ABSTRACT

A screened enclosure having aluminum structural members, joints interconnecting the structural members, and screen panels formed by the interconnected structural members. The structural members include two-piece box beams formed by two mating extrusions, wherein flanges of the extrusions continuously engage each other along their length by means of interlocking lips, and one-piece hybrid beams. The joints include rigid joints and hinged joints, wherein the hinged joints allow at least one degree of freedom between the interconnected structural members. A computer-implemented design method determines the reaction loads on the individual structural members and determines compliance with applicable building construction standards.
FIG. 17B

1. **CONTINUE**
2. **CONTINUE**
3. **CONTINUE**
4. **CALCULATE LENGTH BASED ALLOWABLES FACTORS**
5. **FILL MEMBER(I2) ROW OF ALLOWABLES ARRAY FOR COMPONENT (I1)**
6. **READ LOAD CASE (I)**
7. **FILL ELEMENT TABLE WITH RESULTS**
8. **SELECT COMPONENT(J)**
9. **GET NUMBER OF LINES FOR COMPONENT(J)**
10. **DETERMINE LOAD BASED FACTORS FOR LINE(J1)**
11. **CONTINUE**
BEAM AND JOINTS FOR USE IN SCREENED ENCLOSURE AND METHOD FOR DESIGNING SCREENED ENCLOSURE

RELATED APPLICATIONS

[0001] This application claims the benefit of priority of U.S. provisional application Ser. No. 60/709,470, filed Aug. 18, 2005, U.S. provisional application Ser. No. 60/720,361, filed Sep. 23, 2005, and U.S. provisional application Ser. No. 60/775,430, filed Feb. 21, 2006, which are relied on and incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to screened enclosures used to enclose pools, patios, and other outdoor facilities. More particularly, the present invention relates to beams used in constructing such screened enclosures, joints for joining such beams, and a computer-implemented method for designing such screened enclosures.

BACKGROUND OF THE INVENTION

[0003] Screened enclosures are typically used to enclose pools, patios, and other outdoor facilities. Such screened enclosures are generally constructed of a frame structure of aluminum structural members that are employed as roof beams, rafters, columns, purlins, K-braces, wind braces, chair rails, or eave rails. Screening is stretched over the frame to complete the enclosure. The screened enclosure is constructed in accordance with various local building codes. If the screened enclosure is in compliance with those building codes, the screened enclosure is intended to withstand specified wind loading conditions and other forces.

[0004] During recent hurricanes in Florida, USA, many screened enclosures that were purportedly built in accordance with local building codes failed even when wind loading forces did not exceed those specified in the local building codes. Multiple failure mechanisms for such screened enclosures apparently existed. The failure mechanisms included failure of the aluminum structural members that were used in constructing such screened enclosures, failure of the joints connecting the aluminum structural members, and failure of the overall design of the screened enclosures.

[0005] With respect to the failure of the aluminum structural members used in the screened enclosures, a prior art aluminum structural member, such as beam 10, is shown in FIGS. 1A, 1B, and 2. The prior art beam 10 consists of two identical extrusions, a first extrusion 12 and a second extrusion 14. Each of the extrusions 12 and 14 (FIG. 2) consists of a first flange 18, a second flange 20, and a web 16 between the flanges 18 and 20. The extrusions 12 and 14 are mated and stitched together with screws (not shown) through the flanges 18 and 18 and through the flanges 20 and 20. The mated extrusions 12 and 14 thereby create the prior art two-piece box beam 10.

[0006] One reason that the prior art beam 10 is weaker than previously thought is a phenomenon known as local flange buckling. According to the Aluminum Design Manual (“ADM”) Part IA, section 3.4.15 (which describes how to design structural elements supported on one side), if two C-shaped members are mated together and are loaded, the flange sections between the screws may buckle before the extrusion fails. This, by definition, constitutes a failure. FIG. 1B illustrates a local flange buckling beam failure mode in which the flanges 18 and 18 and the flanges 20 and 20 buckle between the screws (not shown) holding the flanges together. FIG. 1A illustrates another local buckling beam failure mode, namely, web buckling, in which one of the webs 16 buckles before the extrusion 12 fails. In FIGS. 1A and 1B, the buckled shape of the flanges 18 and 18 and the flanges 20 and 20, and the buckled shape of the web 16, respectively, are shown using dotted lines.

[0007] Professional trade organizations, such as The Aluminum Association of Florida (“AAF”), publish manuals that specify screened enclosure design. The specified designs are based on the imprecise assumption, however, that the structural member, such as the beam 10, is a solid tube. The significance of this assumption is that the properties of the beam 10 are not as strong as the AAF (or other individuals or organizations) assumes them to be, and the beam 10 often fails before its intended design loading is reached. In addition, the graduation in strength from one beam size to the next beam size is inconsistent, resulting in the metal being used inefficiently.

[0008] With respect to the failure of the joints connecting the aluminum structural members, prior art screened enclosures use semi-rigid joints utilizing multiple fasteners to interconnect the structural members of the screened enclosure to each other. Consequently, the prior art joints do not allow for relative movement between the structural members to thereby relieve stresses within the screened enclosure structure.

[0009] With respect to failures based on the overall design of the screened enclosure, those failures appear to have resulted from the lack of a proper analysis of the entire enclosure assembly under loading conditions. Consequently, the prior art design does not accurately predict the loads in both the structural members and joints connecting them.

[0010] A need therefore exists for (1) improved beams for use in constructing screened enclosures, (2) improved joints for joining such beams in screened enclosures, and (3) an improved method for designing screened enclosures that overcome the shortcomings found in the prior art.

SUMMARY OF THE INVENTION

[0011] The present invention answers this need by providing (1) a two-piece box beam with interlocking lips and a one-piece hybrid beam for use in constructing a screened enclosure; (2) a rigid joint and a hinged joint for joining the two-piece box beams and the one-piece hybrid beams in the screened enclosure; and (3) a computer-implemented method that uses finite element analysis for designing the screened enclosure. The inventive method involves the proper construction of the two-piece box beams and the one-piece hybrid beams, the proper construction of the rigid joints and the hinged joints for interconnecting the structural members, and an integrated design approach for arriving at the overall design of the screened enclosure.

[0012] Screened enclosures are most efficient when the correct combination of joint flexibility, member stiffness, and bracing arrangements are used. When screened enclosures are constructed properly, the load transfer due to wind
from any direction is more evenly distributed throughout the structure. The proper enclosure construction thus depends on joint flexibility, member stiffness, and bracing arrangement.

**Joint Flexibility.**

**Rigid Joint Locations:**

1. each connection of a roof beam to another roof beam, i.e., all roof beam splices;
2. each connection of a column to a roof beam or a rafter; and
3. each connection of a K-brace to a column.

**Hinged Joint Locations:**

1. each connection of an eave rail to a column;
2. each connection of a rafter to a side of a roof beam;
3. each connection of a purlin to a roof beam;
4. each connection of a column to a footing of the screened enclosure;
5. each connection of a roof beam to a host structure (e.g., house); and
6. each connection of a chair rail to a column.

**Member Stiffness.**

With respect to member stiffness, member stiffness relates to the size and type of extrusion used in various locations throughout the structure. Prior art designs use large section self-mating beams for “primary members” only. Primary members are defined as roof beams, rafters, and wall columns. All other members in prior art designs, namely, purlins, K-braces, wind braces, chair rails, and eave rails, comprise small box section extrusions (typically 2 in. × 2 in. × 0.045 in.) and are referred to as “secondary members.” Analysis with three-dimensional frame or finite element analysis reveals that current art member selection is inadequate, largely due to excessive compressive loading (or combination of compression and bending) of many of the secondary members.

**Extrusions:**

In accordance with the present invention, large-section, two-piece, self-mating, box beams are used for the rafters (defined as the member that connects the top of wall columns to an intermediate point on the side of a roof beam), roof beams and columns. In addition, larger (than the prior art), one-piece, hybrid-shaped, box-section extrusions are used for all secondary members. These larger box-section extrusions may be 3 in. × 3 in. in size and could be selected from a variety of wall thicknesses.

**Bracing Arrangement.**

Bracing arrangement refers to the placement of diagonal members across the rectangular panels of the structure to provide lateral rigidity. Current designs typically use a convention that places diagonals on panels adjacent to wall corners. Conventional diagonals run from the bottom of the corner column and alternate directions, in a zigzag pattern, to the top of the wall. Such diagonals are commonly referred to as “K-braces” because the typical wall is divided into two panels and the braces form a “K” with the adjacent wall column. Based on the judgment of the individual designer or engineer, the K-braces may or may not be placed on both sides of the corner columns.

Bracing in the roof panels (roof bracing) is also left to the discretion of the individual designer or engineer. Often, current designs form a truss on the row of panels adjacent to the edges where the roof meets the walls. The braces may be arranged in a zigzag pattern or such that the left half braces are diagonal in one direction and the right half in the other.

In accordance with the present invention, K-braces are reversed from current art designs such that the bottom diagonals do not meet at the bottom of the corner column. (Such a design reduces the vertical load at the bottom of the corner columns and distributes the load more evenly into the bottoms of all columns.) In addition, K-braces are used on both sides of all corner columns.

Further, roof bracing is used to form a truss parallel to all edges where the roof meets the walls. The truss is formed by diagonal braces that alternate directions (zigzag) and is offset from the edge by one panel. Moreover, no load carrying diagonal is used in any corner panel of the roof.

**Structural Member Design.**

Two-Piece Box Beam.

With respect to the structural member design, the present invention includes a two-piece box beam and a one-piece hybrid beam. The two-piece box beam resists flange buckling, which limits the prior art, thus providing greater loading capacity. The two-piece box beam in accordance with the present invention keeps localized flange buckling from occurring by including an interlocking lip on each flange that engages an end of the other flange so that each of the flanges is supported along its longitudinal edge.

In one embodiment, when specific applications require member stiffness in the strongest two-piece box beam in accordance with the present invention can accommodate, a flange extender can be used to modify the inventive two-piece box beam to make the flange 3 inches wide, instead of the standard 2 inch width. By using the flange extender, the beam width increases to 3 inches, thus having more strength and efficiency. Because the flange extender converts 2 inch beams to 3 inch beams, there is no need to extrude more shapes than are currently used, and the increased cost of shipping 3 inch wide extrusions is eliminated. The flange extender significantly increases the strength and the strength to weight ratio of existing 2 inch beams.
B. One-Piece Hybrid Beam.

Prior art secondary members generally comprise one-piece box, or square, extrusions. Such one-piece square extrusions are primarily designed to resist bending. Secondary members, however, actually experience as much stress in axial compression as in bending. Because axial compression is best resisted by a round-shaped member, as opposed to bending that is best resisted by a rectangular-shaped member, a hybrid-shaped member can better withstand axial compression and be of lighter weight than the square-shaped prior art secondary structural members. Particularly, a secondary structural member of the present invention is a one-piece hybrid beam having a generally square cross section with severely rounded corners.

The load profiles for secondary members, i.e., purlins, K-braces, wind braces, chair rails, and eave rails, found within the screened enclosure of the present invention, fall into three levels. The chair rails and eave rails experience a relatively low level of loading; the purlins experience a middle level of loading; and the K braces and wind braces experience a relatively high level of loading.

To accommodate the three levels of loading, in one embodiment of the present invention the one-piece hybrid beam is manufactured in three wall thicknesses. In another embodiment, the one-piece hybrid beam is manufactured in four wall thicknesses. Because the external appearance of the one-piece hybrid beam is the same for all wall thicknesses, an external coding system of grooves on the outside of the one-piece hybrid beam is used so that workers and inspectors can determine the thickness of the one-piece hybrid beam that is installed.

Joints.

With respect to the joints constructed in accordance with the present invention, the joints include rigid, or fixed, joints and hinged joints. These joints are arranged strategically about the screened enclosure structure to enable the frame of the structure to move where necessary so that loading on individual structural members is reduced. The hinged joints, in accordance with the present invention, thus allow loading to be distributed within the screened enclosure structure. Because of the hinged joints, the screened enclosure structure can flex, thereby reducing localized loading on specific structural members.

Method.

With respect to the overall design of the screened enclosure, the method in accordance with the present invention utilizes a computerized system for deriving an optimum design for the screened enclosure. In one embodiment, the method uses the ANSYS® command language to create a specific screened enclosure structure. (ANSYS® is a registered trademark of SAS Acquisition Corp.) In other embodiments, any suitable finite element analysis software, such as ALGOR, ABAQUAS, NASTRAN, or STAAD-Pro, may be used or modified to achieve the results of the inventive method. Consequently, a user with only basic knowledge of screened enclosure design can input dimensions for a proposed screened enclosure.

The computer-implemented method includes generating a three-dimensional ("3-D") finite element model of the screened enclosure structure. The resulting model incorporates all of the properties of the screened enclosure structure, including the properties of the structural members, the joints (including fasteners), and the screen panels. Consequently, the model accurately represents a physical screened enclosure structure in accordance with the present invention.

From a minimal amount of data, the screened enclosure design method of the present invention uses finite element analysis to simulate the entire structure and thereby accurately captures the interactions between the structural members and their end constraints. The design method further models the screen panels so that their reaction loads due to wind loading conditions are accurately represented on the structural load bearing members of the screened enclosure. Therefore, from the finite element analysis, the stress and deflection for each structural member can be determined and compared to the requirements of a local building code.

It is thus an object of the present invention to provide a two-piece box beam for use in a screened enclosure that efficiently uses materials to improve resistance to flange buckling and other failures.

Another object of the present invention is to provide a means for extending the width of the two-piece box beam that increases beam strength and does not require manufacture of additional extrusions.

Yet another object of the present invention is to provide a one-piece hybrid beam for use as secondary structural members in a screened enclosure that provides sufficient resistance to bending and axial compression while minimizing the amount of materials required to construct the beam.

Still another object of the present invention is to provide a strategic arrangement of rigid joints and hinged joints in a design of a screened enclosure that results in sufficient rigidity to withstand expected loads and also permits relative movement among structural members to relieve stresses within the screened enclosure.

A still further object of the present invention is to provide a computer-implemented method for designing a screened enclosure that incorporates the properties of the structural members and the joints to generate a finite element model of the screened enclosure.

Another object of the present invention is to provide a computer-implemented method for designing a screened enclosure that compares a finite element model of the screened enclosure to a construction standard to determine whether the screened enclosure design complies with the construction standard.

Further objects, features, and advantages will become apparent upon consideration of the following detailed description of the invention when taken in conjunction with the drawing and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a sectional view of a two-piece box beam for a screened enclosure in accordance with the prior art and illustrating a web buckling failure mode.

FIG. 1B is a sectional view of a two-piece box beam for a screened enclosure in accordance with the prior art and illustrating a flanged buckling failure mode.
FIG. 2 is a sectional view of an extrusion used to form the two-piece box beam illustrated in FIGS. 1A and 1B in accordance with the prior art.

FIG. 3 is a sectional view of a two-piece box beam for a screened enclosure in accordance with the present invention.

FIG. 4 is a sectional view of another embodiment of a two-piece box beam for the screened enclosure in accordance with the present invention.

FIG. 5 is a sectional view of yet another embodiment of a two-piece box beam for the screened enclosure in accordance with the present invention.

FIG. 6 is a sectional view of still another embodiment of a two-piece box beam for the screened enclosure in accordance with the present invention utilizing a flange extender to create a wider assembled beam.

FIG. 7 is a sectional view of a one-piece hybrid beam for the screened enclosure in accordance with the present invention.

FIG. 8A is a side view of (1) a rigid joint between a column and a rafter (or a rafter and a roof beam), and (2) a hinged joint between an eave rail and the column of the screened enclosure in accordance with the present invention.

FIG. 8B is a side view, a front view, and a top view of a cleat used in the hinged joint, such as the hinged joint between the eave rail and the column, for the screened enclosure in accordance with the present invention.

FIG. 8C is a front view and a side view of a hinged joint between a purlin and the roof beam of the screened enclosure in accordance with the present invention.

FIG. 9A is a side view of a rigid joint between a column, a K brace, and a chair rail for the screened enclosure in accordance with the present invention.

FIG. 9B is a top view of a rigid joint between a column, a K brace, and a chair rail for the screened enclosure in accordance with the present invention.

FIG. 10A is a front view of a rigid joint between a column, a K brace, and an eave rail for the screened enclosure in accordance with the present invention.

FIG. 10B is a top view of a rigid joint between a column, a K brace, and an eave rail for the screened enclosure in accordance with the present invention.

FIG. 11A is a side, sectional view of a hinged joint between a column and a footing for the screened enclosure in accordance with the present invention.

FIG. 11B is a top, sectional view of a hinged joint between a column and a footing for the screened enclosure in accordance with the present invention.

FIG. 12A is a front, perspective view of a hinged joint between a rafter and a side of a roof beam for the screened enclosure in accordance with the present invention.

FIGS. 12B and 12C are side views of a hinged joint between a rafter and a side of a roof beam for the screened enclosure in accordance with the present invention.

FIG. 12D is a rear view of a hinged joint between a rafter and a side of a roof beam for the screened enclosure in accordance with the present invention.

FIG. 13 is a perspective view of a screened enclosure in accordance with the present invention.

FIG. 14A is a perspective view of a screened enclosure subjected to a wind loading condition.

FIG. 14B is a perspective view of the screened enclosure of FIG. 14A showing the loading on the structural members when the screened enclosure is subjected to the wind loading condition shown in FIG. 14A.

FIG. 14C is a perspective view of the screened enclosure of FIG. 14A showing the deflection of the structural members when the screened enclosure is subjected to the wind loading condition shown in FIG. 14A.

FIG. 15A is a perspective view of a screened enclosure subjected to a second wind loading condition.

FIG. 15B is a perspective view of the screened enclosure of FIG. 15A showing the loading on the structural members when the screened enclosure is subjected to the wind loading condition shown in FIG. 15A.

FIG. 15C is a perspective view of the screened enclosure of FIG. 15A showing the deflection of the structural members when the screened enclosure is subjected to the wind loading condition shown in FIG. 15A.

FIG. 16 is a flow diagram illustrating a method for generating a finite element model of the screened enclosure and calculating the reaction load on each structural member of the screened enclosure in accordance with the present invention.

FIGS. 17A, 17B, 17C, and 17D together comprise a flow diagram illustrating a method for comparing the reaction loads to a construction standard to determine whether the screened enclosure complies with the construction standard in accordance with the present invention.

FIG. 18 is a graph illustrating the relative strength of the two-piece box beam in accordance with the prior art, the two-piece box beam in accordance with the present invention having interlocking lips, and the two-piece box beam in accordance with the present invention having interlocking lips and the flange extender.

FIG. 19 is a side view of a rigid joint between a column and a rafter (or a rafter and a roof beam of the screened enclosure in accordance with the present invention.

FIG. 20A is a sectional view of a second embodiment of the one-piece hybrid beam for the screened enclosure in accordance with the present invention.

FIG. 20B is a perspective view of the second embodiment one-piece hybrid beam for the screened enclosure in accordance with the present invention.

FIG. 21A is a sectional view of the second embodiment one-piece hybrid beam with bosses added for the screened enclosure in accordance with the present invention.

FIG. 21B is a perspective view of the second embodiment one-piece hybrid beam with bosses added for the screened enclosure in accordance with the present invention.
FIG. 22 is a perspective view of (1) a rigid joint between a column and a rafter and (2) a hinged joint between an eave rail and the column of the screened enclosure in accordance with the present invention.

FIG. 23 is a perspective view of (1) a rigid joint between a rafter and a roof beam, and (2) a hinged joint between a purlin and the rafter of the screened enclosure in accordance with the present invention.

FIG. 24 is a perspective view of a hinged joint between a purlin and the roof beam of the screened enclosure in accordance with the present invention.

FIG. 25 is a perspective view of hinged joints between rafters and each side of a roof beam for the screened enclosure in accordance with the present invention.

FIG. 26 is an outside perspective view of a rigid joint between a column, a K brace, and a chair rail at a corner of the screened enclosure in accordance with the present invention.

FIG. 27 is an inside perspective view of a rigid joint between a column, a K brace, and a chair rail at a corner of the screened enclosure in accordance with the present invention.

FIG. 28 is an outside perspective view of a rigid joint between a column, a K brace, and a chair rail at a side of the screened enclosure in accordance with the present invention.

FIG. 29 is an inside perspective view of a rigid joint between a column, a K brace, and a chair rail at a side of the screened enclosure in accordance with the present invention.

FIG. 30 is an outside perspective view of a rigid joint between a column and a K brace at a foundation of the screened enclosure in accordance with the present invention.

FIG. 31 is an inside perspective view of a rigid joint between a column and a K brace at a foundation of the screened enclosure in accordance with the present invention.

FIG. 32 is a rear view of a hinged joint using a first connection between a rafter and a side of a roof beam for the screened enclosure in accordance with the present invention.

FIG. 33 is an outside perspective view of a hinged joint using a first connection between a rafter and a side of a roof beam for the screened enclosure in accordance with the present invention.

FIG. 34 is an inside perspective view of a hinged joint using a first connection between a rafter and a side of a roof beam for the screened enclosure in accordance with the present invention.

FIG. 35 is a rear view of a hinged joint using a second connection between a rafter and a side of a roof beam for the screened enclosure in accordance with the present invention.

FIG. 36 is an outside perspective view of a hinged joint using a second connection between a rafter and a side of a roof beam for the screened enclosure in accordance with the present invention.

FIG. 37 is a top view of a joint between the chair rail and a column for the screened enclosure in accordance with the present invention.

FIG. 38 is an inside perspective view of the joint between the chair rail and a column for the screened enclosure in accordance with the present invention.

FIG. 39 is a sectional view of a reinforcement plug used in the hinged joint, such as the hinged joint between the eave rail and the column, for the screened enclosure in accordance with the present invention.

FIG. 40 is a perspective view of the reinforcement plug used in the hinged joint, such as the hinged joint between the eave rail and the column, for the screened enclosure in accordance with the present invention.

FIG. 41 is a sectional view of a second embodiment of a reinforcement plug used in the hinged joint, such as the hinged joint between the eave rail and the column, for the screened enclosure in accordance with the present invention.

FIG. 42 is a perspective view of the second embodiment reinforcement plug used in the hinged joint, such as the hinged joint between the eave rail and the column, for the screened enclosure in accordance with the present invention.

FIG. 43 is a sectional view of the reinforcement plug within a one piece hybrid beam for the screened enclosure in accordance with the present invention.

FIG. 44 is a sectional view of the reinforcement plug installed at a hinged joint for the screened enclosure in accordance with the present invention.

FIG. 45 is a top view of a hinged joint between a one piece hybrid beam and a two piece box beam using a reinforcement plug for the screened enclosure in accordance with the present invention.

FIG. 46 is a perspective view of a hinged joint between a one piece hybrid beam and a two piece box beam using a reinforcement plug for the screened enclosure in accordance with the present invention.

FIG. 47 is a top view of an angled hinged joint between a one piece hybrid beam and a two piece box beam using a reinforcement plug for the screened enclosure in accordance with the present invention.

FIG. 48 is a sectional view of a gutter for the screened enclosure in accordance with the present invention.

FIG. 49 is a perspective view of the gutter for the screened enclosure in accordance with the present invention.

FIG. 50 is a perspective view of a hinged joint between a rafter and a gutter for the screened enclosure in accordance with the present invention.

FIG. 51 is a top plan view of the hinged joint between the rafter and the gutter for the screened enclosure in accordance with the present invention.

FIG. 52 is a side view of the hinged joint between the rafter and the gutter for the screened enclosure in accordance with the present invention.

FIG. 53 is a top perspective view of the hinged joint between the rafter and the gutter for the screened enclosure in accordance with the present invention.
FIG. 54 is a side view of a gutter cleat used in the hinged joint between the rafter and the gutter for the screened enclosure in accordance with the present invention.

FIG. 55 is a perspective view of the gutter cleat used in the hinged joint between the rafter and the gutter for the screened enclosure in accordance with the present invention.

FIG. 56 is a side view of a second embodiment of the cleat used in a hinged joint for the screened enclosure in accordance with the present invention.

FIG. 57 is a perspective view of the second embodiment of the cleat used in a hinged joint for the screened enclosure in accordance with the present invention.

FIG. 58 is a side view of a third embodiment of the cleat used in a hinged joint for the screened enclosure in accordance with the present invention.

FIG. 59 is a perspective view of the third embodiment of the cleat used in a hinged joint for the screened enclosure in accordance with the present invention.

FIG. 60 is a side view of a fourth embodiment of the cleat used in a hinged joint for the screened enclosure in accordance with the present invention.

FIG. 61 is a perspective view of the fourth embodiment of the cleat used in a hinged joint for the screened enclosure in accordance with the present invention.

FIG. 62 is a side view of a fifth embodiment of the cleat used in a hinged joint for the screened enclosure in accordance with the present invention.

FIG. 63 is a perspective view of the fifth embodiment of the cleat used in a hinged joint for the screened enclosure in accordance with the present invention.

Detailed Description of the Invention

A. Two-Piece Beam.

The first aspect of the present invention relates to aluminum structural members used in constructing a screened enclosure 2 (FIG. 13) in accordance with the present invention. Referring now to the drawings, in which like reference numerals represent like parts throughout the several views, FIG. 3 illustrates an aluminum two-piece box beam 26 in accordance with the present invention. The two-piece box beam 26 is used for primary structural members, i.e., columns 74, rafters 96, and roof beams 28 (FIG. 13).

The two-piece box beam 26 comprises a first extrusion 30 and a second extrusion 46. The first extrusion 30 comprises a web 32, a right side flange 34, a left side flange 36, a right outside interlocking lip 38, a left side interlocking lip 40, a right side spline groove 42, and a left side spline groove 43. Similarly, the second extrusion 46 comprises a web 48, a right side flange 50, a left side flange 52, a right side interlocking lip 54, a left side interlocking lip 56, a right side spline groove 57, and a left side spline groove 58. The interlocking lips 38 and 54 continuously support the ends of the flanges 50 and 34 along their lengths on the right side of the two-piece box beam 26. Similarly, the interlocking lips 40 and 56 continuously support the ends of the flanges 52 and 36 along their lengths on the left side of the two-piece box beam 26. The extrusions 32 and 48 are stitched together by means of screws 62 that interconnect the flanges 34 and 50 and the flanges 36 and 52 along the length of the beam 26. The spline grooves 42, 43, 57, and 58 are used to receive an edge of a section of screen (not shown).

Because the interlocking lips 38 and 54 continuously support the ends of the flanges 50 and 34 along their lengths and because the interlocking lips 40 and 56 continuously support the ends of the flanges 52 and 36 along their lengths, the flanges 34, 50, 36, and 52 are stronger than flanges of the prior art, which are supported on one edge only.

FIG. 4 illustrates another embodiment of the beam of the present invention. The shapes of the flanges 50, 34, 52, and 36 and lips 38, 54, 40, and 56 have been modified to provide for a flat surface on the right side of the beam 26 where the flanges 50 and 34 interconnect and on the left side of the beam 26 where the flanges 52 and 36 interconnect. In particular, each flange 50, 34, 52, and 36 includes an offset 51, 35, 53, and 37 to bring the flanges 50, 34, 52, and 36 within the interlocking lips 38, 54, 40, and 56. The operating principles of the beam 26 shown in FIG. 4 remain unchanged, and the strength of the beam 26 relies on the continuous support of the ends of the flanges 50, 34, 52, and 36 along the length of the beam 26.

With reference to FIG. 5, a two-piece box beam 226 is shown that is similar to the two-piece box beam 26 of FIG. 3. As such, the two-piece box beam 226 comprises a first extrusion 230 and a second extrusion 246. The first extrusion 230 comprises a web 232, a right side flange 234, a left side flange 236, a right outside interlocking lip 238, a left inside interlocking lip 240, a right side spline groove 242, and a left side spline groove 243. Similarly, the second extrusion 246 comprises a web 248, a right side flange 250, a left side flange 252, a right inside interlocking lip 254, a left outside interlocking lip 256, a right side spline groove 257, and a left side spline groove 258.

In addition, the two-piece box beam 226 includes internal protrusions 60, 61, 64, and 65 that run perpendicular to the flanges 236, 234, 250, and 252 and parallel to the webs 232 and 248 of the two-piece box beam 226. The internal protrusions 60, 61, 64, and 65 allow for insertion of reinforcing plates inside of the two-box beam 226 to reinforce the beam webs 232 and 248 so that fasteners cannot pull through the beam webs 232 and 248. Such reinforcement may be required for a rigid spliced joint between beams joined end to end, for a rigid joint between a column 74 and a rafter 96, or for a rigid joint between the rafter 96 and the end of a roof beam 28.

In general, and as described in further detail below, such rigid joints are made by inserting a gusset plate 116 (FIGS. 8A and 19) into the channels formed by protrusion 60, 61, 64, and 65 inside the beam 226. A single fastener 124 (FIG. 8A) or an arrangement of fasteners 124 (FIG. 19), located on each side of the joint, connects the gusset plate 116 (FIG. 8A) to the web 232 or 248 of the beam 226. Because of the protrusions 60, 61, 64, and 65, the fasteners 124 (FIG. 8A) are not subjected to bending moment forces. Instead the fasteners 124 (FIG. 8A) are only required to
resist the shear forces associated with separation of the joint between the two-piece box beams 226. The two-piece box beam’s 226 and the gusset plate’s 116 (FIG. 8A) engagement with the bottom of the channel resist the bending moment forces.

interlocking lips 38, 54, 40 and 56 (FIG. 3). As used in Table 1, “Ag” is the gross cross sectional area of metal (indicative of weight), “Max” is the allowable bending moment (strength in inch-kips), and “Max/Ag” is a measure of efficiency (how efficiently the metal is used).

<table>
<thead>
<tr>
<th>Width D in.</th>
<th>Depth b in.</th>
<th>web thk t w in.</th>
<th>flg thk t f in.</th>
<th>Area A gross in^2</th>
<th>M max in-k</th>
<th>M max/Ag in-k/in^2</th>
<th>Max/Ag</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
<td>0.045</td>
<td>0.100</td>
<td>0.750</td>
<td>7.3</td>
<td>9.7</td>
<td>0.045</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>0.050</td>
<td>0.116</td>
<td>0.841</td>
<td>11.7</td>
<td>12.4</td>
<td>0.050</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>0.050</td>
<td>0.120</td>
<td>1.056</td>
<td>14.7</td>
<td>13.9</td>
<td>0.050</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>0.055</td>
<td>0.120</td>
<td>1.224</td>
<td>18.7</td>
<td>15.3</td>
<td>0.070</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>0.072</td>
<td>0.224</td>
<td>1.983</td>
<td>55.7</td>
<td>28.6</td>
<td>0.080</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>0.072</td>
<td>0.224</td>
<td>2.127</td>
<td>64.1</td>
<td>30.1</td>
<td>0.085</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>0.092</td>
<td>0.374</td>
<td>3.198</td>
<td>129.4</td>
<td>40.5</td>
<td>0.092</td>
</tr>
</tbody>
</table>

Consequently, the two-piece box beam 26 in accordance with the present invention has strength properties that are 136% to 464% of those of the prior art beam 10 (an average of 295%) and an efficiency (a measure of weight to strength) that is 136% to 280% of that of the prior art beam 10. While the 2 in. x 5 in. two-piece box beam 26 of the present invention weighs 34% more than its prior art beam 10 counterpart, it is 262% stronger, and the metal used is 172% more efficient.

Moreover, the Max curve of the inventive two-piece box beam 26 increases more uniformly than the prior art beam 10. Thus, two-piece box beam 26 of the present invention based on the strength requirements) are more efficient because the strength properties are greater from one size to another. For example, if a particular application called for a beam to withstand a 70 in-k load, one would have to use a 2 in. x 10 in. prior art beam 10, or use a 2 in. x 7 in. two-piece box beam 26 in accordance with present invention.

With reference to FIG. 18, further advantages of the present invention for providing beam strength are shown. FIG. 18 shows three points of strength. The three lines represent the industry standard beam strengths using prior art beams 10 (FIGS. 1A, 1B, and 2), the improved beam strengths using the two-piece box beam 26 of the present invention with interlocking lips 38, 54, 40 and 56 (FIG. 3), and the improved beam strengths using the two-piece box beam 26 of the present invention with interlocking lips 38, 54, 40 and 56 and the flange extender 666 (FIG. 6). The results shown in FIG. 18 demonstrate that the present invention significantly increases the strength of beams used for screened enclosures.

Table 2, below, lists the strengths and efficiencies of the two-piece box beam 26 of the present invention with interlocking lips 38, 54, 40 and 56 and the flange extender 666 (FIG. 6).
TABLE 2

<table>
<thead>
<tr>
<th>Flange Extender</th>
<th>Web Thk</th>
<th>Flg Thk</th>
<th>Area (gross)</th>
<th>$M_{xx}$</th>
<th>$M_{yy}$/Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x 4</td>
<td>0.045</td>
<td>0.100</td>
<td>0.942</td>
<td>25.6</td>
<td>27.2</td>
</tr>
<tr>
<td>3 x 5</td>
<td>0.050</td>
<td>0.200</td>
<td>1.600</td>
<td>62.4</td>
<td>37.6</td>
</tr>
<tr>
<td>3 x 6</td>
<td>0.060</td>
<td>0.240</td>
<td>2.102</td>
<td>92.8</td>
<td>44.1</td>
</tr>
<tr>
<td>3 x 7</td>
<td>0.070</td>
<td>0.280</td>
<td>2.582</td>
<td>128.6</td>
<td>49.8</td>
</tr>
<tr>
<td>3 x 8</td>
<td>0.080</td>
<td>0.320</td>
<td>3.098</td>
<td>170.7</td>
<td>55.1</td>
</tr>
<tr>
<td>3 x 9</td>
<td>0.085</td>
<td>0.340</td>
<td>3.454</td>
<td>208.6</td>
<td>60.4</td>
</tr>
<tr>
<td>3 x 10</td>
<td>0.092</td>
<td>0.374</td>
<td>3.946</td>
<td>258.3</td>
<td>65.4</td>
</tr>
</tbody>
</table>

[0149] B. One-Piece Hybrid Beam.

[0150] As previously disclosed, secondary structural members are used for purlins 72, K braces 76, wind braces 77, chair rails 70, and eave rails 94. In accordance with the present invention, the secondary structural member is a one-piece hybrid beam 100 shown in FIG. 7. The one-piece hybrid beam 100 comprises an extruded body 102, four flat sides sections 104, and four rounded sides sections 106. The body 102 may be extruded in three wall thicknesses, 0.125 inch, 0.090 inch, and 0.060 inch. The body 102 with the 0.060 inch wall thickness may have bosses 108 located on the inside of the extruded body 102. The bosses 108 accept screws to thereby provide a means for connecting one end of the one-piece hybrid beam 102 to other structural members of the screened enclosure of the present invention. The body 102 with wall thicknesses of 0.125 inch and 0.090 inch generally do not have the bosses 108, but instead are connected to the other structural members by means of cleats that are inserted into the body 102. The joint connections will be described in greater detail below.

[0151] In accordance with another embodiment, the secondary structural member is a one-piece hybrid beam 100 shown in FIGS. 20A, 20B, 21A, and 21B. The one-piece hybrid beam 100 comprises an extruded body 102, four flat sides sections 104, and four rounded sides sections 106. The body 102 may be extruded in four wall thicknesses, 0.125 inch, 0.090 inch, 0.060 inch, and 0.046 inch. The body 102 with wall thicknesses of 0.060 inch and 0.046 inch (FIGS. 21A and 21B) may have bosses 108 located on the inside of the extruded body 102. The bosses 108 accept screws to thereby provide a means for connecting one end of the one-piece hybrid beam 102 to other structural members of the screened enclosure of the present invention. The body 102 with wall thicknesses of 0.125 inch and 0.090 inch generally do not have the bosses 108, but instead are connected to the other structural members by means of cleats that are inserted into the body 102.

[0152] The load profiles for the secondary structural members within the screened enclosure 2 (FIG. 13) show that there are three levels of loading experienced by the secondary structural members. The chair rails 70 and the eave rails 94 experience a relatively low level of loading. For the chair rails 70 and eave rails 94, the one-piece hybrid beam 100 is approximately 3 in. x 3 in. with a 0.060 inch or 0.046 inch wall thickness.

[0153] The purlins 72 experience a middle level of loading. In particular, the purlins 72 experience a higher degree of loading than the chair rails 70 due to the fact that they experience axial compression because of truss-action. For the purlins 72, the one-piece hybrid beam 100 is approximately 3 in. x 3 in. with a 0.090 inch wall thickness.

[0154] The bracing, both the K braces 76 and the wind braces 77, experience the highest level of loading. For the K braces 76 and the wind braces 77, the one-piece hybrid beam 100 is approximately 3 in. x 3 in. with a 0.125 inch wall thickness.

[0155] The external appearance of the one-piece hybrid beam 100 is generally the same for the four wall thicknesses. Consequently, there must be some way to distinguish those four beams 100 with different wall thicknesses from each other for factor workers, construction workers, and building inspectors. In one embodiment, to differentiate the various one-piece hybrid beams 100 a v-groove marking system 110 (FIGS. 7, 20A, and 21B) is extruded on the outside of the one-piece hybrid beams 100 so that a beam 100 with a particular wall thickness can be identified. For example, the v-groove marking system 110 may be simple: no groove for the lightest (0.046 inch) one-piece hybrid beam 100, one groove for the light (0.060 inch) one-piece hybrid beam 100, two grooves for the medium (0.090 inch) one-piece hybrid beam 100, and three grooves for the heavy (0.125 inch) one-piece hybrid beam 100.


[0157] The second aspect of the present invention relates to construction and placement of hinged joints and rigid joints used in constructing the screened enclosure 2 (FIG. 13) in accordance with the present invention. The rigid joints depend on their structure for rigidity and not on the joint fasteners. The hinged joints essentially decouple one structural member from the next structural member in at least one degree of freedom.

[0158] FIG. 13 shows the placement of the rigid joints and the hinged joints. A rigid joint 112 is used to connect the columns 74 to the rafters 96 (FIGS. 8A and 22) and to connect the rafters 96 to the roof beams 28 (FIG. 23). A rigid joint 134 is used to connect the K braces 76, the columns 74, and chair rails 70 at a corner of the screened enclosure 2 (FIGS. 9A, 9B, 26, and 27). A rigid joint 200 is used to connect the K braces 76, the columns 74, and chair rails 70 at a side of the screened enclosure 2 (FIGS. 28 and 29). A rigid joint 136 is used to connect the K braces 76, the columns 74, and eave rails 94 (FIG. 10A and 10B). A rigid joint 202 is used to connect the K braces 76 and columns 74 adjacent the foundation of the screened enclosure (FIGS. 30 and 31). A rigid joint 138 is used to connect the wind braces 77, the roof beams 28, and the purlins 72.

[0159] A hinged joint 114 is used to connect the eave rails 94 to the columns 74 (FIGS. 8A and 22) and to connect the purlins 72 to the rafters 96 (FIG. 23). A hinged joint 144 is used to connect the rafters 96 to the sides of the roof beams 28 (FIGS. 12A, 12B, 12C, and 12D). A hinged joint 146 is used to connect the purlins 72 to the roof beams 28 (FIGS. 8C and 24). A hinged joint 148 is used to connect the column 74 to the footing of the screened enclosure 2 (FIGS. 11A and 11B). A joint 142 is used to connect the chair rails 70 to the columns 74 (FIGS. 37 and 38). A hinged joint 270 is used to connect the rafters 96 to the gutter 290 (FIGS. 50, 51, 52, and 53).
FIGS. 8A and 22 show the rigid joint 112 between an end of the column 74 and an end of the rafter 96. FIGS. 8A and 22 also show the hinged joint 114 between the column 74 and the eave rail 94.

With respect to the rigid joint 112, one end of a gusset plate 116 (FIG. 8A) slides into the channels formed by protrusions 60 and 61 in the two-piece box beam 226 (FIG. 5), which constitutes rafter 96. The other end of the gusset plate 116 slides into the channels formed by protrusions 60 and 61 in the two-piece box beam 226 (FIG. 5), which constitutes column 74. The gusset plate 116 is held in place by means of fasteners 124. Because the bending moment about 112 is carried by the gusset plate’s 116 engagement with the channels formed by protrusions 60 and 61, the fasteners 124 do not carry the force created by that bending moment. Instead, the fasteners 124 are only required to resist the shear force tending to separate the rafter 96 from the column 74.

FIGS. 8A, the hinged joint 114 between the column 74 and the eave rail 94 includes a cleat 118 (FIG. 8B) attached to the web 248 of the two-piece box beam 226 (column 74) by means of fasteners 122. The eave rail 94, comprising the one-piece hybrid beam 100 (FIG. 7), slips over legs 121 of the cleat 118. The one-piece hybrid beam 100 (eave rail 94) is attached to the cleat 118 by means of a hinge bolt 120 that passes through the beam 100 and the cleat 118. There is sufficient tolerance between the outside of the cleat 118 and the inside of the one-piece hybrid beam 100 (eave rail 94) so that the beam 100 can rotate about the axis of the hinge bolt 120.

It will be appreciated that cleat 118 may be constructed of various sizes and shapes and remain suitable for use at the hinged joint 114 or other hinged joints hereinafter described. For example, with reference to FIGS. 56-63, several embodiments of the cleat 118 are shown wherein the cleat 118 comprises a base 119 and at least one leg 121.

FIGS. 8C and 24 show the hinged joint 146 between the purlin 72 and a side of the roof beam 28. The hinged joint 146 includes a cleat 118 (FIG. 8B) attached to the web 248 of the roof beam 28, which comprises the two-piece box beam 226 (FIG. 5). The cleat 118 is attached to the web 248 of the roof beam 28 by means of fasteners 122. The purlin 72, which comprises the one-piece hybrid beam 100 (FIG. 7), slides over the cleat 118 and is anchored to the cleat 118 by means of a hinge bolt 120. The tolerances are such that the purlin 72 can rotate about the axis of the hinge bolt 120.

FIGS. 9A, 9B, 26, and 27 show the rigid joint 134 connecting the column 74, K braces 76, and chair rails 70 at a corner of the screened enclosure 2. Gussets 135 are securely attached to column 74, which comprises the two-piece box beam 226 (FIG. 5), and the K braces 76 and the chair rail 70, each comprising the one-piece hybrid beam 100 (FIG. 7), are bolted to the gussets 201 to form the rigid joint 200.

FIGS. 29 and 30 show the rigid joint 202 connecting the column 74 and K braces 76 at a foundation of the screened enclosure 2. Gussets 203 are securely attached to column 74, which comprises the two-piece box beam 226 (FIG. 5), and the K brace 76 comprising the one-piece hybrid beam 100 (FIG. 7) is bolted to the gussets 203 to form the rigid joint 202. A spline rail 204 may be provided below the K brace 76 that extends between the columns 74 and rests on the ground surface.

FIGS. 10A and 10B show the rigid joint 136 connecting the column 74 and the K brace 76. A gusset 137 is securely attached to the column 74, which comprises the two-piece box beam 226 (FIG. 5), and the K brace 76, which comprises the one-piece hybrid beam 100 (FIG. 7), to form the rigid joint 136. The eave rail 94, which comprises the one-piece hybrid beam 100 (FIG. 7), is attached to the column 74 by means of a cleat 118 and hinge bolt 120 as shown in FIG. 8A.

FIGS. 11A and 11B show the hinged joint 148 between the column 74 and the footing of the screened enclosure 2. The hinged joint 148 includes a footing cleat 126 and a footing bolt 128. The footing bolt 128 is inserted into the footing material, generally concrete, to hold the cleat 126 in place. The column 74, which comprises the two-piece box beam 226 (FIG. 5), slides over the cleat 126 and is anchored to the cleat 126 by means of the hinge bolt 120. The tolerances are such that the column 74 can rotate about the hinge bolt 120.

FIGS. 12A, 12B, 12C, and 12D show the hinged joint 144 between the rafter 96 and a side of the roof beam 28 of the screened enclosure 2. The hinged joint 144 includes a rafter cleat 130 attached to web 248 of the roof beam 28, which comprises the two-piece box beam 226 (FIG. 5). The cleat 130 is attached to the web 248 of the roof beam 28 by means of fasteners 122. A washer 132 is located on the inside of the web 248 to reinforce the web 248 of the roof beam 28. The rafter 96, which comprises the two-piece box beam 226 (FIG. 5), slides over the rafter cleat 130 and is anchored to the rafter cleat 130 by means of the hinge bolt 120. The tolerances are such that the rafter 96 can rotate about the hinge bolt 120. FIGS. 32, 33, and 34 show the hinged joint 144 connected using two fasteners 122 and two hinge bolts 120. FIGS. 35 and 36 show another embodiment wherein the hinged joint 144 is connected using a single fastener 122 and a single hinge bolt 120. FIG. 25 shows two rafters 96 each connected to a side of a roof beam 28 by the hinged joint 144.

FIGS. 37 and 38 show the joint 142 between the chair rail 70 and the column 74 of the screened enclosure 2. The chair rail 70 is attached to the web 248 of the column 74 by means of screws 143. The screws 143 are accepted by the bosses 108 located on the inside of the extruded body 102 of the one-piece hybrid beam 100 (FIG. 7, 21A, and 21B) that comprises the chair rail 70.

FIGS. 50, 51, 52, and 53 show the hinged joint 270 between the rafter 96 and the gutter 290 of the screened enclosure 2. The gutter 290 comprises an extruded body 292 having a front web 294, a trough 296, and a rear web 298. The gutter 290 may be attached to a host structure, such as
a house, by means of gutter cleats 272. The trough 296 receives and carries away rainwater from the surface of the house and the screened enclosure 2. The hinged joint 270 includes the two gutter cleats 272, each having a base 119 and a plurality of legs 121 (FIGS. 54 and 55). The gutter cleats 272 are mated at the legs 121 and attached by means of a hinge bolt 120. The gutter cleat 272 and the rafter 96 are each attached to front web 294 of the gutter 290 via gussets 274 and are anchored by means of hinge bolts 120. The tolerances are such that the rafter 96 can rotate about the hinge bolts 120.

[0173] Reinforcement Plug.

[0174] With reference to FIGS. 39, 40, 41, and 42, in various embodiments of the present invention a reinforcement plug 300 is used in the hinged joint, such as hinged joint 114 (connecting the eave rails 94 to the columns 74 and the purlins 72 to the rafters 96); hinged joint 144 (connecting the rafters 96 to the sides of the roof beams 28); hinged joint 146 (connecting the purlins 72 to the roof beams 28); hinged joint 148 (connecting the columns 74 to the footing of the screened enclosure); hinged joint 142 (connecting the chair rails 70 to the columns 74); or hinged joint 220 (connecting the rafters 96 to the gutter 230) to reinforce the one-piece hybrid beam 100 at the hinged joint.

[0175] The reinforcement plug 300 has a generally square cross section and is sized to fit within the hollow one-piece hybrid beam 100. The reinforcement plug 300 comprises an extended body 302 having an outer wall 304 and at least one inner wall 306. The inner wall 306 and the outer wall 304 define a hollow chamber 308 for receiving a portion of a cleat, such as cleat 118, footing cleat 126, or rafter cleat 130, at the hinged joint 114, 144, 146, 148, or 142, as will be described in greater detail below. In one embodiment, the reinforcement plug 300 has a length equal to about 6 inches. In other embodiments, the reinforcement plug 300 has a length sufficient to extend from the end of the one-piece hybrid beam 100 to about the end of the legs 121 of the cleat, such as 118 (FIG. 8B), when installed at the hinged joint, such as 114.

[0176] With reference to FIGS. 39 and 40, the reinforcement plug 300 shown is sized to fit within the heavy and middle one piece hybrid beams 100 having wall thicknesses of 0.125 inches and 0.090 inches. With reference to FIGS. 41 and 42, in another embodiment, the reinforcement plug 300 is sized to fit within the lightest one piece hybrid beams 100 having wall thicknesses of 0.060 inches and 0.04 inches, wherein the outer wall 304 of the reinforcement plug 300 includes channels 310 for receiving the bosses 108 located on the inside of the light and lightest one-piece hybrid beams 100 (FIGS. 7, 21A, and 21B).

[0177] With reference to FIG. 43, the reinforcement plug 300 is shown within the one-piece hybrid beam 100. The chambers 308 of the reinforcement plug 300 are sized to receive legs 121 of the cleat, such as 118, at the hinged joint, such as 114. With reference to FIGS. 44, 45, and 46, the hinged joint, such as 114, is shown with the reinforcement plug 300 installed. The reinforcement plug 300 is situated within the one-piece hybrid beam 100 and the legs 121 of the cleat, such as 118, are received and supported within the chambers 308 of the reinforcement plug 300 (FIG. 44). The cleat, such as 118, is attached to the web 248 of the two-piece box beam 226 (FIG. 5) by means of fasteners 122.

The one-piece hybrid beam 100 and the reinforcement plug 300 are anchored to the cleat 118 by means of a hinge bolt 120. The tolerances are such that the one-piece hybrid beam 100 and the reinforcement plug 300 can rotate about the hinge bolt 120.

[0178] With reference to FIG. 47, a hinged joint 208 is shown with the reinforcement plug 300 installed, wherein the one-piece hybrid beam 100 is connected to the two-piece box beam at an angle, A. The angled hinged joint 208 might be used to create a diagonal brace at a flat portion of the roof 85 of the screened enclosure (FIG. 13).

[0179] By using the reinforcement plug 300, the one-piece hybrid beam 100 is significantly strengthened in its ability to resist shear forces. Use of the reinforcement plug 300 provides two additional shear planes at the hinged joint 114, one additional plane on the inside of each leg 121 of the cleat 118, compared with the hinged joint 114 without the reinforcement plug 300. Further, the operating principles of the hinged joint 114 remain unchanged.


[0181] The third aspect of the present invention relates to a computer aided design method used in designing the screened enclosure 2 (FIG. 13) in accordance with the present invention. Turning to FIG. 13, the screened enclosure 2, with a choice of a mansard roof 85, a half mansard roof, a dome roof, a gable roof, or a hip roof comprises structural members 4 with screen extending across the structural members 4 to create screen panels 6. The screened enclosure 2 has a width 86, a depth 88, a height 90, a front wall 78, a back wall 80, a right side 84, a left side 82, and a roof 85. The screen enclosure 2 may have a floor plan with any number of walls, each perpendicular to its adjacent wall. The structural members 4 include chair rails 70, purlins 72, wall columns 74, roof beams 28, K braces 76, wind braces 77, rafters 96, and eave rails 94. In addition, wind braces 77 may be diagonal members or arranged in an "X" configuration. Coordinates X Y Z (92) correspond to the depth 88, the width 86, and the height 90 of the screened enclosure 2.

[0182] FIGS. 14A and 15A show outputs of the inventive method that illustrate the screened enclosure 2 subjected to two separate wind loading conditions, such as two of the multiple wind loading conditions described by the Florida Building Code. FIG. 14A shows an example of the screened enclosure 2 subjected to a first wind loading condition with wind creating a pressure in the direction of the arrows of approximately 18 lbs. per square foot on the front wall 78 (equal to a wind velocity of approximately 140 m.p.h. directed toward the front wall 78). Under the first wind loading condition, the roof 85 experiences an upward pressure in the direction of the arrows of about 6 lbs. per square foot. FIG. 15A shows the screened enclosure 2 subjected to a second wind loading condition with wind creating a pressure in the direction of the arrows of approximately 18 lbs. per square foot on the right wall 84 (equal to a wind velocity of approximately 140 m.p.h. directed toward the right wall 84). Under the second wind loading condition, the roof 85 experiences a downward pressure in the direction of the arrows of about 6 lbs. per square foot.

[0183] In certain embodiments, the computer-implemented method of the present invention permits the user to select each of the wind loading conditions described in a particular building code, such as Table 2002.4 of the Florida Building Code.
[0184] FIGS. 14B and 15B show outputs of the inventive method that illustrate the force vectors on the structural members 4 of the screened enclosure 2 as a result of the loading conditions illustrated in FIGS. 14A and 15A, respectively. FIGS. 14C and 15C show outputs of the inventive method that illustrate the deflections (greatly exaggerated in the figures) of the structural members 4 of the screened enclosure 2 as a result of the loading illustrated in FIGS. 14A and 15A. FIGS. 14C and 15C show a spectrum of deflections, from lowest value to highest value along each structural member 4 of the screened enclosure 2.

[0185] In order to design the screened enclosure 2 in accordance with the present invention, a first software method 700 is used to determine the forces to which the structural members 4 are subjected, and a second software method 800 is used to evaluate the screened enclosure 2 and its structural members 4 for compliance with the requirements of a construction standard, such as the Aluminum Design Manual ("ADM"). In one embodiment, the software used for method 700 and method 800 is based on ANSYS® finite element analysis software. Particularly, the software for implementing the method 700 and method 800 has been written in the ANSYS Parametric Design Language (APDL) and uses specific commands and techniques applicable to the ANSYS® finite element analysis software. It will be appreciated that, in other embodiments, any suitable finite element analysis software may be used.

[0186] Turning to FIG. 16, the method of 700 begins at step 702. At step 702, preliminary data, relating to the screened enclosure that is to be designed and constructed, is compiled. The preliminary data includes geometric data relating to the size of the screened enclosure 2, data relating to the requirements for wind exposure (based on geographic location), data relating to the size of the structural members to be used, and data relating to the type of structural members to be used (e.g., rafters, columns, roof beams, purlins, K-braces, wind braces, chair rails, and eave rails) in the construction of the screened enclosure 2. In one embodiment of the method 700 of the present invention, the preliminary data collected at step 702 is collected by means of a form provided on a website. Such preliminary data may also include the general dimensions (height, length, and width) of the desired enclosure, the type of roof desired (mansard, half mansard, etc.), the general dimensions of the floor plan, the locations of connection to the host structure, the locations of corners, the location, orientation, extrusion size, and extrusion type (e.g., AAF or Stronghold) of roof beams, carrier beams, and other structural members. The preliminary data collected at step 702 is supplied to the computer software for implementing method 700 as a file, such as a text file or any suitable file type, at step 704.

[0187] Once the preliminary data relating to the screened enclosure to be built has been input at step 704, the method 700 moves to step 706. At step 706, the method 700 defines arrays that include structural member groupings (component) names and a table of wind exposure pressures. Once the arrays had been defined at step 706, the method 700 proceeds to step 708. At step 708, the method 700 defines finite element analysis model data that includes screen material properties, structural member material properties, and structural member section properties. From step 708, the method 700 proceeds to step 710 in which the method 700 generates a rigid finite element model for the structural enclosure 2.

[0188] Having initialized the method 700 in steps 706-710, the method 700 proceeds through steps 720-730. In steps 720-730, the method 700 solves and stores the reactions of the screened enclosure 2 to loading based on the constraints of the structural members of other portions of the structure of the screened enclosure 2. Particularly, the method 700 captures reaction loads of the screen on each of the structural members so that the reaction loads can be used later in connection with the generation of a hinged finite element model of the screened enclosure, described below.

[0189] In steps 720-730, the calculations and reaction load data are based on the assumption that each of the structural members is rigidly connected to its adjacent structural member. Beginning at step 732, the method 700 proceeds to refine the analysis by replacing rigid joints with hinged joints in accordance with the locations of hinged joints described above. The hinged joints essentially decouple one structural member from the next structural member in at least one degree of freedom. The screened enclosure 2 may have a number of hinged joints throughout the structure either by design or due to the flexibility of the joint between the structural members. The initial definition of the screened enclosure 2 requires that the finite element model be contiguous. As a result, the screened panels 6 share all points (nodes) on adjacent edges. Therefore, all structural members (which lie on these edges) share the nodes of the areas and thus must share nodes at their intersections. This arrangement results in a condition where all joints of the structural members are fixed in all degrees of freedom, or act as welded joints.

[0190] In order to achieve the desired hinged effects, the structural members to be hinged are duplicated at step 732 of method 700. (The original hinged members are no longer used and cleared from the model.) Hinged members, separate yet coincident with the original hinged members, are created that are not rigidly attached to the screen panels 6 or adjacent members 4. Mathematical equations are used to provide the appropriate level of fixity to the adjacent members, thus providing hinging action. These duplicate structural members share no common nodes with the screen panels 6 or the remaining original structural members of the rigid finite element model. In order to achieve the desired reaction load from the screen panels 6, the node numbering of the duplicate structural members is managed by defining their nodes using a predefined numbering offset. This offset is used in the transfer from the screen reaction data at the original nodes to the nodes on the duplicate members.

[0191] In addition, because the joint locations of the duplicate members share no common nodes with the remaining original structural members, connectivity must be established. Connectivity is achieved at step 734 by coupling degrees of freedom between the coincident nodes (i.e., both nodes are forced to deflect identically) at the intersections of the original and duplicate structural members. All degrees of freedom are coupled except for the rotation about the axis upon which the hinging action is desired. At step 736, the method 700 retrieves the screen reaction loads calculated at step 710. The method 700 then proceeds to step 738 where the reaction loads on each of the original structural members
is transferred taking into account the hinged structural members. At step 740, the method 700 saves the hinged finite element model and reaction load results in files.

[0192] Once the screened enclosure 2 has been analyzed by method 700, the design process moves to a second method 800 in which the screened enclosure 2 is compared to the ADM standards (or other construction standard) for compliance. Such a comparison may comprise undertaking a comprehensive evaluation of the rigorous standards imposed by the Aluminum Design Manual ("ADM"), produced by The Aluminum Association. The ADM standards involve the calculation of multiple allowable forces and stresses. The ADM standards also involve calculating "allowable stresses" for phenomena such as member buckling (collapse) and local buckling (local deformation and loss of structural integrity) of a structural member due to compressive loading or bending loading. In addition, several of the ADM standards are dependent upon the length of the structural member and/or the distribution of loading along the structural member.

[0193] Turning to FIGS. 17A, 17B, 17C, and 17D, the second method 800 begins with the collection of the standards data at steps 802, 804, and 806. At step 802, the ADM material property required for calculation of allowables is collected. At step 804, the section property data for all available structural member styles (i.e., member sizes and cross sections, such as 2x4, 2x5, or 2x6) is collected. At step 806, the pre-calculated allowables data for all available structural member styles is collected. The standards data collected in steps 802, 804, and 806 is input into the software of the method 800 at steps 808, 810, and 812, respectively. After the input of the standards data, the method 800 enters two nested do loops 813 at step 814. The nested do loops 813, comprising steps 816-834, determine the length for each structural member of the screened enclosure 2 based on the ADM standards. The nested do loops 813 update the allowables tables to account for the member lengths where the allowable calculations specified by the ADM standards require updating of the allowables table.

[0194] Once each of the structural members has been processed by the nested do loops 813, the method 800 moves to step 836 and enters five nested do loops 835. The nested do loops 835, comprising steps 838-882, calculate the reaction loads along the length of each of the structural members of the screened enclosure 2. The nested do loops 835 loop through (a) each load condition result set calculated, (b) each component (or member type, such as roof beams), (c) each member (one length of material between connections) of that component, (d) each element (a subdivision of the geometrical representation of a member) of that member to update load distribution allowables and calculate the interaction ratios.

[0195] Once the nested do loops 835 have completed their calculations of the loading of the structural members, the method 800 moves to step 884 in which the output data is formatted for producing a text file at steps 886 and 888. The text file created at step 886 can be used for acquiring construction permits and as a bill of materials for the construction of screened enclosure 2.

[0196] In another embodiment, the computer-implemented method of the present invention may also run an optimization sequence. The optimization sequence will cycle a predetermined number times, changing structural member sizes and quantities (adding more structural members and/or adjusting the spacing) to generate a standards compliant screened enclosure structure with the lightest weight. The same reports described above can then be generated. In addition, the user can choose to see the finished optimized screened enclosure structure performs under the loading cases as described above.

[0197] The present invention improves upon current methods to evaluate ADM compliance by (1) evaluating the finite element modeling results for an entire structure; (2) automatically defining length-based allowable forces and stresses for each structural member; (3) automatically updating the load distribution allowable forces and stresses for each structural member for each load case; (4) automatically calculating the interaction ratios (ratio of actual-to-allowable force or stress) for each load case to determine compliance; (5) completing these evaluations for each finite element (or along the entire length) of each structural member; (6) identifying the limiting structural member for each specific load case for each specific structural member type (e.g., roof beam, column); and (7) providing the results of this evaluation in a report format for documentation and permitting purposes.

[0198] In accordance with the present inventive method, the user can manually specify structural member sizes, and the computer-implemented method will subject the model to various wind load cases. The program will also calculate the reaction load on the individual structural members and compare that reaction load to the values as specified in the ADM standards. Once the analysis is complete, the program will generate a report indicating the locations and values of the stresses experienced by the structural members of the screened enclosure. In the event that a structural member is not adequate to handle the loading, the user then makes the necessary changes to the screened enclosure structure, and the program cycles again to analyze the modified screened enclosure structure. After the screened enclosure structure passes the loading analysis, a final report on the resulting screened enclosure structure is generated. This final report also can be used for cost analysis and for a factory to use as an inventory pull list.

[0199] While this invention has been described with reference to preferred embodiments thereof, it is to be understood that variations and modifications can be affected within the spirit and scope of the invention as described herein and as described in the appended claims.

We claim:

1. A beam for use in a screened enclosure comprising:
   a. a first extrusion having flanges; and
   b. a second extrusion having flanges;
   c. wherein the first and second extrusions are mated together to form the beam;
   d. wherein each flange of the first extrusion is engaged at an end and supported along a length by an interlocking lip on the second extrusion; and
   e. wherein each flange of the second extrusion is engaged at an end and supported along a length by an interlocking lip on the first extrusion.
2. The beam of claim 1 wherein at least the extrusions includes protrusions extending perpendicular to the flanges of the extrusion for receiving a reinforcing plate.

3. The beam of claim 1 wherein at least one flange of the first extrusion includes an offset to facilitate engagement with the interlocking lip on the second extrusion and wherein at least one flange of the second extrusion includes an offset to facilitate engagement with the interlocking lip on the first extrusion.

4. A beam for use in a screened enclosure comprising:
   a. a first extrusion having a first side flange and a second side flange; and
   b. a second extrusion having a first side flange and a second side flange;
   c. wherein the first side flange of the first extrusion and the first side flange of the second extrusion are each engaged at an end and supported along a length by a first flange extender, the first flange extender being engaged at a first end by an interlocking lip on the first extrusion and at a second end by an interlocking lip on the second extrusion;
   d. wherein the second side flange of the first extrusion and the second side flange of the second extrusion are each engaged at an end and supported along a length by a second flange extender, the second flange extender being engaged at a first end by an interlocking lip on the first extrusion and at a second end by an interlocking lip on the second extrusion; and
   e. wherein the first and second extrusions are mated together via the first and second flange extenders to form the beam.

5. The beam of claim 4 wherein at least one of the extrusions includes protrusions extending perpendicular to the flanges of the extrusion for receiving a reinforcing plate.

6. A beam for use in a screened enclosure comprising a substantially hollow extrusion, wherein the extrusion has a generally square cross-section and severely rounded corners.

7. The beam of claim 6, wherein an exterior surface of the beam includes a mark to indicate a wall thickness of the beam.

8. The beam of claim 6 further comprising a reinforcement plug within the substantially hollow extrusion, wherein the reinforcement plug includes at least one chamber.

9. A method of constructing a screened enclosure having a plurality of roof beams, rafters, columns, purlins, K-braces, wind braces, chair rails, and eave rails, the method comprising the steps of:
   a. using a rigid joint for
      i. each connection of a roof beam to another roof beam;
      ii. each connection of a column to a roof beam or a rafter;
      iii. each connection of a K-brace to a column;
   b. using a hinged joint for
      i. each connection of an eave rail to a column;
      ii. each connection of a rafter to a side of a roof beam;
      iii. each connection of a purlin to a roof beam; and
      iv. each connection of a column to a footing of the screened enclosure.

10. A screened enclosure comprising:
    a. a plurality of interconnected two-piece beams, wherein each two-piece beam has
        i. a first extrusion having flanges; and
        ii. a second extrusion having flanges;
    b. wherein the first and second extrusions are mated together to form the beam;
    c. wherein each flange of the first extrusion is engaged at an end and supported along a length by an interlocking lip on the second extrusion; and
    d. wherein each flange of the second extrusion is engaged at an end and supported along a length by an interlocking lip on the first extrusion; and
    e. a plurality of one-piece beams connected to at least a portion of the two-piece beams, wherein each one-piece beam has a generally square cross-section and severely rounded corners.

11. The screened enclosure of claim 10, wherein the one-piece beams comprise a plurality of first one-piece beams having a first wall thickness and a plurality of second one-piece beams having a second wall thickness, and wherein an exterior surface of the one-piece beams include a mark to differentiate the first one-piece beams from the second one-piece beams.

12. A computer-implemented method for designing a screened enclosure comprising the steps of:
    a. generating a finite element model of the screened enclosure that includes a plurality of structural members and a plurality of screen panels, wherein the structural members are connected by rigid joints;
    b. calculating a first reaction load for each structural member based on at least one loading condition;
    c. replacing at least one rigid joint in the finite element model with a hinged joint;
    d. calculating a second reaction load for each structural member using the first reaction loads;
    e. comparing the second reaction loads with a construction standard to determine whether the screened enclosure complies with the construction standard.

* * * * *