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(54) **BUCKLING RESTRAINED BRACED FRAME**

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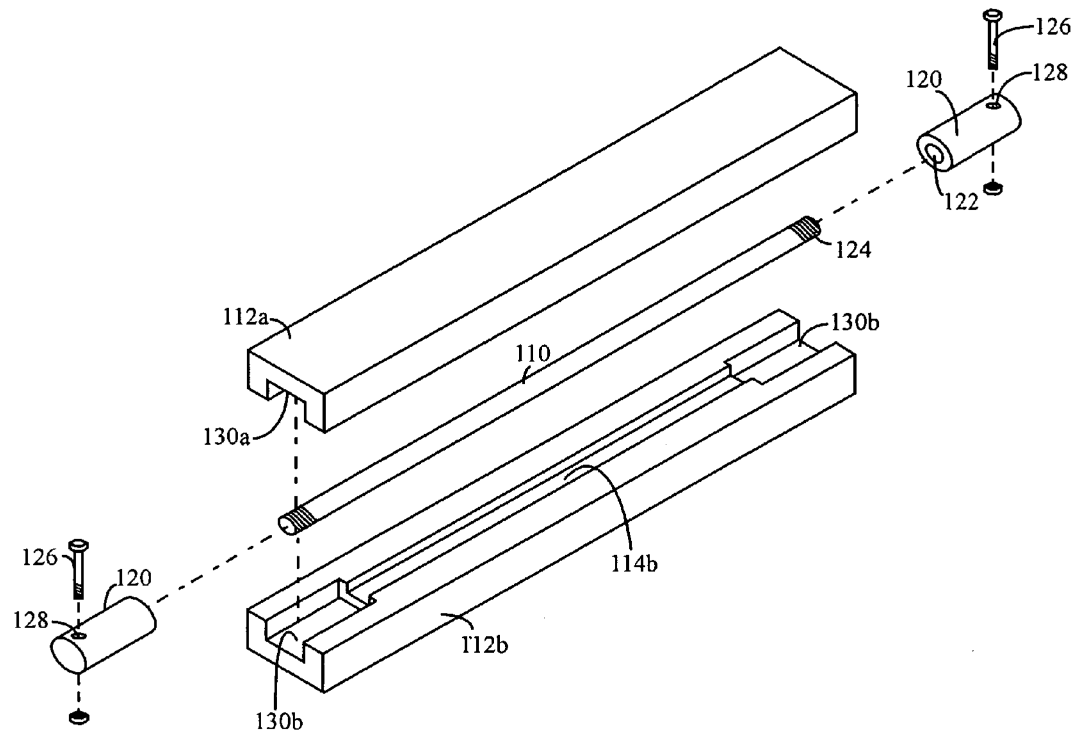
(57) **ABSTRACT**

A buckling restrained braced frame for use in light-framed constructions which includes a ductile load bearing core surrounded by a lightweight casing which resists buckling of the core under compressive loads.



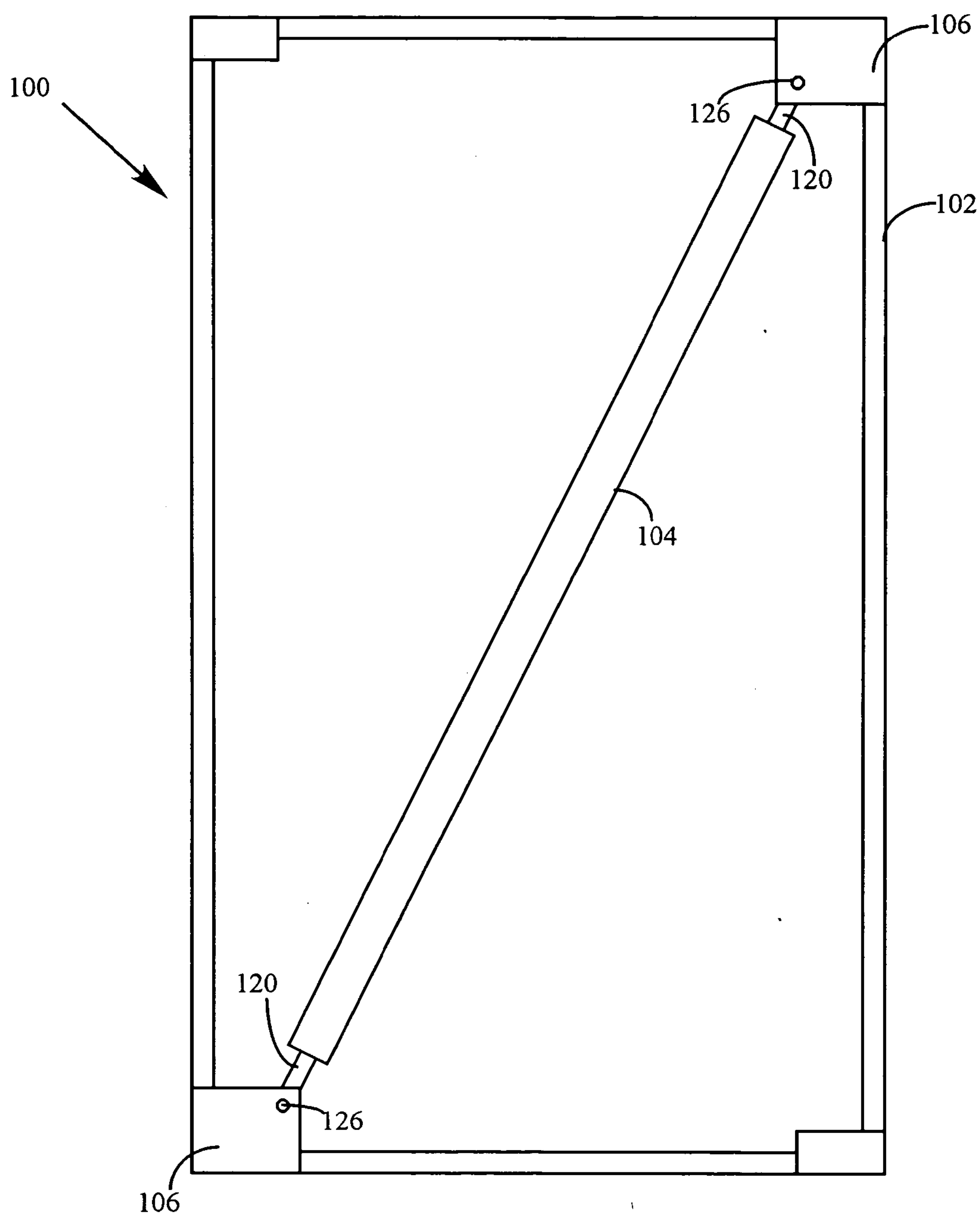
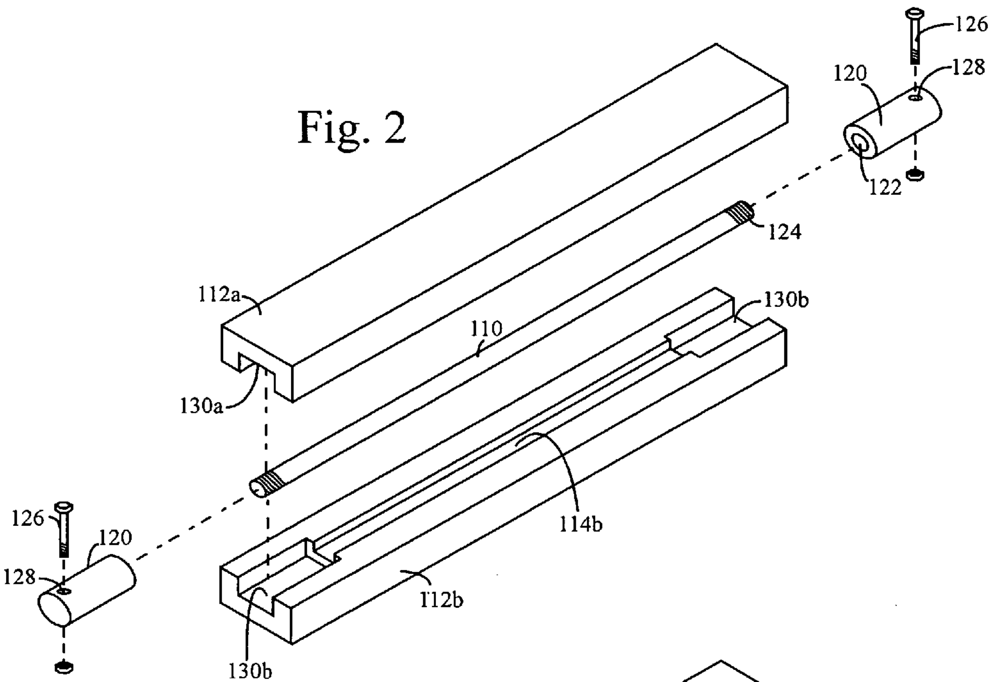


Fig. 1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122
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112a
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130a
114b
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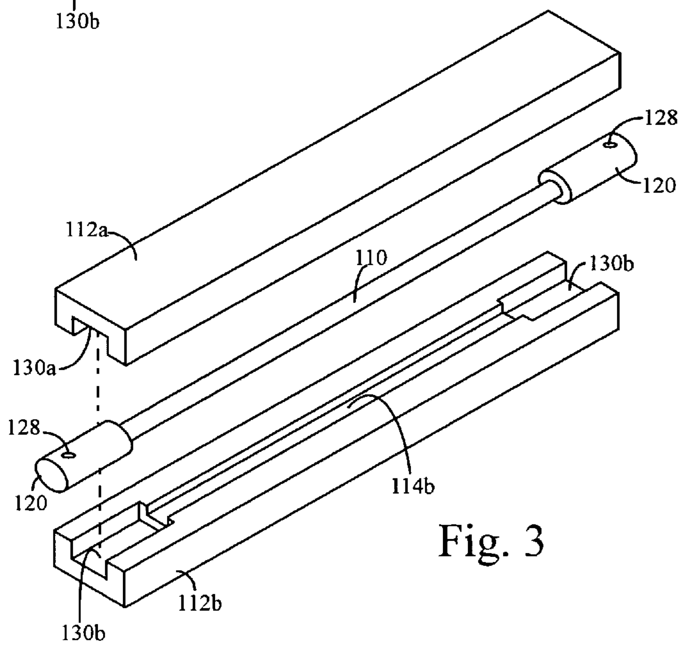
Fig. 2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112a
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130b
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128
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114b
112b
130b

Fig. 3

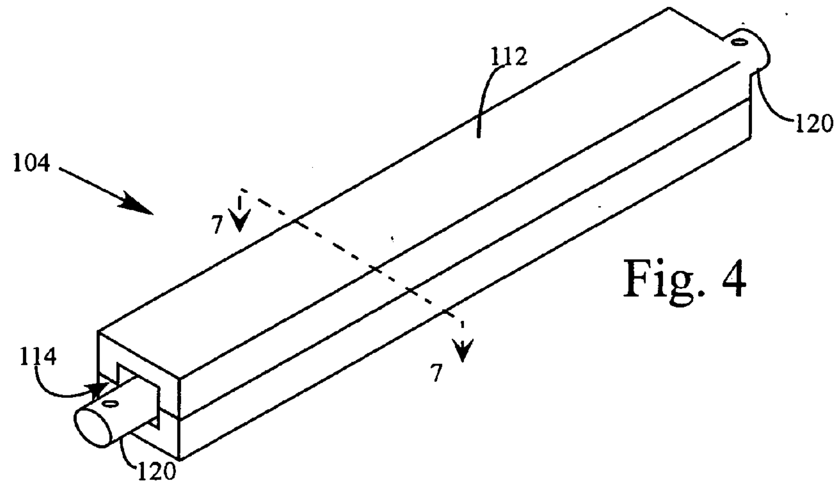


Fig. 4

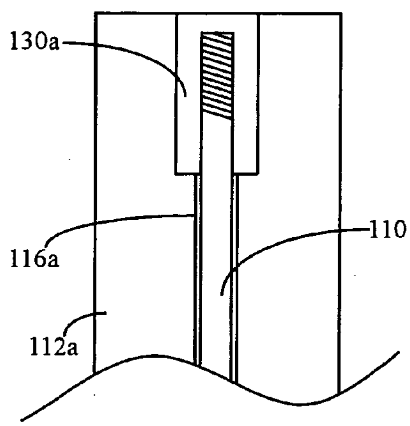


Fig. 5

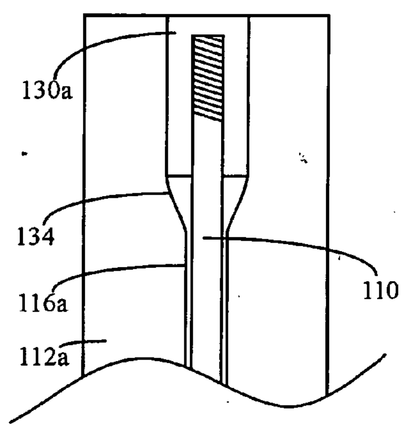


Fig. 6

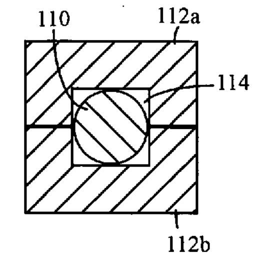


Fig. 7

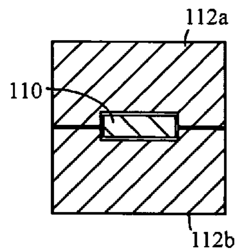


Fig. 8

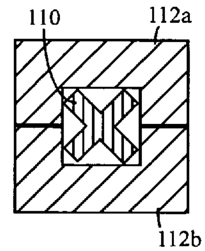


Fig. 9

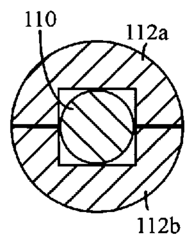


Fig. 10

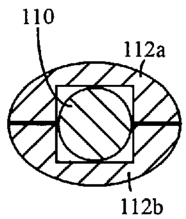


Fig. 11

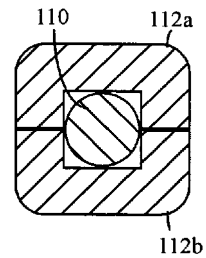


Fig. 12

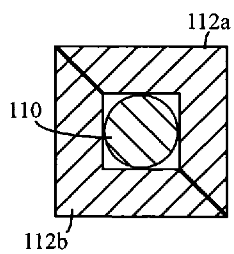


Fig. 13

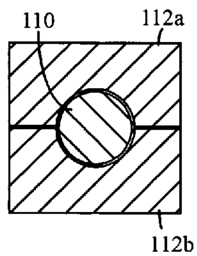


Fig. 14

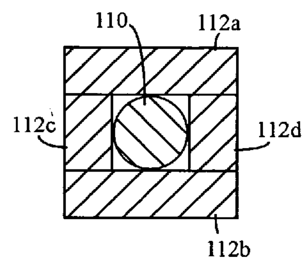
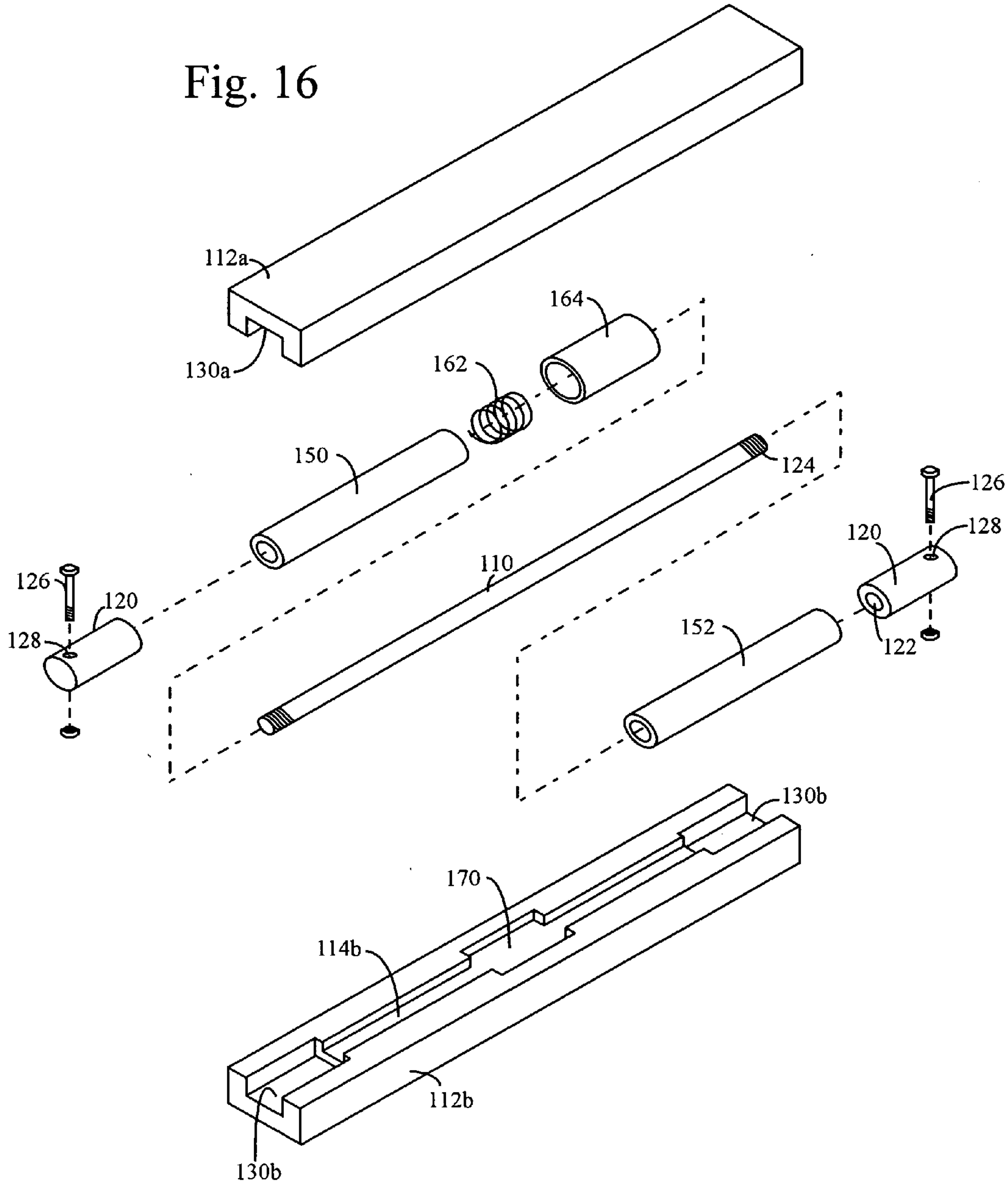


Fig. 15

Fig. 16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152
122
130b
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114b
112b
130b

Fig. 17

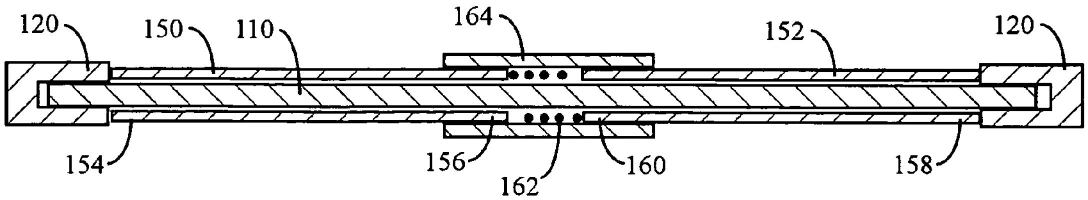
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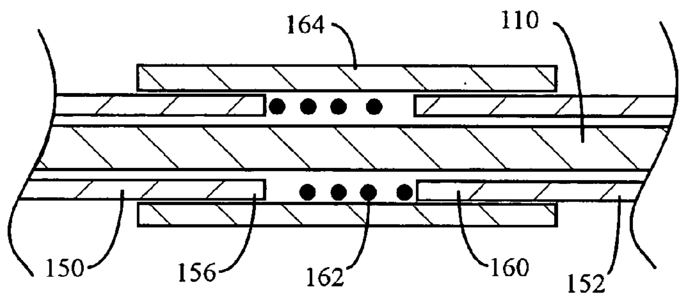
Fig. 18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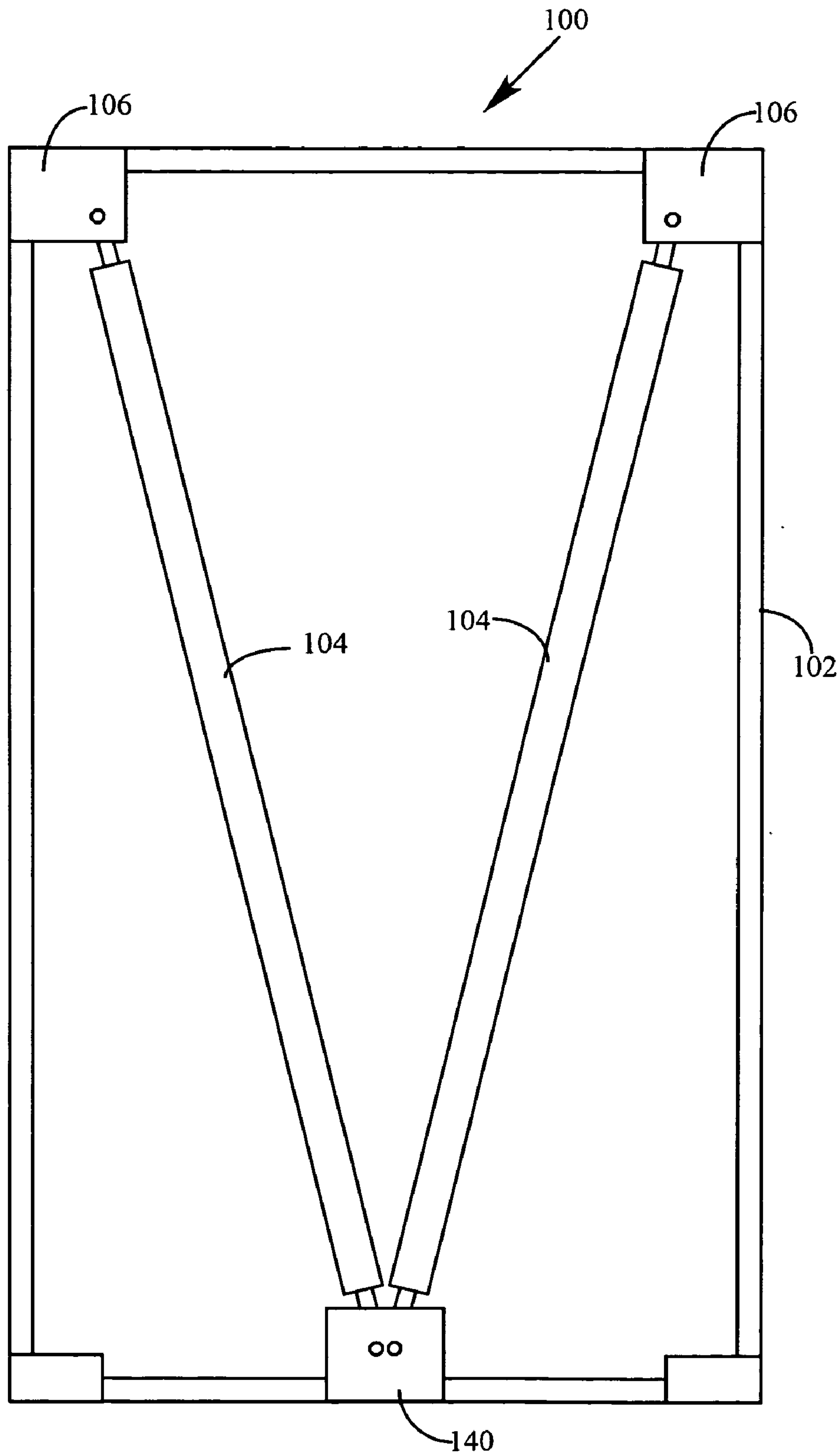

Fig. 19

BUCKLING RESTRAINED BRACED FRAME

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to hysteretic damping elements for use in light-framed constructions, and in particular to a buckling restrained braced frame for use in light-framed constructions which includes a ductile load bearing core surrounded by a lightweight casing which resists buckling of the core under compressive loads.

[0003] 2. Description of the Related Art

[0004] Shear stresses due to natural phenomena such as seismic activity and high winds can have devastating effects on the structural integrity of light-framed constructions. Lateral forces generated during such natural phenomena may cause the top portion of a wall to move laterally with respect to the bottom portion of the wall, which movement can result in structural failure of the wall and, in some instances, collapse of the building. One method of preventing damage due to shear stresses is through the use of buckling restrained braced frames. Originally developed and deployed in Japan, and now widely used in the United States, buckling restrained braced frames are installed in large steel and concrete frame buildings and skyscrapers to provide passive hysteretic damping of shear stresses generated during seismic activity and high winds.

[0005] Buckling restrained braced frames used in such large-scale constructions comprise a central steel core mounted diagonally within a structural steel frame. The steel core is capable of withstanding high tensile loads. In order to provide stiffness under compressive loads, the central steel core is conventionally encased over its length in a steel tube filled with concrete or mortar. The concrete-filled steel tube prevents buckling of the steel core under compressive forces. Buckling restrained braced frames absorb the energy generated in seismic and other shear stress events by repeatable yielding without failure in both tension and compression to thereby prevent damage to the primary structural frame.

[0006] For the braced frame to yield properly under tensile and compressive loads, it is important that the loads are borne by the steel core as opposed to the casing. A slip interface, or "unbending" layer, is therefore provided between the steel core and the surrounding concrete to decouple the steel core from the concrete and ensure that compression and tensile loads are carried only by the steel core. In conventional braced frames, the materials and geometry of the slip layer had to be carefully designed and constructed to allow relative movement between the steel core and the concrete due to shearing and Poisson's effect, while simultaneously inhibiting local buckling of the core as it yields in compression.

[0007] Owing to their construction, conventional buckling restrained braced frames are not well suited for use in light-framed constructions. While effectively used in large-scale, multistory buildings and skyscrapers, the expense and offsite manufacturing requirements of conventional braces, together with their weight, have prevented their use in light-framed constructions. Moreover, upon a seismic event, it is impossible to inspect the steel core of conventional braced frames without having to destroy the braced frame itself.

SUMMARY OF THE INVENTION

[0008] It is therefore an advantage of the present invention to provide a buckling restrained braced frame specifically adapted for use in light-framed constructions.

[0009] It is a further advantage of the present invention to provide a buckling restrained braced frame providing stable and predictable hysteretic behavior.

[0010] It is another advantage of the present invention to provide a buckling restrained braced frame which is easy to manufacture and which may be easily retrofit into existing light-framed constructions.

[0011] It is a still further advantage of the present invention to provide a buckling restrained braced frame which allows the integrity of the core to be inspected without having to replace the entire braced frame.

[0012] It is another advantage of the present invention to provide an effective buckling restrained braced frame without the use of a slip layer between the core and the casing composed of a separate material layer.

[0013] These and other advantages are provided by the present invention which in embodiments relates to a buckling restrained braced frame for use in light-framed constructions. The buckling restrained braced frame includes a frame and a buckling restrained brace diagonally mounted to opposed corners of the frame. The buckling restrained brace includes a ductile load-bearing core surrounded by a lightweight casing which resists buckling of the core under compressive loads. In embodiments of the present invention, the core may be formed of a steel rod having a circular cross-sectional area, and the casing may be formed of wood or other lightweight material having an opening defined through its longitudinal center for receiving the core. The casing may be formed from two separate halves which are affixed together to prevent slip with respect to each other by various affixation methods. Alternatively, the casing may be a single, unitary construction. Both the casing and the core may have a variety of cross-sectional shapes, and the opening in the casing in which the core is positioned may or may not conform to the shape of the core in alternative embodiments.

[0014] Tubular extensions may be connected to each end of the core to maintain the casing in position around the core, and to allow affixation of the brace to the corners of the frame. The extensions fit partially within recessed sections formed in the ends of the casing, and may be screwed, welded bolted, glued and/or otherwise affixed onto the ends of the core.

[0015] With such a configuration, tensile and compressive loading of the buckling restrained brace resulting from shear stresses within a wall are effectively dampened by repeatable yielding of the buckling restrained brace in both tension and compression. The inherent ductile properties of the core allow the buckling restrained brace to yield under tensile loads, and the restraint of the casing against the core allows the buckling restrained brace to yield under compressive loads. Moreover, as there is low friction between the core and the casing, the tensile and compressive loads are borne by the core and are not transferred to the casing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The present invention will now be described with reference to the drawings in which:

[0017] **FIG. 1** is a front view of a buckling restrained braced frame according to the present invention;

[0018] **FIG. 2** is an exploded perspective view of a buckling restrained brace used in the frame according to the present invention;

[0019] **FIG. 3** is a partially exploded perspective view of a buckling restrained brace showing tubular extensions fastened onto the central core according to the present invention;

[0020] **FIG. 4** is a perspective view of a buckling restrained brace according to the present invention;

[0021] **FIG. 5** is a partial bottom view of an end section of a buckling restrained brace according to the present invention;

[0022] **FIG. 6** is a partial bottom view of an alternative embodiment of an end section of a buckling restrained brace according to the present invention;

[0023] **FIG. 7** is a cross-sectional view through line **7-7** of the buckling restrained brace shown in **FIG. 4**;

[0024] **FIGS. 8 and 9** are cross-sectional views from the same perspective as **FIG. 7** illustrating alternative configurations of the core of the buckling restrained brace according to the present invention;

[0025] **FIGS. 10, 11** and **12** are cross-sectional views from the same perspective as **FIG. 7** illustrating alternative configurations of the outer surface of the casing of the buckling restrained brace according to the present invention;

[0026] **FIG. 13** is a cross-sectional view from the same perspective as **FIG. 7** illustrating an alternative configuration of the casing of the buckling restrained brace according to the present invention;

[0027] **FIG. 14** is a cross-sectional view from the same perspective as **FIG. 7** illustrating an alternative configuration of the inner surface of the casing of the buckling restrained brace according to the present invention;

[0028] **FIG. 15** is a cross-sectional view from the same perspective as **FIG. 7** illustrating a further alternative configuration of the casing of the buckling restrained brace according to the present invention;

[0029] **FIG. 16** is an exploded perspective view of a buckling restrained braded frame according to an alternative embodiment of the present invention;

[0030] **FIGS. 17 and 18** are enlarged cross-sectional views of the embodiment of the buckling restrained braded frame shown in **FIG. 16**; and

[0031] **FIG. 19** is a front view of an alternative buckling restrained braced frame according to the present invention.

DETAILED DESCRIPTION

[0032] The present invention will now be described with reference to **FIGS. 1 through 19**, which in embodiments relate to a buckling restrained braced frame for use in light-framed constructions which includes a ductile load bearing core surrounded by a lightweight casing which resists buckling of the core under compressive loads. It is understood that the present invention may be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein. Rather these embodiments are provided so that this disclosure will be thorough and complete and will fully convey the invention to those skilled in the art. Indeed, the invention is intended to cover alternatives, modifications and equivalents of these embodiments, which are included within the scope and spirit of the invention as defined by the appended claims. Furthermore, in the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be clear to those of ordinary skill in the art that the present invention may be practiced without such specific details.

[0033] Referring now to **FIG. 1**, there is shown a buckling restrained braced frame ("BRBF") **100** for use in light-framed constructions. As used herein, a light-framed construction is any type of construction whose vertical and horizontal structural elements are primarily framed by a system of repetitive wood and/or light gauge steel framing members. BRBF **100** includes a steel frame **102** and a buckling restrained brace **104**. The brace **104** is affixed to the frame **102** at gusset plates **106** welded, bolted, glued and/or otherwise attached to diagonal corners **108, 110** of the frame **102**. Although only the gusset plates **106** on the front of frame **102** are visible in **FIG. 1**, an additional two such gusset plates are also welded, bolted, glued and/or otherwise attached to the back of the frame **102** behind the gusset plates **106** shown in **FIG. 1**. The frame **102** is preferably formed of steel having sufficient strength so as to remain below the yield stress level for the maximum forces deliverable by the brace **104**, thus ensuring that yielding will be limited to the brace **104** and not the frame **102**.

[0034] Referring to **FIGS. 2 through 4**, buckling restrained brace **104** is comprised of a ductile inner core **110** enclosed within an outer casing **112**. In embodiments of the present invention, the core **110** may be formed of a steel rod having a circular cross-sectional diameter of approximately ½ inch. The core may be formed of other ductile materials and with other diameters in alternative embodiments. For example, the core **110** may be formed of copper or a polymer such as thermoplastic polyurethane. Similarly, the diameter of the core **110** may be between ¼ inch to 2 inches in alternative embodiments.

[0035] According to the present invention, the casing **112** may be formed for example of wood having an opening **114** (**FIGS. 4 and 7**) defined by channels **114***a* and **114***b* through its longitudinal center for receiving core **110**. Various types of wood may be used for the casing **112**, including sawn lumber from lumber groups including spruce-pine-fir, Douglas fir-larch, hem-fir and southern pine. The casing **112** may alternatively be formed of engineered lumber, such as glulam and wood composites. Other types of wood are contemplated. It is further understood that casing **112** may alternatively be formed of a variety of other materials such as a lightweight metal including for example, aluminum, copper, brass, bronze and alloys thereof. The casing may further be formed of other lightweight materials, such as fiberglass or a rigid polymer including for example various plastics. It is understood that a variety of other lightweight metals and materials are accepted equivalents to the metals and materials described above and are contemplated for use in the present invention. For the purposes of the present invention, a conventional steel with cement or mortar combination is not considered equivalent to the lightweight materials described above and would not be used for casing **112**.

[**0036**] In embodiments of the present invention, casing **112** may be formed from two separate halves **112***a* and **112***b* such as shown in **FIGS. 2-4**. Each half **112***a*, **112***b* may have cross-sectional dimensions perpendicular to its length of 2 inches by 4 inches, so that when assembled together, the cross-sectional dimensions of the casing **112** are 4 inches by 4 inches. It is understood that dimensions of the respective halves and overall casing may vary in alternative embodiments.

[**0037**] The halves **112***a*, **112***b* are affixed together to prevent slip with respect to each other. Various affixation methods may be applied to prevent slip between the halves **112***a*, **112***b* including an adhesive, epoxy, screws, nails, bolts, or a combination thereof. The affixation method may additionally include one or more mending plates at the interface between halves **112***a*, **112***b*. Such mending plates, available for example from Simpson Strong-Tie, Co., Inc., of Dublin, Calif., may include sharp prongs protruding from the front and back surfaces of the plate which can be driven into the respective opposed surfaces of the halves **112***a*, **112***b* when the halves are affixed to each other to prevent slip between the halves.

[**0038**] The halves may additionally or alternatively be affixed to each other by one or more ropes, straps or bands applied tightly around the halves **112***a*, **112***b*. A further method of preventing slip between the halves **112***a*, **112***b* that may be used in addition to or instead of the above-described methods is a wrap applied around the outer surface of the casing once the halves are joined together. The wrap may be applied in liquid form that dries hard, and may be for example a fibrous resin.

[**0039**] As shown for example in **FIGS. 2 and 3**, where casing **112** is formed of halves **112***a*, **112***b*, the opening **114** may be defined by a pair of channels **116***a* and **116***b* formed in the respective halves (channel **116***a* is not visible in the views of **FIGS. 2-3**, but is shown for example in **FIGS. 5-6**). The channels **116***a*, **116***b* may be formed by a router or other known devices for forming channels in wood. Channels **116***a*, **116***b* are sized depending on the diameter of the core **110** so that core fits within the opening **114** upon connection of the halves **112***a*, **112***b* as described above and hereinafter. While it may be difficult to form opening **114** through a unitary piece of wood, it is contemplated that casing **112** may be formed of a single, unitary piece of wood with the opening **114** formed therethrough, for example by drilling.

[**0040**] As indicated above, casing **112** may alternatively be formed of other lightweight metals and materials in a single, unitary construction, such as for example aluminum, copper, brass, plastic or fiberglass. In such embodiments, the opening **114** may be formed during an extrusion, casting or other process for fabricating the unitary casing. A casing **112** formed of these lightweight metals and materials may alternatively be formed in separate halves, as explained above, having channels **116***a*, **116***b* which are then affixed together using at least some of the affixation methods described above.

[**0041**] In addition to the advantages of using lightweight materials in light-framed constructions, the material of the casing **112** and the fit of the core **110** within the opening **114** allow the buckling restrained brace to provide hysteretic damping of shear forces on the BRBF **100** without the use of a slip layer conventionally required between the casing and core. In particular, while the core undergoes axial loads (i.e., along the central axis of the core), the relatively low friction between the casing and core prevents the core from transferring any appreciable axial loads to the casing.

[**0042**] The buckling restrained brace **104** may further include tubular extensions **120** connected to each end of core **110**. The extensions may be formed of the same material as the core **110** or another material having a like coefficient of thermal expansion so that the extensions remain securely fixed to the ends of the core **110** at different temperatures and conditions. In embodiments of the invention, each tubular extension **120** includes a threaded bore **122** (**FIG. 2**) formed partially through the extension, into which bores threaded ends **124** of core **110** are received. The threads in ends **124** may be cut threads which are cut into the core so that the outer diameter of the threads is equal to the outer diameter of the core **110**. Alternatively, the threads in ends **124** may be rolled threads which are formed in a rolling process which displaces the material between the threads. In such an embodiment, the threads have an outer diameter that is slightly larger than the outer diameter of the core. In addition to or instead of screwing onto the ends of core **110**, the tubular extensions **120** may be welded, bolted, glued and/or affixed by other means onto the ends of core **110**.

[**0043**] The extensions **120** are provided to maintain the casing **112** in position around the core **110**, and protrude out of the ends of the casing **112** as shown to allow affixation of the brace **104** to the frame **102**. In one embodiment, a bolt **126** may fit through holes formed in the front and rear gusset plates **106** at opposed corners of frame **102**, and a hole **128** may be formed through each tubular extension allowing the brace **104** to be bolted to frame **102**. The bolts **126** through holes **128** allow some relative movement between the frame **102** and brace **104** without generating stress within the tubular extensions **120** or gusset plates **106** as a result of such relative movement.

[**0044**] The extensions **120** fit within recessed sections **130***a*, **130***b* (**FIGS. 2 and 3**) formed in casing halves **112***a*, **112***b*, respectively, at each end of the halves. The tubular extensions **120** preferably have a larger diameter than core **110**, for example 1 inch in embodiments where the core has a diameter of ½ inch. Accordingly, recessed sections **130***a*, **130***b* are recessed into halves **112***a*, **112***b* to a slightly greater degree than are channels **116***a*, **116***b* to thereby accommodate the extensions **120**. When assembled, the fit of extensions **120** within recessed sections **130***a*, **130***b* maintains the casing **112** in position about the core **110**. In embodiments where casing **112** comprises a single, unitary member, the recessed sections may be formed by drilling (where the casing is formed of wood), or during the extrusion or casting process (where the casing is formed of other lightweight metals and materials).

[**0045**] **FIGS. 5 and 6** are views of the channel **116***a* and recessed section **130***a* in casing half **112***a*. As shown in **FIG. 5**, the boundary between the channel **116***a* and the recessed section **130***a* may be abrupt right angles formed in casing half **112***a*. Alternatively, as shown in **FIG. 6**, the boundary between the channel **116***a* and the recessed section **130***a* may be a gradual blending at a section **134** between the diameter of the recessed section **130***a* and the diameter of channel **116***a*. The gradual blending at section **134** may reduce stress concentrations within the casing **112** upon compressive deformation of core **110**. The configurations shown in **FIGS. 5 and 6** may also be provided in casing half **112***b*.

[**0046**] **FIG. 7** is a cross-sectional view through line **7-7** in **FIG. 4**, namely through a plane perpendicular to a central axis of the core **110**. As shown therein, the casing **112** is comprised of halves **112***a* and **112***b* defining the opening **114** within which the core **110** is positioned so as to lie in contact with the casing **112** along four lines of contact. In alternative embodiments, the diameter of the core may be slightly smaller than that of opening **114** so that there is a small spacing between the core **110** and the casing **112**.

[**0047**] The shape of the core **110** may vary from circular in alternative embodiments. For example, **FIG. 8** illustrates a cross-sectional view from the same perspective of **FIG. 7**, but in the embodiment of **FIG. 8**, the core **110** may have a square or rectangular cross-section. In embodiments where the core has a rectangular cross-section, the dimensions of the channels forming opening **114** may be sized so that opening **114** substantially conforms to the shape of the core **110**, leaving little or no space between the core and casing on all sides. In an alternative embodiment not shown, the dimensions of the channels forming opening **114** may be sized so that some space exists between one or more surfaces of the rectangular core **110** and the casing **112**.

[**0048**] In the embodiment shown in **FIG. 8**, the plane defined where the halves **112***a* and **112***b* come together is substantially parallel to the planes of the two opposed major surfaces of the core **110** (i.e., the planes are all horizontal from the perspective shown in **FIG. 8**). It is understood however that the core may be rotated from the position shown in **FIG. 8** relative to the casing. For example, the core may be rotated 45° from that shown in **FIG. 8** so that the core lies diagonally within the opening **114**. Alternatively, the core may be rotated 90° from that shown in **FIG. 8** so that the plane between the halves **112***a*, **112***b* lies perpendicular to the planes of the major surfaces of the core **110**. All other angular orientations of the core relative to the intersecting plane of halves **112***a*, **112***b* are contemplated.

[**0049**] **FIG. 9** illustrates a further cross-sectional shape of core **110**, where the core is shaped by perpendicularly intersecting planes that form a cross- or "X"-shape. Other shapes, such as oval or elliptical, are contemplated, and other angular orientations of the core relative to the intersecting plane of halves **112***a*, **112***b* are contemplated. Moreover, the opening **114** may be square shaped as shown in **FIG. 9**, or it may be cut to conform to the shape of the core **110** shown in **FIG. 9**.

[**0050**] It is further understood that the shape of the outer surface of casing **112** and/or the shape of opening **114** may vary in alternative embodiments. For example, the casing may have a circular cross-section as shown in **FIG. 10**, or an elliptical or oval cross-section as shown in **FIG. 11**. While the major axis of the ellipse shown in **FIG. 11** is parallel to the intersecting plane of halves **112***a*, **112***b*, all other orientations of the ellipse major axis to the intersecting plane of halves **112***a*, **112***b* are contemplated. In an alternative embodiment, the outer corners of the casing **112** may be rounded as shown in **FIG. 12**. Although not shown, the outer surface of casing **12** may further be formed with a triangular cross-sectional shape in alternative embodiments.

[**0051**] In a further alternative embodiment, each of the halves themselves may be formed in substantially triangular sections that fit together as shown in **FIG. 13**. Other angular orientations between the intersecting plane of halves **112***a* and **112***b* and the outer surfaces of the casing **112** are contemplated in further embodiments. **FIG. 14** illustrates a cross-sectional view from the same perspective of **FIG. 7**, but in the embodiment of **FIG. 14**, both the opening **114** and core **110** have substantially conforming cross-sectional circular, elliptical or oval shapes.

[**0052**] Up to this point, casing **112** has been described as being either unitary or formed of two separate halves. However, in a further alternative embodiment, the casing **112** may be formed of more than two halves. For example, as shown in **FIG. 15**, the casing may be formed of 4 separate pieces, two larger sections **112***a*, **112***b* connected by two smaller sections **112***c*, **112***d*. Each of the sections may be affixed to each other by any of the affixation methods described above. As a further example (not shown), the four separate sections may each have a cross-sectional shape of a rhombus, each being the same size, so that the respective sections fit together to define the opening **114**.

[**0053**] It is understood that the various embodiments described above which are shown in, or are described variations of, **FIGS. 8 through 15** may be combined with each other to provide a buckling restrained brace **104** having a wide variety of core and casing configurations.

[**0054**] A further alternative embodiment of the present invention is shown in **FIGS. 16-18**. In accordance with this embodiment, the core **110** is encased within a pair of cylindrical conduits **150** and **152**. The conduits **150**, **152** may be identical to each other and may have an inner diameter slightly larger than the outer diameter of the core **110**. For example, where the core diameter is 1 inch, the inner diameter of the conduits **150**, **152** may be 2 inches. The conduits may have wall thicknesses of about ¼ inch. It is understood that the spacing between the core and inner diameters of the conduits, as well as the wall thicknesses of the conduits, may vary above and below the dimensions disclosed above in alternative embodiments. The conduits may be formed of steel, or other materials including different metals such as copper or bronze, and polymers such as thermoplastic polyurethane.

[**0055**] As best seen in the cross-sectional view of **FIG. 17**, when assembled, the conduit **150** has a first end **154** abutting against the tubular extension **120** and a second end **156**. Likewise, the conduit **152** has a first end **158** abutting against the tubular extension **120** and a second end **160**. The lengths of the conduits **150** and **152** are provided so that, when assembled, a gap exists between the ends **156** and **160** of the respective conduits **150** and **152**. The gap may be approximately 1 to 4 inches and may further be approximately 2 inches, and is provided so that the conduits **150** and **152** do not interfere with the buckling of the brace **104** under a compressive load. It is understood that the gap between the ends **156**, **160** of the respective conduits may be less than 1 inch and greater than 4 inches in alternative embodiments.

In a preferred embodiment, the gap may be located half way along the length of the brace **104**. However, it is understood that the lengths of the respective conduits **150** and **152** may be different than each other so that the position of the gap is not centered along the brace **104** in alternative embodiments.

[**0056**] A spring **162** is provided around the core **110** within the gap between the conduits **150** and **152**. When assembled, spring **162** is compressed between the conduit ends **156** and **158**. In addition to maintaining the conduit ends **154** and **158** in contact with the respective tubular extensions **120**, the spring **162** also provides some resistance to buckling of the core.

[**0057**] In order to provide greater resistance to core buckling at the gap between the conduits, a slightly larger diameter conduit **164** may be placed over the spring **162** and has ends which overlap by a few inches the ends **156** and **160** of the conduits **150** and **152**. In embodiments, the wire diameter of the coil spring **162** is provided to be the same as the wall thicknesses of conduits **150** and **152**. Thus, when assembled, the spacing between the core **110** and spring **162** may be the same as the spacing between the core **110** and conduits **150, 152**. At the same time, the conduit **164** may be slid into position over both the conduits **150, 152** and the spring **162**. The conduit **164** may be approximately 4 to 6 inches long, but it is understood that it may be shorter or longer than that in alternative embodiments. The conduit **164** may be held in place as by welding, screws, bolting, glue and/or other affixation methods.

[**0058**] Referring to **FIG. 16**, the dimensions of channels **114***a* and **114***b* may be provided to fit relatively snugly around conduits **150** and **152**. In order to accommodate the enlarged conduit section **164**, the respective halves **112***a* and **112***b* of the casing may be locally routed to define an enlarged portion **170** (one such portion shown in half **112***b*). It is understood that the cross-section of the inner and/or outer diameters of the conduits **150, 152** and **164** may be other than circular in alternative embodiments.

[**0059**] In the embodiments of the present invention described to this point, the BRBF **100** includes a frame **102** and a single buckling restrained brace **104** diagonally mounted in frame **102**. **FIG. 16** illustrates a further alternative embodiment including more than one buckling restrained brace **104** forming a "V" within frame **102**. In this embodiment, a pair of additional central gusset plates **140** may be provided (the second plate **140** not seen is mounted to frame **102** behind the plate **140** shown). Each buckling restrained brace **104** may be of identical structure to the brace **104** described above, except that each brace **104** shown in **FIG. 16** has a first end connected to the upper corners of the frame **102**, and a second end connected to the central gusset plates **140**. The BRBF **100** shown in **FIG. 16** may alternatively be inverted so that the braces **104** form an upside down "V." The connection points of the respective braces **104** on central gusset plates **140** are preferably near to each other to minimize the moment forces generated on the central gusset plates **140** by the braces **104**.

[**0060**] The BRBF **100** is scalable to different sizes, and may be provided with different aspect ratios. In one embodiment, the frame **102** may be 4 feet wide by 8 feet high. In such an embodiment, by way of example only and not limiting on the invention, the buckling restrained brace **104** shown in **FIG. 1** may be approximately 8½ feet long, with the casing **112** being approximately 8 feet long, and the tubular extensions **120** extending approximately 3 inches out from each end of the casing **112**. The core **110** in such an embodiment may be approximately 7 feet, 8 inches long, with one inch on each end of the core being received within the tubular extensions. The tubular extensions may extend into the recessed sections **130***a,* **130***b* approximately 3 inches to give a total length of the tubular extensions of approximately 6 inches. It is understood that, for a 4 foot by 8 foot frame, the length for the casing, the length of the core, the length of the threads on the core, the length of the tubular extensions and the amount the tubular extensions extend from the casing may all vary from the values given above in alternative embodiments. Similarly, the values given above may vary for different sizes and aspect ratios of the BRBF **100**.

[**0061**] The BRBF **100** can be mounted within a wall of a light-framed construction to add structural rigidity and resistance to shear. It may be mounted to an underlying support surface which may be a concrete building foundation, a floor diaphragm on the building foundation or a floor diaphragm on a top plate of a lower floor. It may be fastened to the underlying support surface by means of anchors provided through holes formed in the lower bar of frame **102**. Other anchoring mechanisms may be used in alternative embodiments, such as for example by strap anchors, mudsill anchors, retrofit bolts, foundation plate holdowns, straps, ties, nails, screws, framing anchors, ties, plates, straps or a combination thereof. The BRBF **100** may similarly include holes in the top bar of the frame **102** for affixation to a top plate of a wall as by bolts or other anchoring mechanisms described above.

[**0062**] Upon both tensile and compressive loading of the buckling restrained brace **104** by shear forces exerted on a wall, for example during seismic activity or high winds, the brace **104** may repeatably yield in both tension and compression to provide hysteretic damping of the shear forces. The inherent ductile properties of the core **110** allows the buckling restrained brace to yield under tensile loads and the restraint of the casing **112** against the core **110** allows the buckling restrained brace to yield under compressive loads, thus damping the shear stresses that would otherwise bear on the frame **102**. Moreover, as previously indicated, the nature of the materials used for the core and casing allow the tensile and compressive loads to be borne by the core and not the casing.

[**0063**] A further advantage of the BRBF **100** according to the present invention is that they may be constructed on-site during construction. Additionally, after a seismic event, the casing **112** may be easily removed and the core inspected. Thus, if the integrity of the core remains intact, a new casing may be assembled around the core and no replacement of the BRBF **100** is necessary.

[**0064**] Although the invention has been described in detail herein, it should be understood that the invention is not limited to the embodiments herein disclosed. Various changes, substitutions and modifications may be made thereto by those skilled in the art without departing from the spirit or scope of the invention as described and defined by the appended claims.

What is claimed is:

1. A buckling restrained brace for use in a buckling restrained braced frame, comprising:

a core; and

a casing surrounding at least a portion of the core for resisting buckling of the core under compressive loads on the core, the casing being formed of wood.

2. A buckling restrained brace as recited in claim 1, wherein the casing is formed from two separate halves that are affixed together.

3. A buckling restrained brace as recited in claim 2, wherein the separate halves are affixed to each other by at least one of an adhesive, an epoxy, screws, nails, bolts, and a mending plate provided at an intersection between the halves.

4. A buckling restrained brace as recited in claim 2, wherein the separate halves are affixed to each other by at least one of a rope, a strap, and a band applied around the halves.

5. A buckling restrained brace as recited in claim 2, wherein the separate halves are affixed to each other by a wrap applied around the outer surface of the casing once the halves are joined together.

6. A buckling restrained brace as recited in claim 2, wherein the separate halves are affixed to each other by means for preventing slip between the halves.

7. A buckling restrained brace as recited in claim 2, wherein each half of the casing is formed with a channel for receiving the core when the halves are affixed together, the core lying in contact with at least one surface defining at least one of the channels when the halves are affixed together.

8. A buckling restrained brace as recited in claim 1, wherein the core is ductile.

9. A buckling restrained brace as recited in claim 1, wherein the core has a circular diameter through a plane perpendicular to a central axis of the core.

10. A buckling restrained brace as recited in claim 1, wherein the core has a diameter through a plane perpendicular to a central axis of the core in the shape of one of a square, a rectangle, an oval, an ellipse, or cross-shaped.

11. A buckling restrained brace as recited in claim 1, wherein the casing has an outer surface which is in the shape of one of a square, a rectangle, a circle, an oval, and an ellipse.

12. A buckling restrained brace as recited in claim 1, wherein the casing has an outer surface including rounded edges.

13. A buckling restrained brace as recited in claim 1, wherein the casing includes an opening through its center, the opening being substantially square.

14. A buckling restrained brace as recited in claim 1, wherein the casing includes an opening through its center, the opening substantially conforming in shape to the core.

15. A buckling restrained brace as recited in claim 1, wherein the casing is formed of four separate sections which may be affixed to each other to define an opening capable of at least partially enclosing the core.

16. A buckling restrained brace as recited in claim 1, further comprising a pair of tubular extensions affixed to first and second ends of the core, the pair of tubular extensions affixing the core to a frame of the buckling restrained braced frame.

17. A buckling restrained brace as recited in claim 16, wherein a tubular extension of the pair of tubular extensions has a threaded bore for mating with threads on the first or second end of the core.

18. A buckling restrained brace as recited in claim 16, wherein a tubular extension of the pair of tubular extensions is welded to the first or second end of the core.

19. A buckling restrained brace for use in a buckling restrained braced frame, comprising:

a core; and

a casing surrounding at least a portion of the core for resisting buckling of the core under compressive loads on the core, the casing being formed of a material from a group of materials including:

wood,

metals including aluminum, copper, brass, bronze and alloys thereof,

polymers including rigid plastic, and

fiberglass.

20. A buckling restrained brace as recited in claim 19, wherein the casing is formed from two separate halves that are affixed together.

21. A buckling restrained brace as recited in claim 19, wherein the casing is formed from a unitary member with an opening capable of at least partially enclosing the core.

22. A buckling restrained brace as recited in claim 20, wherein the separate halves are affixed to each other by means for preventing slip between the halves.

23. A buckling restrained brace as recited in claim 19, wherein the core has a diameter through a plane perpendicular to a central axis of the core in the shape of one of a circle, a square, a rectangle, an oval, an ellipse, or cross-shaped.

24. A buckling restrained brace as recited in claim 19, wherein the casing has an outer surface which is in the shape of one of a square, a rectangle, a circle, an oval, and an ellipse.

25. A buckling restrained brace as recited in claim 19, wherein the casing has an outer surface including rounded edges.

26. A buckling restrained brace as recited in claim 19, wherein the casing includes an opening through its center, the opening substantially conforming in shape to the core.

27. A buckling restrained brace as recited in claim 19, further comprising a pair of tubular extensions affixed to first and second ends of the core, the pair of tubular extensions affixing the core to a frame of the buckling restrained braced frame.

28. A buckling restrained brace for use in a buckling restrained braced frame, comprising:

a core; and

means for resisting buckling of the core under compressive loads on the core.

29. A buckling restrained braced frame for hysteretic damping in light-framed constructions, comprising:

a frame; and

a buckling restrained brace, including

a core, and

a casing surrounding at least a portion of the core for resisting buckling of the core under compressive loads on the core, the casing being formed of a material from a group of materials including:

wood,

metals including aluminum, copper, brass, bronze and alloys thereof,

polymers including rigid plastic, and fiberglass.

30. A buckling restrained brace as recited in claim 29, wherein the casing is formed from two separate halves that are affixed together.

31. A buckling restrained brace as recited in claim 29, wherein the casing is formed from a unitary member with an opening capable of at least partially enclosing the core.

32. A buckling restrained brace as recited in claim 30, wherein the separate halves are affixed to each other by means for preventing slip between the halves.

33. A buckling restrained brace as recited in claim 29, wherein the casing has an outer surface which is in the shape of one of a square, a rectangle, a circle, an oval, and an ellipse.

34. A buckling restrained brace as recited in claim 29, wherein the casing has an outer surface including rounded edges.

35. A buckling restrained brace as recited in claim 29, wherein the casing includes an opening through its center, the opening substantially conforming in shape to the core.

36. A buckling restrained brace as recited in claim 29, further comprising a pair of tubular extensions affixed to first and second ends of the core, the pair of tubular extensions affixing the core to a frame of the buckling restrained braced frame.

37. A buckling restrained brace for use in a buckling restrained braced frame capable of hysteretic damping of shear forces, the buckling restrained brace comprising:

a core; and

a casing surrounding at least a portion of the core for resisting buckling of the core under compressive loads on the core, the casing being formed of a material from a group of materials including:

wood,

metals including aluminum, copper, brass, bronze and alloys thereof,

polymers including rigid plastic, and

fiberglass;

wherein tensile and compressive loads exerted on the core are not transferred to the casing without employing a slip layer between the core and the casing.

38. A buckling restrained brace for use in a buckling restrained braced frame, comprising:

a core having a length;

a first conduit circumjacent about the core;

a second conduit circumjacent about the core, the first and second conduits having a combined length less than the length of the core to define a gap between the first and second conduits; and

a spring wrapped around the core within the gap between the first and second conduits, the spring biasing the first and second conduits away from each other.

39. A buckling restrained brace as recited in claim 38, further comprising:

a third conduit circumjacent about the spring and at least end portions of the first and second conduits adjacent the gap.

40. A buckling restrained brace as recited in claim 39, further comprising:

a casing surrounding the third conduit, and at least a portion of the first conduit, the second conduit and the core for resisting buckling of the core under compressive loads on the core, the casing being formed of wood.

41. A buckling restrained brace as recited in claim 38, the first and second conduits formed of steel.

42. A buckling restrained brace for use in a buckling restrained braced frame, comprising:

a core having a length;

a first conduit circumjacent about the core;

a second conduit circumjacent about the core, the first and second conduits having a combined length less than the length of the core to define a gap between the first and second conduits;

a spring wrapped around the core within the gap between the first and second conduits; and

a third conduit circumjacent about the spring and at least end portions of the first and second conduits adjacent the gap.

43. A buckling restrained brace as recited in claim 42, further comprising:

a casing surrounding the third conduit, and at least a portion of the first conduit, the second conduit and the core for resisting buckling of the core under compressive loads on the core, the casing being formed of wood.

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