these points of engagement are not shifted or changed. These points of engagement never completely "let go" of the nail, and the nail can not be walked out of the slot. Additional bends would be redundant.

Regardless of whether or not the foregoing theory is exactly correct, it is true that the addition of the second reverse bend or corrugation does greatly increase the ability of the member to retain nails, particularly when the nails are subjected to live load, and this ability to retain nails is much greater than would be expected from the additional friction established as a result of the additional length of nail engagement.

It has been found that the second reverse curve should be larger—that is, have a greater radius of curvature than the first reverse curve. With the radius 58 longer than radius 54, the nail is first bent through a relatively sharp bend and

work-hardened. The work-hardened nail is then bent through the larger more gradual reverse bend. The work-hardened nail has a greater resistance to being bent than the original nail, and, by having the second reverse curve larger, the force required to bend the nail through one reverse curve is equal or more nearly equal to the force required to bend the nail through the other reverse curve. This results in two advantages. First, the structural member can be produced from thinner steel sheet or strip. Second, there is less tendency for the nail to spread apart the walls of the nail receiving slot. Where, as has happened in the past, the nail spreads the web and nail guiding portions, a length of the nail receiving means loses its ability to retain nails. This is true despite the fact that the walls of the nail receiving means are usually held together by suitable fastening means at spaced points, as will be hereinafter described. Thus, having the second reverse curve larger than the first reverse curve increases the ability of the member to retain securely a driven nail.

Referring more particularly to Figures 1 and 3, fastening means 90 are located at spaced intervals along the length of the nail bending and holding means 28. The fastening means 90 prevents spreading apart of the web portion 31 and the nail guiding portion 32 and fastens these two portions together so that the flanges 15 and 16 and portions 31 and 32 are tied together whereby the flanges will equally support a load applied uniformly to the flanges. The exact spacing apart of the fastening means depends on a number of factors including the thickness or gauge of the metal. Any suitable type of fastening means may be used though the type of fastening means shown and hereinafter described is preferred. The fastening means 90 is similar to that shown and described in patent No. 2,457,148 to William J. Hall et al. The lower nail holding means 29 also includes identical fastening means 90 for holding the web and nail guiding portions 33 and 34 together in properly spaced relationship.

The fastening means 90 comprises a flattened portion 91 formed on the curved web portion 31 and a flat portion 92 formed on the curved nail guiding portion 32. The two flat portions 90 and 91 are bosses displaced laterally from their respective portions 31, 32 so that when the flat portions 91, 92 are in abutting relationship, the web and nail guiding portions are spaced apart to provide the nailing groove therebetween. An opening 93 is formed in boss 91. An opening is formed in boss 92, and the metal 94 around this opening is formed into a tubular projection 94 which extends through and snugly fits opening 93. The outer end of the projection 94 is flanged or flared outwardly at 95 against the outer surface of the boss 91 to securely hold together the web portion 31 and the nail guiding portion 32. The bosses 91 and 92 are in contact with each other, but throughout the length of the nail receiving means 28 the web and nail guiding portions 31, 32 are spaced apart except at the location of the fastening means. The fastening means 90 located along the lower nail receiving means 29 is identical with the upper fastening means 90 and will not be described in detail.

The important discovery has been made that the introduction of the second, more gradual reverse curve to the tortuous nail bending groove enables the nailable structural member 10 to be constructed so that the member when loaded will develop maximum strength and stiffness and will not twist. In the following discussion, it will be assumed that the load is uniformly distributed over the area of the flanges and that the load is applied vertically—that is, in a direction parallel to axis y—y in Figure 1, unless otherwise stated.

The section properties of a structural member are always figured about coordinate axes. These coordinate axes are two axes which intersect each other at 90° and which are located in a plane normal to the length or longitudinal axis of the beam. Coordinate axes are axes of the area of cross-section of the beam. Axes x—x and y—y are coordinate axes for the section of the beam of Figure 1 intersecting at point "O".

For a structural member to develop maximum strength and stability, coordinate axes x—x and y—y should be gravity axes, should be principal axes and should be axes of the section outline. For axis x—x to be a gravity axis, the static moment about x—x must equal zero, or expressed mathematically $\int ydA=0$. In other words, the area A, the area of the cross-section, would balance on a knife edge along axis x—x. Similarly, for axis y—y to be a gravity axis, the static moment about y—y must equal zero or $\int xdA=0$. The area A would balance now on a knife edge along axis y—y.

The axes x—x and y—y may be gravity axes without being principal axes and may be principal axes without being gravity axes. For axes x—x or y—y to be principal axes, the product of inertia must equal zero or $\int xydA=0$. By inspection of Figure 1 it can be seen that if axis x—x is a principal axis, it is the major axis or a minor axis, depending on whether the moment of inertia about axis x—x, which may be expressed as $\int y^2dA$, is greater than or less than the moment of inertia about axis y—y expressed as $\int x^2dA$. If axis x—x is the major axis, then axis y—y is the minor axis and $\int y^2dA$ is greater than $\int x^2dA$.

For members having an I-shape such as is shown in Figure 1 and which are used as beams, the greatest bending load is applied against the flanges, and it is important that the bending load be applied about the principal axis that is the major axis, for the beam is stiffer about the major axis. If the axis of bending is not a principal axis, some of the bending force or load will produce twist. It also is desirable in beams that the major axis be parallel to the outside faces of the flanges and midway between them so that axis x—x is a major axis. In columns, it may be desirable to have the greatest stiffness about axis y—y so that axis y—y is the major axis. In a loaded beam, the area above the axis about which bending is applied is under compression, and the area below this axis is under tension. If this axis—axis x—x—is not exactly midway between the outer faces of the flanges, then the flange farther from this axis will be overstressed before the full allowable stress is developed in the other nearer flange. The beam cannot be fully loaded. If the major axis about which the bending load is applied is not parallel to the outer faces of the flanges, then twist will develop.

In addition, the minor axis—axis y—y—must be normal to the outer faces of the flanges or the bending load will develop twist because the center of the load will not be directly above the center of gravity. The center of load is midway between the outer extremities of the flanges, and if the minor axis is a coordinate axis of the outline of the area, then the center of the load is located along a principal axis. If, as previously

described, the minor axis is a gravity axis, the center of gravity is located along this axis and the beam will have structural symmetry—that is, there will be no tendency to twist under bending.

It has been discovered that the addition of the second reverse curve enables the nailing beam 10 to meet the foregoing requirements. In other words, the beam can be arranged so that coordinate axes x—x and y—y are principal axes intersecting at the centroid "O" of the cross-sectional area so that these axes are gravity axes. Additionally, the axis x—x may be the major axis and the axis y—y the minor axis. Axes x—x and y—y are axes of the outline of the cross-sectional area—that is, the major axis x—x is parallel to the outer faces of the flanges and midway therebetween and minor axis y—y is midway between the outer edges of the upper and lower flanges. The polar axis z—z is located along the plane of zero stress. Accordingly, the beam develops maximum strength and stability against twisting.

Heretofore, it has been impossible to develop a nailing beam having tortuous nailing slots along opposite sides that would not tend to twist when loaded. The prior art nailing beams of this type usually could not carry their maximum load—that is, a load which stressed both flanges equally.

The manner in which addition of the second reverse curve enables proportioning the beam so that it will provide maximum stability and can be loaded to maximum capacity will be readily explained by first considering a beam that has no nail receiving means. Referring to Figure 1 and assuming that the beam consists of flanges 15, 16, flanges 21, 22 and the flat connecting web 36, then by inspection it can be seen that coordinate axes x—x and y—y are gravity axes. The cross-sectional area of flanges 16 and 22 balances the cross-sectional area of flanges 15 and 21 and the web 36 is symmetrical about axis y—y so that static moment about axis y—y is zero and the expression $\int xdA=0$ is satisfied. Similarly, axis x—x is a gravity axis as the static moment about axis x—x is zero and the expression $\int ydA=0$ is satisfied. This is true regardless of the area of the web connecting the flanges as long as the connecting web is symmetrical about both axes.

Now assume that the first reverse curve of each nail receiving means is added to the flanges 11 and 12, the axis y—y is no longer an axis of gravity. The static moment about axis y—y is not zero and the expression $xdA=0$ is no longer correct. The first reverse curve of the nail receiving means 28 comprises the curved portions of web portion 31 and nail guiding portion 32 extending from point 48 to point 53. This first reverse curved portion of the nail receiving means will be hereinafter referred to as curved portion F–1. The first reverse curved portion of the nail receiving means 29 consists of the curved portions of web portion 33 and of nail guiding portion 34 extending to point 76 and is hereinafter referred to as F–2. The reversed curved portions F–1 and F–2 are symmetrical about axis x—x but asymmetrical about axis y—y. While the static moment about axis x—x equals zero, the static moment about axis y—y is no longer zero and axis y—y is not a gravity axis. Accordingly, axes x—x and y—y can not be principal axes intersecting at the centroid or center of gravity of the area of the beam, and the beam when loaded along the upper flanges will tend to twist. The principal axis for point "O" would be displaced and the principal minor axis for the area through the center of gravity would be to the right so that if the flanges were equally loaded, the center of the load would be to the left of the minor axis. This is especially pronounced when the nail receiving means comprises walls spaced apart to provide a nail receiving slot. This spacing apart of the walls accentuates the unbalance or tendency of the beam to twist under load.

The areas of the second reverse curved portions S–1 and S–2 are proportioned relative to the respective areas of F–1 and F–2 so as to bring the area of the beam back into balance and so as to bring the static moment about axis y—y back to zero whereby axes x—x and y—y are principal axes intersecting at the centroid of the cross-sectional area of the beam. In this one piece beam, this can only be done if radius 58 is longer than radius 54. If radius 58 equalled radius 54, then web portion 36 would be to the left of its position shown and would not be symmetrical about axis y—y.

As the cross-sectional area of the member 10, except for the nail receiving and bending portions, is symmetrical about axis y—y, the member when used as a beam and uniformly loaded only along the upper flange will not tend to twist if the two nail receiving and bending means are arranged so that these means together maintain the structural symmetry. With the area, except for 28 and 29, being symmetrical about axis y—y, it is believed obvious that flange 15 must be equal to flange 16 and flange 21 must be equal to flange 22 and that axis x—x is parallel to the outer surfaces of the flanges. Usually with structural members, and especially columns, some load is directed against the side of the member. This load will cause twist if the axis x—x is not midway between the flanges 11 and 12. Accordingly, the member preferably should be structurally symmetrical about axis x—x with axis x—x being midway between the outer surfaces of the flanges so as to reduce the bracing required.

As an illustration, the structural member of Figure 1 having the previously described characteristics can be produced by using, for example, 18 gauge steel and by having radii 51, 54, 73 and 77 each equal to .221 inch and by having radii 58 and 80 each equal to .540 inch. With this particular arrangement, the distance between center 59 and the inner surface of web portion 31 equals .186 inch with the width of slot 33 equal to .70 inch.

Referring more particularly to Figure 4 which is an end view of a structural member embodying the principles of the present invention, this elongated member essentially consists of a pair of U-shaped channels 100 and 101 connected together in back-to-back relationship. The channel member 100 includes a first flange 102 and a second flange 103 connected by a web 104. Similarly, the channel member 101 includes flanges 105 and 106 connected by a web 107. The two channel members 100 and 101 are arranged in back-to-back relationship with the webs 104 and 107 in opposed parallel relationship. The flanges 102 and 105 are coplanar and extend equally outwardly from the coordinate axis y—y. Flanges 103 and 106 are coplanar and extend equally outwardly from axis y—y. Adjacent the pair of flanges 102 and 105, there is a nail receiving and bending means 109. There is a similar nail receiving and bending means 110 adja-

cent flanges 103 and 106. The nail receiving and bending means 109 includes a web portion 111 and a parallel, nail guiding or web portion 112 adapted to receive and bend a nail driven therebetween. The parallel web portions 111 and 112 are spaced apart and define an elongated nail receiving slot or groove 114 having a constant width throughout its length. The nail receiving and bending means 110 includes a web portion 116 and a parallel, nail guiding or web portion 117 constructed and arranged to define therebetween an elongated tortuous nailing groove 118 at a constant width throughout its length. The web portions 111 and 117 are connected together by a flat web portion 119 which is part of the web 107. The web portions 112 and 116 also are connected together by a flat web portion 120 which is part of the channel web 104. The structural member of Figure 4 has substantially an I-shape. The flanges 102 and 105 together with the nail receiving and bending means 109 constitute a T-shape as do the flanges 103 and 106 taken with the nail receiving and bending means 110. These two T-shapes extend along opposite sides of the member with the legs of the T's being directed inwardly toward each other. The two T-shapes are joined by web means which in this structural member is made up of the web portions 119 and 120.

As shown, axes x—x and y—y are coordinate, mutually perpendicular axes of the cross-sectional area of the elongated structural member. These axes are located in a plane normal to the longitudinal axis of the member and intersect at point "O." As will become clear from the following description, all of the various structural members are arranged and proportioned in a certain manner relative to a pair of coordinate axes. There is a similarity of the various members to the coordinate axes of each member. To simplify this relationship, the coordinate axes for each structural member will be referred to as axes x—x and y—y. Each pair of coordinate axes intersect at a point, and this point of intersection is designated as point "O."

Referring to Figure 4, the flanges 102 and 105 are symmetrical about axis y—y as are flanges 103 and 106. The web portions 119 and 120 also are symmetrical about axis y—y. The cross-sectional area of the entire structural member except for the cross-sectional area of the two nail receiving and bending means 109 and 110 is symmetrical about axis y—y. The cross-sectional area of flanges 105 and 102 is symmetrical with the cross-sectional area of flanges 103 and 106 about axis x—x. The two flange portions 119 and 120 are also symmetrical about axis x—x. Accordingly, the cross-sectional area of the sectional member, except for the cross-sectional area of the two nail receiving and bending means 109 and 110, is symmetrical about axis x—x. Except for the nail receiving and bending means, the structural member is symmetrical about both axes so that axes x—x and y—y are principal axes intersecting at the center of gravity for the cross-sectional area of the beam if the area of the two nail receiving and bending means is excluded. As will be more fully hereinafter described, the two nail receiving and bending means are arranged so that the axes x—x and y—y are principal axes intersecting at the center of gravity of the structural member.

It will be noted that despite the fact that the flanges and flat web portions are symmetrical about both axes, the cross-sectional area of the structural member is asymmetrical about axis x—x and is asymmetrical about axis y—y. The two nail receiving and bending means and, therefore, the entire beam are anti-symmetrical. In other words, if that portion of the cross-sectional area below axis x—x is rotated through 180° about point "O", the boundaries of the area of the rotated portion will coincide with the boundaries of the area of the portion above axis x—x. This is of particular importance because as will be more fully hereinafter described, the two channel members 100 and 101 are identical. When they are arranged in back-to-back relationship, one of the members is turned upside down relative to the other. The corrugated web portion 116 is identical with the corrugated web portion 111, and the corrugated web portions 112 and 117 are identical.

In each of the nail receiving means 109 and 110, the parallel web portions are curved or corrugated through two reverse curves or two corrugations so that the axis of each nail receiving groove curves in a particular manner. At least a portion of the web portions defining each nail receiving means are curved to provide means for bending a nail driven therebetween. The longitudinal axis 122 of the nail receiving and bending slot 114 is located midway between the opposed inner surfaces of the parallel web portions 111 and 112. The web portion 111 is integrally joined to the flange 105 and at their juncture the metal at 123 is curved about the center 124. Similarly, the web portion 112 is integrally joined to the flange 102, and at their juncture the metal 125 is curved about center 126. Centers 124 and 126 are equally and oppositely spaced from axis y—y and are located along a line 127 which is normal to axis y—y. The portions of curved metal 123 and 125 define therebetween an entrance throat 129, and this throat is symmetrical about axis y—y. Preferably, the throat has the diverging walls as shown, so that the point of a nail will be guided into the nail receiving slot 114. Starting at line 127, the metal of both web portions 111 and 112 is curved about the center 130 disposed on one side of, or to the left of, axis y—y so that the axis 122, starting at point 131 where axis 122 coincides with and is tangent to axis y—y, curves to point 134. The radius of curvature indicated by line 135 is relatively quite small. Web portions 111 and 112 are next curved through an arc about center 136 disposed on the opposite or right hand side of axis y—y so that axis 112 curves from point 134 away from axis y—y and then back toward axis y—y to a point 137. The radius of curvature about axis 136 is indicated by line 138. Point 134 is the point at which a line drawn between centers 130 and 136 would intersect center line 122. The web and nail guiding portions 111 and 112 are next curved about center 140 disposed on said one side or left side of axis y—y. The axis 122 is curved from point 137 across axis y—y to said opposite or right hand side of axis y—y and then back toward axis y—y to point 141 through a relatively large radius of curvature indicated by line 142. The point 137 is the point at which a line drawn from center 140 to center 136 intersects axis 122. The web portions 112 and 111 are finally curved about point 143 to join web portions 104 and 107. The axis 122 is curved from point 141 about center 143 to point 144 which point is on axis y—y and which point is located along a horizontal line drawn from center 143. The radius of curvature of this final portion of axis 122 is

relatively small and is indicated by line 145. Point 141 is a point at which a line drawn from center 140 to center 143 intersects the axis 122. Thus, that portion of axis 122 which extends from point 133 to point 137 is bent or curved through a single reverse curve, and the remaining length of axis 122 which extends from point 137 to point 144 is curved through a second relatively larger and more gradual reverse curve. It is essential that radius 142 be longer than radius 138.

As previously pointed out, the nail receiving and bending means 110 is anti-symmetrical relative to the nail receiving and bending means 109. This in turn means that there are definite fixed relationships between the various portions of the nail receiving and bending means 110 and the corresponding portions of the nail receiving and bending means 109. The nail bending web portion 116 is integrally joined to flange 103, and at their juncture 147 the metal is curved about center 148 which is to the right and on said opposite side of axis y—y. Similarly, the web portion 117 is integrally joined to the flange 106 and the metal at their juncture 149 is curved about center 150 which is on the left or on said one side of axis y—y. Centers 148 and 150 are equally oppositely spaced from axis y—y and are also equally spaced inwardly from the outer face of coplanar flanges 103 and 106. The metal at 147 and 149 define therebetween a nail entering and guiding throat 151 which is symmetrical about axis y—y. The metal of web portions 116 and 117, starting at line 152 which is a line drawn between centers 148 and 150, is curved about a center 153 disposed on the right side of axis y—y. The axis 154 of the nail receiving and bending slot 118 starting at point 155 curves toward the right and away from axis y—y to point 146, and the relatively small radius of curvature is indicated by line 157. The centers 153 and 130 are equally oppositely spaced from axis y—y. The axis 154 of the nail receiving slot or groove is tangent to axis y—y at point 155. The web portions 116 and 117 are next curved about a center 159 disposed on the left side of axis y—y so that axis 154 curves from point 156 away from and then back toward axis y—y to point 160 through a radius of curvature indicated by line 161. The center 159 and the center 136 are equally and oppositely spaced from axis y—y. The point 146 is that point at which a line drawn between centers 159 and 153 intersects axis 154. Thus, axis 154 curves from point 155 away from and to the right of axis y—y and then back toward axis y—y through a single reverse curve. The web portions 116 and 117 are next curved about center 162 disposed to the right of axis y—y. The axis 154 is curved from point 160 across axis y—y to the left of axis y—y and then back toward axis y—y to point 163 through a relatively long radius indicated by line 164. The point 160 is the point at which a line drawn between centers 159 and 162 intersects axis 154. The last or final portion of the web portions 116 and 117 are curved about center 166 so that axis 154 curves from point 163 about center 166 to point 167 at which point the axis 154 coincides with and is tangent to axis y—y. The radius of curvature of this last or final portion of axis 154 is indicated by line 168. Thus, that portion of axis 154 which extends from point 155 to point 160 is bent or curved through a reverse curve, and the remaining length of axis 154 which extends from point 160 to point 167 is bent through a second reverse curve. The radius of curvature 164 is equal to the radius of curvature 142 and is longer than the radius of curvature 161.

The addition of the second corrugation or second reverse curve greatly increases the ability of the member to retain a nail driven into the nail receiving slot, particularly when the nail is subjected to a live load. The nail is securely retained when subjected to live load for the reasons pointed out in connection with the structural member shown in Figure 1 and will not be repeated at this time. The second reverse curve is larger than the first reverse curve so that as the nail has been relatively sharply bent by the first reversed curve portion, it is then more gradually bent by the second reverse curve portion. As the work-hardened nail is more gradually bent in the second reverse curved portion, the forces required to confine the nail being bent by either reverse curved portion are more nearly equal and the structural member may be made from relatively thinner metal.

The two channel members 100 and 101 may be fastened together by any suitable means and may be fastened together at spaced points throughout their length by means of fastening elements substantially as shown and described in connection with the structural member of Figure 1.

With the structural member of Figure 4, like the structural member of Figure 1, the important discovery has been made that the introduction of the second more gradual reverse curve to the tortuous nail bending groove enables the various portions of the nailable structural member to be constructed and arranged so that the member will develop maximum strength and stiffness and will not tend to twist. The axes x—x and y—y are coordinate axes of the area of cross-section of the structural member, and these axes intersect at point "O." The addition of the second reverse curve that is relatively larger and more gradual than the first reverse curve to each of the nail bending means 109 and 110 permits the two nail bending means 109 and 110 to be arranged so that the structural member of Figure 4 will not tend to twist. As has been previously pointed out, cross-sectional area of this structural member is symmetrical about axis x—x and symmetrical about axis y—y if the cross-sectional area of the two nail bending means 109 and 110 is not considered. As more fully described in connection with the structural member of Figure 1, if the structural member is to be used as a beam and it be assumed that it is uniformly loaded along the flanges 102 and 105, then this load will be concentrated along axis y—y. This load will produce twist if the axis y—y is not a gravity axis so that the center of gravity lies along a point on the axis and will develop twist if axis y—y is not a principal axis that is midway between and normal to the two pairs of flanges 102, 105 and 103, 106. This last is merely another way of stating that axis x—x must be parallel to the outer surfaces of the flanges as coordinate axes are always perpendicular to each other. If the structural member is to be used as a column and if a load is uniformly applied against the side of the structural member, then this load or force will be centered on axis x—x. This load will tend to twist the column if axis x—x is not a principal gravity axis equally spaced from the outer surfaces of the flanges. Accordingly, it is preferable that the axis x—x be equally spaced from the outer surfaces of the flanges for, regardless of where the structural member is used in a

building framework, some force will be applied to the side of the structural member. Accordingly, if axis x—x is not a principal gravity axis midway between the outer surfaces of the flanges, considerable bracing will be required. For axis x—x to be a gravity axis, the static moment about axis x—x must equal 0 or expressed mathematically $\int ydA=0$. In other words, the area A, the area of the cross-section, would balance on a knife edge along axis x—x. Similarly, for axis y—y to be a gravity axis, the static moment about axis y—y must equal 0 or $\int xdA=0$. The area A would then balance on a knife edge along axis y—y. For axes x—x and y—y to be principal axes, the product of inertia must equal 0, or expressed mathematically, $\int xydA=0$.

As previously described, it has been discovered that the presence of the second reverse curve enables the nailing beam shown in Figure 4 to meet the foregoing requirements. This can be done only because the second reverse curve, particularly that portion between points 137 and 141, is larger than the first reverse curve, particularly that portion between point 136 and 137. In other words, the radius 142 must be longer than the radius 138. While nailable structural members of general I-shape and having reverse curves similar to the first reverse curves have been used heretofore, these structural members have not been stable and have tended to twist. The manner in which the addition of a second reverse curve enables proportioning the beam so that it will provide maximum stability may be more readily explained by first considering a structural member which does not have any nail bending and holding means. Assuming that the structural member of Figure 4 does not contain the nail holding and bending means 109 and 110, it is believed clear from the foregoing description that the axes x—x and y—y would be principal axes intersecting at the center of gravity "O." If the first reverse curve is added to each nail receiving and bending means, the axis y—y will be a gravity axis but will not be a principal axis. This follows from the fact that the first reverse curve of the nail bending means 109 adds a larger negative (xy) value than it does a positive (xy) value. Obviously, the area of metal on the left of axis y—y is greater than the area of metal on the right of axis y—y. The first reverse curve of the nail bending means 110 which is anti-symmetrical to the first reverse curve of the nail bending means 109 also adds a greater negative (xy) value than positive (xy) value so that the product of inertia no longer equals 0 and the expression $\int xydA=0$ is no longer satisfied. In other words, the principal axes for the point "O" will be rotated anti-clockwise from the position shown in Figure 4 and the axis y—y will not be normal to the flanges. Thus, when a load is uniformly applied against the flanges 102 and 105, the center of this load will not coincide with axis y—y and the load will tend to twist the beam. For the same reason, a load applied against either side of the beam will also tend to twist the beam. By the addition of the second reverse curve, it is possible to have the axes x—x and y—y principal axes intersecting at the center of gravity. The area of the second reverse curve portion of webs 111 and 112 must add as much positive (xy) value as the first reverse curved portion of web portions 116 and 117 adds negative (xy) value. The second reverse curved portion of the nail holding and bending means 110 must similarly balance the first reverse curved portion of the

nail holding and bending means 109. To do this, the area of the second reverse curved portion must be larger than the area of the first reverse curved portion because the distance of the center of gravity of the second reverse curved portion from axis x—x is less than the distance of the center of gravity of the first reverse curved portion from axis x—x. Therefore, to satisfy the expression $\int xydA=0$, the second reverse curved portions must have a relatively greater area and be curved more gradually than the first reverse curved portions. In view of the foregoing, and remembering that the cross-sectional area of the structural member is symmetrical about both axes except for the nail bending means 109 and 110, the nail bending means 109 and the nail bending means 110 must be carefully arranged so that together they satisfy the three expressions $\int xda=0$, $\int ydA=0$, and $\int xydA=0$, if axes x—x and y—y are to be principal axes intersecting at the center of gravity. If this is done, and with the axes x—x and y—y being principal gravity axes for the cross-sectional area except for the nail holding and bending means 109 and 110, then the nail holding and bending means will not shift the principal gravity axes for the entire cross-sectional area, and these axes will be the principal gravity axes for the entire member whereby the member will have the greatest structural stability.

The structural member of Figure 4 is substantially an I-shape and the structural member is so constructed and arranged that the axes x—x and y—y are principal gravity axes with the flanges 102 and 105 and 103 and 106 being symmetrical about the y—y axis and with the axis x—x parallel to the outer surfaces of these flanges. Where the structural member is to be used as a beam, it is usually desirable to have axis x—x the major axis because the beam is usually uniformly loaded along the top flanges and the beam has the greatest stiffness about axis x—x. Under certain conditions, it may be desirable to have the beam stiffer about axis y—y than axis x—x. This may be true if the structural member is used as a column, but under certain conditions also may be true when the structural member is used as a beam. Accordingly, the flanges and the connecting webs may be proportioned so that axis y—y is the major axis. Where the structural member is used as a beam that is uniformly loaded along the flanges 102 and 105, the load may be considered as a single force applied along axis y—y. If this is the case, axis x—x must be parallel to the outer surfaces of the flanges but may be nearer one pair of flanges than the other pair without the load tending to twist the member. In practice, beams are nearly always subjected to some lateral force tending to bend the beam about axis y—y. If axis x—x is not exactly midway between the outer surfaces of the flanges, then this lateral force can not be considered as a force directed along axis x—x and will tend to twist the beam. Thus, if axis x—x is not exactly midway between the flanges, it is necessary to brace the member quite extensively when it is used in a building framework. Accordingly, it is preferable for the axis x—x to be midway between the outer surfaces of the two pairs of coplanar flanges.

As has been previously pointed out, the structural member of Figure 4 is made up of two identical channel members 100 and 101, with one channel member being reversed relative to the other. With this arrangement, two identical

channels can be used to make up the member and the cost of tools for producing the two shapes is much less than it would be if the channel members were not the same. If cost were ignored, the channel members 100 and 101 could be made so that the nail bending portions instead of being anti-symmetrical would be symmetrical. It is to be noted that if this were the case, then the first reverse curve would be rotated about axis y—y through 180° so that the centers 159 and 135 would be on the same side of the axis y—y. This does not change the fact that the addition of the first reverse curves would change conditions so that axes x—x and y—y would not be principal gravity axes. The condition produced would be substantially the same as is produced in a structural member like that shown in Figure 1 by the addition of the first reverse curves.

Referring more particularly to Figure 5 which shows a structural member also embodying the principles of the present invention, this structural member is made up of a pair of channel members 171 and 172 fastened together in back-to-back relationship. The channel member 171 comprises a web 173 having flanges 174 and 175 disposed along the opposite sides thereof. The channel member 172 also includes a pair of flanges 176 and 177 joined by a web 179. The axes x—x and y—y are coordinate mutually perpendicular axes for the cross-sectional area of the member and these axes intersect at point "O." Axes x—x and y—y are located in a plane normal to the longitudinal axis of the structural member. As will be more fully hereinafter described, the cross-sectional area of this structural member is symmetrical about axis x—x and assymmetrical about axis y—y. The web 173 includes a flat portion 181 adjacent flange 175. Similarly, the channel web 179 includes flat portions 183 and 184. Flat portions 180 and 183 are parallel and spaced apart to define a relatively short straight nailing groove 186 therebetween. The flat portions 181 and 184 are parallel and spaced apart to define a relatively short straight nailing groove or slot 187 therebetween. The metal at the juncture of web 173 and flange 171 is curved about center 188. The metal at the juncture of web 189 and flange 176 is similarly curved about center 189 so that these two curved portions of metal define an entering throat 190. The throat 190 and the slot 186 are symmetrical about axis y—y as are the flanges 174 and 176. The metal at the juncture of web 173 and flange 175 is curved about the center 191 and the metal at the juncture of web 179 and flange 177 is curved about the center 192. These two portions of curved metal define a nail guiding and entering throat 194, and throat 194 and the relatively short straight slot 187 are symmetrical about the axis y—y. The nail bending and holding means which extends from line 195 to 196 comprises the parallel curved web portions 197 and 198. It is believed obvious upon inspection that the cross-sectional area of the structural member except for the cross-sectional area of the nail bending means between lines 195 and 196 is symmetrical about the axis y—y. This nail bending means is not symmetrical about axis y—y.

In the structural member of Figure 5, there is no flat web portion or portions joining the inner edges of the web portions which define the nail bending means. There is an overlapping of the nail bending means. The web portions 197 and 198 are parallel and define therebetween a tortuous nail receiving passage 200 having an axis 201. These web portions are bent so that the axis 201, starting at point 203 which coincides with axis y—y, curves to the right about center 204. The radius of curvature is indicated by line 205 and is relatively short. The axis 201 next curves from point 206 about center 207 and curves away from axis y—y and then back toward axis y—y to point 208. Thus, the nail bending groove 200 is curved through a first reverse curve and a nail driven into the nail receiving groove through the entering throat 190 is curved first to the right and then back toward the left. The axis 201 is next curved from point 208 about center 209 to point 210. The radius of curvature about center 207 is indicated by line 211 and is relatively short. The radius of curvature about center 209 is indicated by line 213 and is relatively long. From point 210, the axis 201 curves about center 215 to point 216, and the radius of curvature is indicated by line 217. The radius of curvature 217 and the radius of curvature 211 are equal and centers 207 and 215 are disposed on the left side of axis y—y. From point 216, the axis 201 is curved about center 219 to point 220 which coincides with axis y—y. The portion of the nail bending groove 200 which extends from point 220 to 219 constitutes the first reverse curve for a nail driven into the nailing groove through the entering throat 194. The nailing groove extending from point 210 to point 208 constitutes the second reverse curve for both of the first reverse curves. If a nail is driven through the throat 190, the nail is bent through a first reverse curve and then as the end of the nail travels through the nail bending groove and beyond the point 208, it is bent through a second reverse curve. Similarly, if a nail is driven through throat 194 into the nail bending slot 200, the nail is bent through a first reverse curve and then as it moves past point 210, it is bent through a second reverse curve. Thus, the portion of the nail bending means between points 219 and 208 constitutes part of the nail bending means adjacent flanges 174 and 176 and also constitutes part of the nail bending means adjacent flanges 175 and 177 so that this portion of the nail bending means serves a dual function. When a nail is driven into the nailable member through either throat, the point or leading end extends beyond axis x—x so that the nail is bent through two reverse curves and is securely held in place when subjected to a live load as described in connection with Figure 1.

The addition of the second reverse curve to the nail bending means enables making the structural member of Figure 5 structurally stable so that it will not tend to twist. This can only be done if radius 213 is longer than radius 211. For the structural member to be stable when loaded only on the top, axis y—y must be a principal gravity axis midway between the flange extremities, axis x—x must be parallel to the outer surfaces of the two pairs of coplanar flanges and axis x—x must be a principal gravity axis. Preferably, axis x—x is also midway between the outer surfaces of the two pairs of flanges so that point "O" is the center of gravity for the cross-sectional area of the member and so that the member will be stable and not tend to twist when a uniform load is applied against the side of the member. Omitting the nail bending means between lines 195 and 196, it is believed clear from inspection that the cross-sectional area is symmetrical about coordinate axis y—y and, therefore, axis y—y is a principal axis and coordinate

axis x—x is parallel to the flanges. Further, axis x—x is a principal gravity axis midway between the outer surfaces of the two pairs of flanges. As described in connection with Figure 1, if the first reverse curve adjacent each pair of flanges is added, axis y—y and axis x—x are no longer principal gravity axes and the member is not stable. Axes x—x and y—y are no longer principal axes because they are not principal axes for the metal of the two reverse curved portions. The addition of the second, larger reverse curve counteracts the unbalance produced by the first reverse curve so that coordinate axes x—x and y—y are again principal gravity axes. For this condition to be true, the first and second reverse curved portions must be so proportioned that axes x—x and y—y are principal gravity axes for these curved portions when taken together. If axes x—x and y—y are principal gravity axes for the curved portions, that is the nail bending means, then if axes x—x and y—y are principal gravity axes for the remainder of the cross-sectional area, these axes are principal gravity axes for the member.

Referring more particularly to Figure 6 which illustrates another embodiment of the present invention, the nailable member shown in this figure is formed from a single piece of sheet metal. This nailable member includes a pair of coplanar flanges 215' and 216' and a second pair of coplanar flanges 217' and 218. The two pairs of flanges are joined by the parallel webs 219' and 220'. This member may be formed out of a single piece of sheet metal in any suitable manner and may be formed by cold rolling steel strip of suitable width. The flange 215' comprises two layers 221 and 222 of metal while the flange 216' comprises two layers 223 and 224 of sheet metal. The flanges 215' and 216' are symmetrical about axis y—y and extend outwardly and equally in opposite directions from axis y—y. Flanges 217' and 218 are made up of a single thickness of sheet metal, and each flange terminates in an outer free edge 225 and 226, respectively. The flanges 217' and 215' are joined by the web 219', and, more particularly, web 219 is integrally joined to the inner layer of metal 221. Similarly, the web 220' is integrally joined to the inner layer of metal 223 of flange 216'. The two webs 219' and 220' are parallel and spaced apart to define a nail receiving and bending slot therebetween similar to the nail receiving and bending slot shown and described in connection with the nailable structural member of Figure 5. The nail bending means extends from line 229 to line 230. The web portions between these lines define the nail receiving passage or slot 231 having a longitudinal axis 232. The axis 232 is curved exactly the same as axis 201 of the nail receiving slot 200 in Figure 5 and, therefore, will not be described in detail.

It will be noted that the axes x—x and y—y are mutually perpendicular coordinate axes for the cross-sectional area of the member and that this area is neither symmetrical about either axis, nor is it anti-symmetrical. The cross-sectional area of the member, except for the cross-sectional area of the nail bending means, is symmetrical about axis y—y but asymmetrical about axis x—x although both axes are principal gravity axes as will be described hereinafter. The metal 234 at the juncture between flange layer 221 and web 219' is curved as is the metal 235 at the juncture of web 220' with the inner layer 223 of flange 216'. The metal at 235 and at 234 defines an entering throat 236 that is symmetrical about axis y—y. The upper layers of flange metal 222 and 224 where they join are preferably depressed to form a groove 237 which aids in guiding the point of a nail into the throat 236. The metal at the bottom of the groove may be thinned as shown to facilitate piercing of the metal by a nail point. The metal at 240 at the juncture of web 219' and flange 217' is curved as is the metal at 241 at the juncture of web 220' and flange 226. The metal at 240 and 241 defines an entering throat 242 which is symmetrical about axis y—y. The two flanges 217' and 218 extend outwardly in opposite directions from axis y—y, and these two flanges are symmetrical about axis y—y as are the two flanges 215' and 216'. The pair of flanges 217' and 218 are not symmetrical about axis x—x with the pair of flanges 215' and 216'. As more fully pointed out in connection with Figure 5, the nail bending means between lines 229 and 230 is curved in such a manner that axes y—y and x—x are principal gravity axes for the cross-sectional area of this portion of the nailing beam. With the flanges being symmetrical about axis y—y, axis y—y is a principal axis for the nailable member, but it does not necessarily follow that axis x—x is a principal gravity axis for the nailable member. For axis x—x to be a principal gravity axis, certain conditions must be met. First, the cross-sectional area of the two flanges 217' and 218 when multiplied by its average distance from the axis x—x must be balanced or be equal to the area of the two flanges 215' and 216' multiplied by its average distance from axis x—x. If this be true, then the static moment about axis x—x=0 and the expression $\int xdA=0$ is satisfied. With the flanges properly spaced from axis x—x and of the correct relative size, then axis x—x is a gravity axis. As previously stated, for axis x—x and axis y—y to be principal axes, the product of inertia must equal 0 or $\int xydA=0$. It will be noted that the area of flange 217' is at a slightly greater distance from axis x—x than is the area of flange 215'. While the flange 215' is made up of two layers of metal and flange 217' is made up of a single layer of metal, the flange 217' may not be quite twice the width of flange 215' as a result of this slight difference in distance from axis x—x. In addition, and in order to have a completely stable nailable structural member that will develop maximum strength, the outer surface of the two flanges 217' and 218 should be the same distance from axis x—x as is the outer surface of flanges 215' and 216'. Accordingly, axes x—x and y—y are principal axes for the nailable member of Figure 6. It is to be noted that for the reasons set forth in connection with the other nailable members, if axes x—x and y—y were not principal gravity axes for the nail bending means located between lines 229 and 230, then these axes would not be principal gravity axes for the beam despite the fact that the flanges are arranged as described.

The structural member of Figure 6 is particularly intended where web stiffness is not too important. It will be noted that neither web 219' nor 220' includes a flat web portion. If the entire web is corrugated or curved as shown, web stiffness is sacrificed. Web stiffness is particularly important for the deeper nailable members such as is shown in Figures 1 and 4.

In each of the structural members previously described in detail, axes y—y and x—x are coordinate axes located in a plane normal to

the length of the elongated member. The cross-sectional area of each of these members may be divided into two parts—the first part or portion being the area of the metal exclusive of the two nail bending means. This portion of the area will hereinafter be referred to as area A. The second portion of the cross-sectional area is the area of the metal of the two nail bending means. This portion of the area will hereinafter be referred to as area B. Now considering more particularly area A, it is believed clear that the area A is symmetrical about axis y—y so that axis y—y is a principal gravity axis for area A. In addition, if the area A is symmetrical about axis y—y, the two pairs of coplanar flange portions are located in planes normal to axis y—y or in other words, axis x—x is parallel to the outer surfaces of the two pairs of coplanar flanges. It is also believed clear that axis x—x is a principal gravity axis for area A.

In the nail bending means of some of the structural members, the parallel web portions which define the nail bending groove or slot are curved about three centers whereas in others these web portions are curved about four centers. In each of the nail bending means and starting at the outer end of the nail receiving slot, the axis of the slot curves from a point tangent to axis y—y away from and to one side of axis y—y through a first arc about a center located on the one side of the axis y—y. The axis of the nail receiving slot then curves further away from axis y—y and then back toward but not to axis y—y through a second arc about a center located on the opposite side of axis y—y. The axis of the nail receiving slot then curves to and across axis y—y and then away from and thereafter back toward axis y—y through a third arc about a center located on the one side of axis y—y. The three radii just mentioned are so proportioned that the two nail bending means together are arranged such that axes x—x and y—y are principal gravity axes for the two nail bending means. These axes are not principal gravity axes for only one of the nail bending means. In fact, axis y—y is not a principal axis for one of the nail bending means but is only a principal axis for the two nail bending means.

Thus, for area B, the addition of the third relatively larger curve to each of the nail bending means enables the nail bending means to be arranged so that axes x—x and y—y are principal gravity axes for the two nail bending means. It is only by the addition of the second relatively larger reverse curve that it is possible to have axes x—x and y—y principal gravity axes for area B. In each of the structural members, if this relatively larger curve were eliminated, it would be impossible to arrange the nail bending means in such a manner that axes x—x and y—y would be principal gravity axes.

As axes x—x and y—y are principal gravity axes for area B and area A, axes x—x and y—y are principal gravity axes for the entire area. Area A is symmetrical about axis y—y with axis x—x parallel to the outer surfaces of the two pairs of coplanar flange portions and, thus, the structural member will have greatly increased stability and will not tend to twist when uniformly loaded along the outer surface of either pair of coplanar flange portions. In addition, the preferred form of each structural member is shown with axis x—x midway between the outer surfaces of the two pairs of coplanar flange portions so that each one of the structural members also has lateral stability. A load uniformly applied against either side of the structural member will not cause twisting and lateral bracing can be greatly reduced or eliminated. As structural members which are used as beams in a framework are usually subjected to some lateral loads, it is preferable that the principal gravity axis x—x be midway between the outer surfaces of the two pairs of coplanar flange portions so that the beam will not have to be extensively braced.

The nailable structural member of Figure 5 is shown with parallel web portions interposed between the nail bending means and each pair of coplanar flange portions. These parallel web portions are symmetrical about axis y—y and are symmetrical about axis x—x. Similar web portions may be added to the other structural members between the nail bending means and the corresponding flange portions.

I claim:

1. An elongated nailable structural member comprising a first pair of flange portions having coplanar outer surfaces, a second pair of flange portions having coplanar outer surfaces, the flange portions of each pair of flange portions being perpendicular to and oppositely disposed with respect to one axis of a pair of mutually perpendicular intersecting axes and the first and second pair of flange portions being parallel to and oppositely disposed with respect to the other axis of the pair of axes, a nail receiving slot defining means joined to each pair of flange portions for receiving and bending a driven nail, web means joining the nail receiving slot defining means, the portions of the flange portions and the nail receiving slot defining means at the juncture of the nail receiving slot defining means and the respective pair of flange portions defining a nail entry throat symmetrical about the one axis, each slot defining means including a pair of nail guiding portions, the nail guiding portions of each slot defining means being spaced apart to define therebetween an elongated nail receiving slot extending inwardly from the entry throat, the nail guiding portions being curved so that the center line of the slot starting at a point tangent to the one axis extends inwardly and curvilinearly first to one side of and away from the one axis through a first arc and then farther away from and then toward the one axis through a second arc and thereafter across and away from and then back toward the one axis through a third arc having a longer radius than the second arc whereby a nail driven through an entry throat and into the respective nail-receiving slot is bent through two reverse curves of progressively greater radius by the curved nail guiding portions of the slot defining means, the axes being principal gravity axes for the area of cross-section of the nailable member exclusive of the curved nail guiding portions of the slot defining means, the relative proportionment of the cross-sectional areas of the curved nail guiding portions of the slot defining means establishing the relations $\int xdA=0$, $\int ydA=0$ and $\int xydA=0$ in which y corresponds to the one axis, x corresponds to the other axis and A corresponds to the cross-sectional area of the nailable member, whereby the axes are principal gravity axes for the nailable member.

2. A nailable structural member as defined in claim 1 in which the second axis is midway between the outer surfaces of the first and second pair of flange portions.

3. A nailable structural member as defined in claim 1 in which the second axis is midway between the outer surfaces of the first and second pair of flange portions and is the major axis of the area of cross-section of the structural member.

4. An elongated nailable structural member formed from a single piece of sheet metal comprising a first pair of flange portions having coplanar outer surfaces, a second pair of flange portions having coplanar outer surfaces, the flange portions of each pair of flange portions being perpendicular to and oppositely disposed with respect to one axis of one pair of mutually perpendicular intersecting axes and the first and second pair of flange portions being parallel to and oppositely disposed with respect to the other axis of the pair of axes, each flange portion including an outer and an inner layer of sheet metal with the outer and inner layers integrally joined at their outer lateral edges, a nail receiving slot defining means adjacent each pair of flange portions for receiving and bending a driven nail, each slot defining means including a web portion joined to the inner layer of one flange portion of the corresponding pair of flange portions and a nail guiding portion joined to the inner layer of the other flange portion of the same pair of flange portions, the portions of the inner layers of the flange portions and the web and nail guiding portions at the juncture of the web portion and the nail guiding portion with the inner layers of the respective pair of flange portions defining a nail entry throat symmetrical about the one axis, the outer layers of each pair of flange portions being integrally joined and overlying their respective nail entry throat, the web portion and the nail guiding portion of each slot defining means being spaced apart to define therebetween an elongated nail receiving slot extending inwardly from the entry throat, each nail guiding portion terminating in a free edge, a flat web portion symmetrical about the one axis connecting the web portions of the slot defining means, the web portion and the nail guiding portion of each slot defining means including curved portions so that the centerline of the slot starting at a point tangent to the one axis extends inwardly and curvilinearly first to one side of and away from the one axis through a first arc and then farther away from and then towards the one axis through a second arc and thereafter across and away from and back towards the one axis through a third arc of relatively longer radius than the radius of the second arc whereby a nail driven through an entry throat and into the respective nail receiving slot is bent through two reverse curves by the curved portions of the slot defining means, the axes being principal gravity axes for the area of cross-section of the nailable member exclusive of the curved portions of the slot defining means, the relative proportionment of the cross-sectional area of the curved portions of the slot defining means establishing the relations $\int xdA=0$, $\int ydA=0$ and $\int xydA=0$ in which y corresponds to the one axis, x corresponds to the other axis and A corresponds to the cross-sectional area of the nailable member, whereby the axes are principal gravity axes for the nailable member.

5. A nailable structural member as defined in claim 4 in which the second axis is midway between the outer surfaces of the first and second pair of flange portions.

6. A nailable structural member as defined in claim 4 in which the second axis is midway between the outer surfaces of the first and second pair of flange portions and in which the second axis is the major axis of the area of cross-section of the member.

7. An elongated nailable structural member comprising a pair of channel members each including a web portion, the channel members being connected in back-to-back relation with the web portions in spaced relationship, a first pair of flange portions having coplanar outer surfaces extending laterally in opposite directions and joined to corresponding ends of the web portions, a second pair of flange portions having coplanar outer surfaces extending laterally in opposite directions and joined to the other ends of the web portions, the flange portions of each pair of flange portions being perpendicular to and oppositely disposed with respect to the one axis of a pair of mutually perpendicular intersecting axes and the first and second pair of flange portions being parallel to and oppositely disposed with respect to the other axis of the pair of axes, the plane of the web portions being parallel to and equally spaced from the one axis and being perpendicular to the second axis, the portions of the flange portions and the web portions at the juncture of the web portions of the channel members with the respective pair of flange portions defining a nail entry throat symmetrical about the one axis, a nail receiving slot defining means adjacent each pair of flange portions for receiving and bending a driven nail, each slot defining means including curved nail guiding portions being spaced apart to define therebetween an elongated nail receiving slot extending inwardly from the respective entry throat, the curved nail guiding portions of each slot defining means being curved so that the center line of the slot starting at a point tangent to the one axis extends inwardly and curvilinearly first to one side of and away from the one axis through a first arc and then farther away from and then toward the one axis through a second arc and thereafter across and away from and then back toward the one axis through a third arc of relatively long radius with respect to the radius of the second arc and finally back to a point tangent to the one axis whereby a nail driven through an entry throat and into the respective nail receiving slot is bent through two reverse curves by the curved portions of the slot defining means, the axes being principal gravity axes for the area of cross-section of the nailable member exclusive of the curved portions of the slot defining means, the relative proportionment of the cross-sectional area of the curved portions of the slot defining means establishing the relations $\int xdA=0$, $\int ydA=0$ and $\int xydA=0$ in which y corresponds to the one axis, x corresponds to the other axis and A corresponds to the cross-sectional area of the nailable member, whereby the axes are principal gravity axes for the nailable member.

8. A nailable structural member as defined in claim 7 in which the second axis is the major axis of the area of cross-section of the member.

9. An elongated nailable structural member comprising a first pair of flange portions having coplanar outer surfaces, a second pair of flange portions having coplanar outer surfaces, the flange portions of each pair of flange portions being perpendicular to and oppositely disposed with respect to one axis of a pair of mutually perpendicular intersecting axes and the first and second pair of flange portions being parallel to

and oppositely disposed with respect to the other axis of a pair of axes, first web means extending from one flange portion of the first pair of flange portions to one flange portion of the second pair of flange portions, second web means extending from the other flange portion of the first pair of flange portions to the other flange portion of the second pair of flange portions, the portions of the flange portions and the web means at the juncture of the first and second web means with the flange portions of each pair of flange portions defining a nail entry throat symmetrical about the one axis, the web means being spaced apart to define therebetween an elongated nail receiving slot extending inwardly from each entry throat, the web means including nail guiding portions curved so that the center line of the slot starting at a point tangent to the one axis extends inwardly and curvilinearly first to one side of and away from the one axis through a first arc and then farther away from and then toward the other axis through a second arc and thereafter across and away from the one axis to the second axis through a third arc of relatively longer radius than the radius of the second arc with the center of the third arc being located at a point on the second axis displaced from the one axis, the centerline of the slot then extending curvilinearly from the second axis toward the one axis through a fourth arc about said center and then farther away from and then back toward the one axis through a fifth arc having a radius less than the radius of the fourth arc and then tangentially to a second point on the one axis through a sixth arc whereby a nail driven through either entry throat into the nail receiving slot is bent through two reverse curves by the nail guiding portions of the web means, the axes being principal gravity axes for the area of cross-section of the nailable members exclusive of the curved nail guiding portions, the relative proportionment of the cross-sectional area of the curved nail guiding portions establishing the relations $\int ydA=0$, $\int xdA=0$ and $\int xydA=0$ in which y corresponds to the one axis, x corresponds to the other axis and A corresponds to the cross-sectional area of the nailable member, whereby the axes are principal gravity axes for the nailable member.

10. A nailable structural member as defined in claim 9 in which the second axis is midway between the outer surfaces of the first and second pair of flange portions.

11. A nailable structural member as defined in claim 9 in which the second axis is the major axis of the area of cross-section of the member.

12. A structural member as defined in claim 9 in which the flange portions of the first pair of flange portions are similar to the flange portions of the second pair of flange portions.

13. A structural member as defined in claim 9 in which the flange portions of the first pair of flange portions include an outer layer of sheet metal and in inner layer of sheet metal integrally joined along their outer edges, in which the flange portions of the second pair of flange portions each terminate in a free edge, and in which the first and second pair of flange portions are symmetrical about the one axis.

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