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(54) **REINFORCED JOINT FOR BEAM-COLUMN CONNECTION**

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E04B 1/24 (2006.01)

(52) **U.S. Cl.**
CPC ***E04B 1/2403*** (2013.01); *E04B 2001/2415* (2013.01); *E04B 2001/2445* (2013.01); *E04B 2001/2448* (2013.01)

(58) **Field of Classification Search**
CPC E04B 1/2403; E04B 2001/2415; E04B 2001/2445; E04B 2001/2448
See application file for complete search history.

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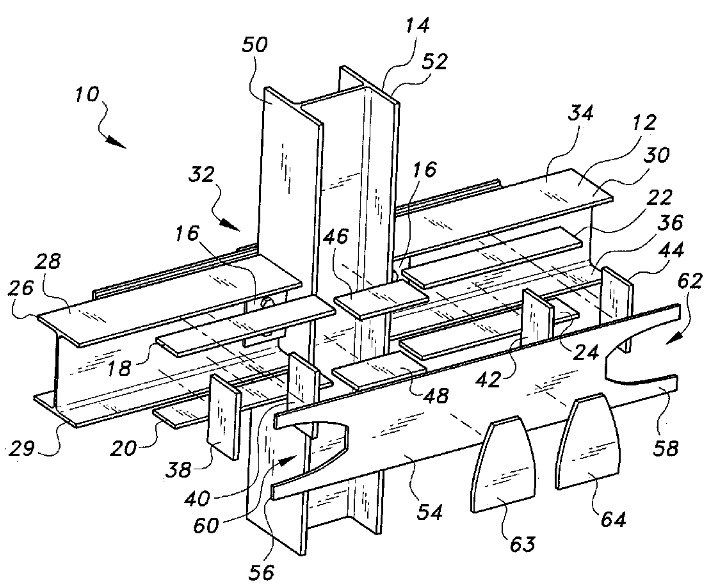
(57) **ABSTRACT**

The reinforced joint for a beam-column connection is provided for improving the resistance of steel-framed buildings against progressive collapse. Flange stiffening plates reinforce flanges of structural beams, with beam web stiffeners being attached to and extending between the flange stiffening plates. Additional column web stiffeners are attached to and extend between flanges of a structural column. A longitudinal cover stiffening plate is attached to the column stiffeners and the flange stiffening plates, extending across the joint and at least partially covering the beam web stiffeners. The reinforced joint between the structural beams and the structural column develops catenary action in the structural beams in the event of collapse.

5 Claims, 11 Drawing Sheets



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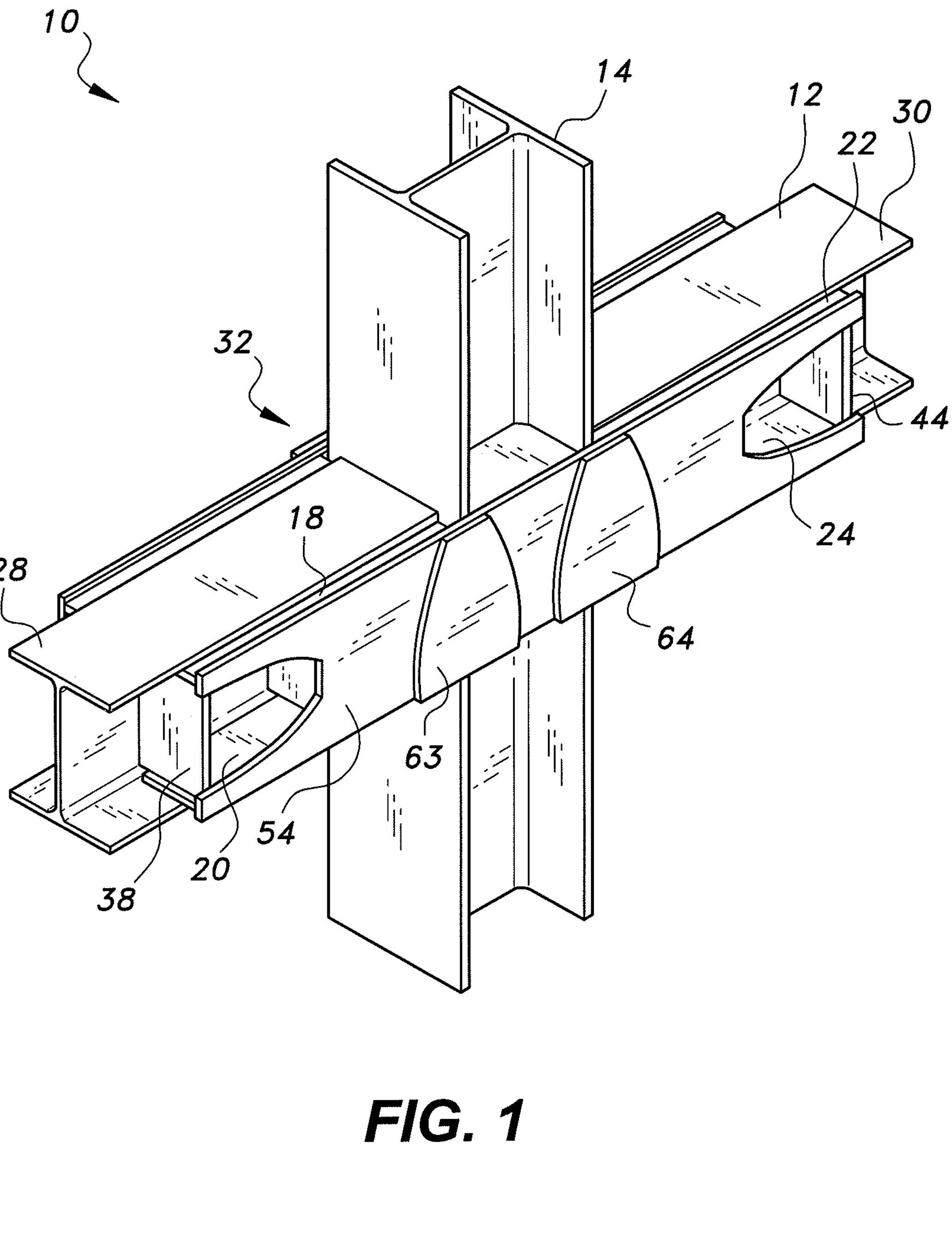

FIG. 1

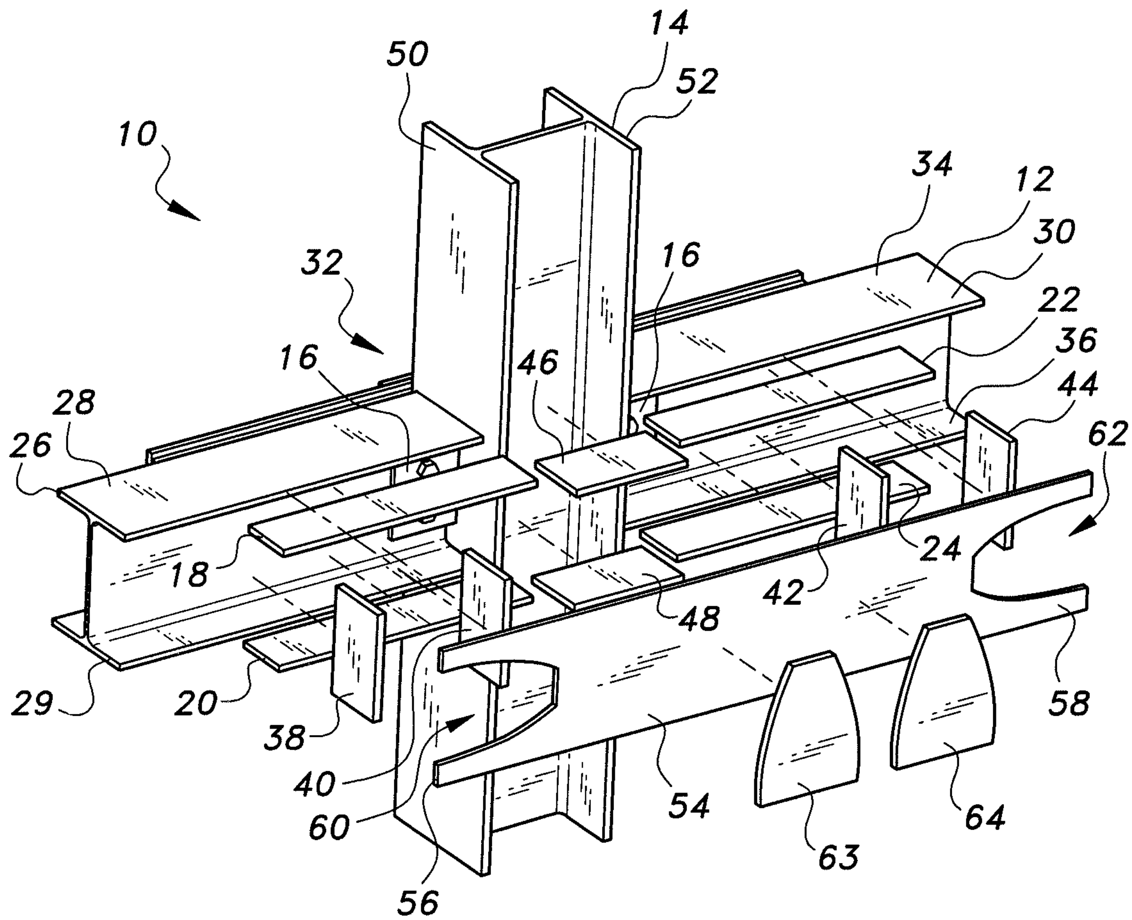
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FIG. 2

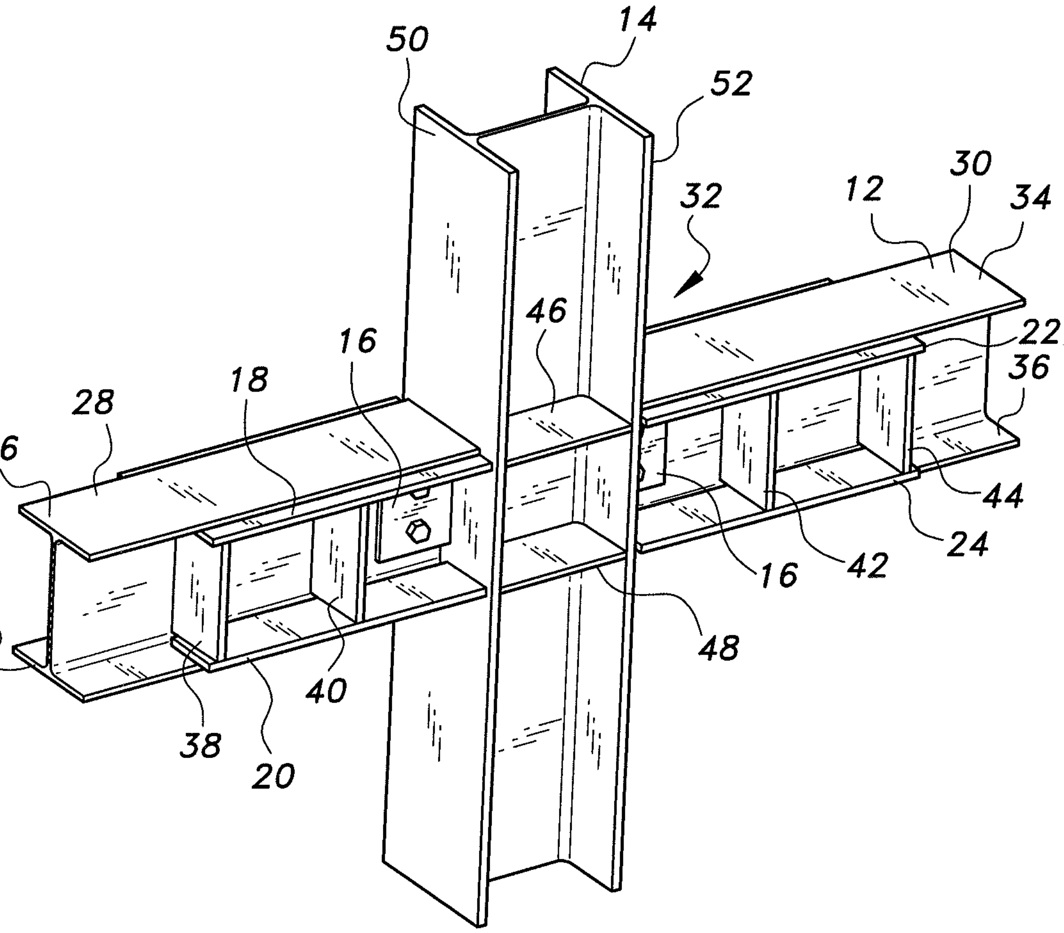

FIG. 3

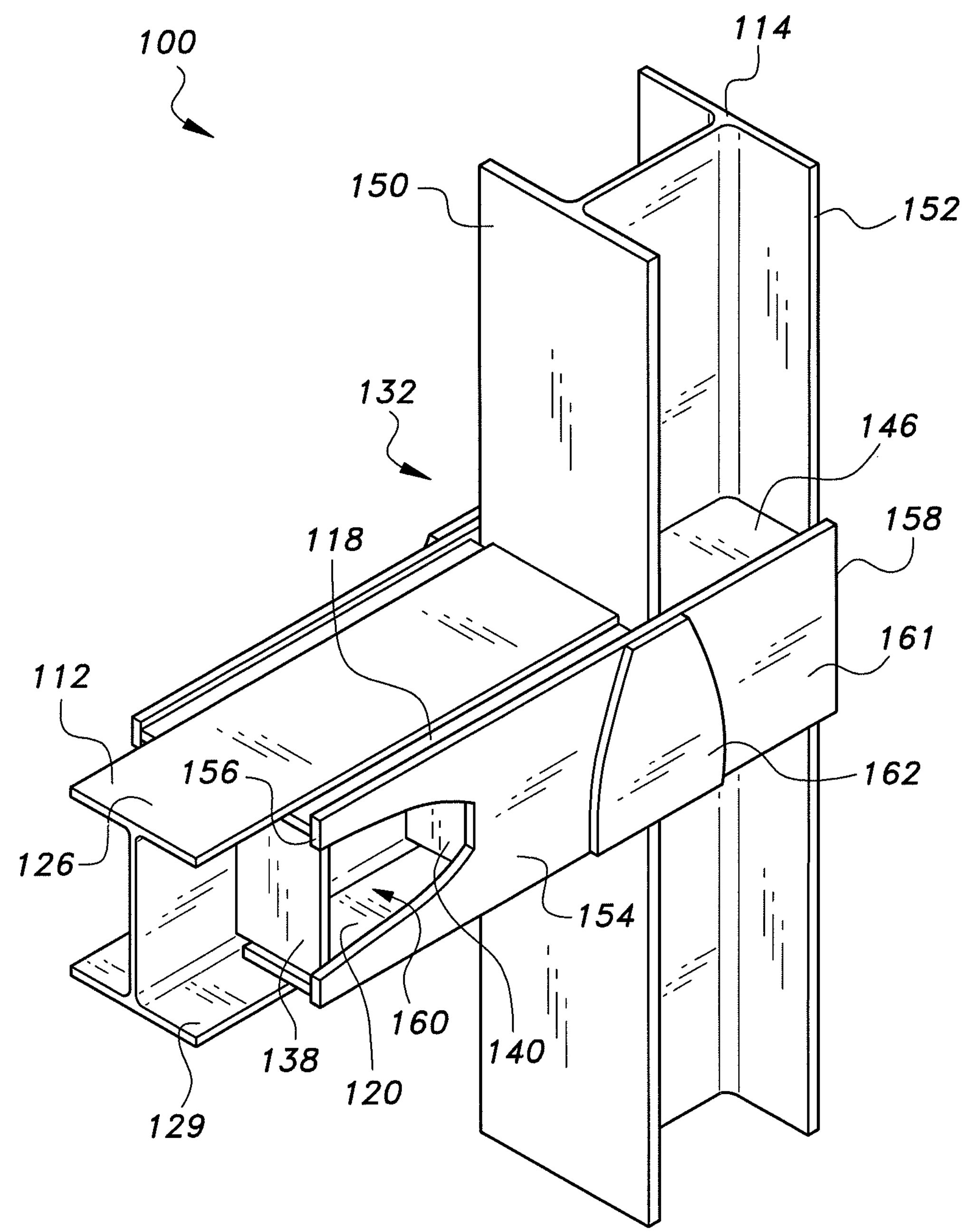
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FIG. 4

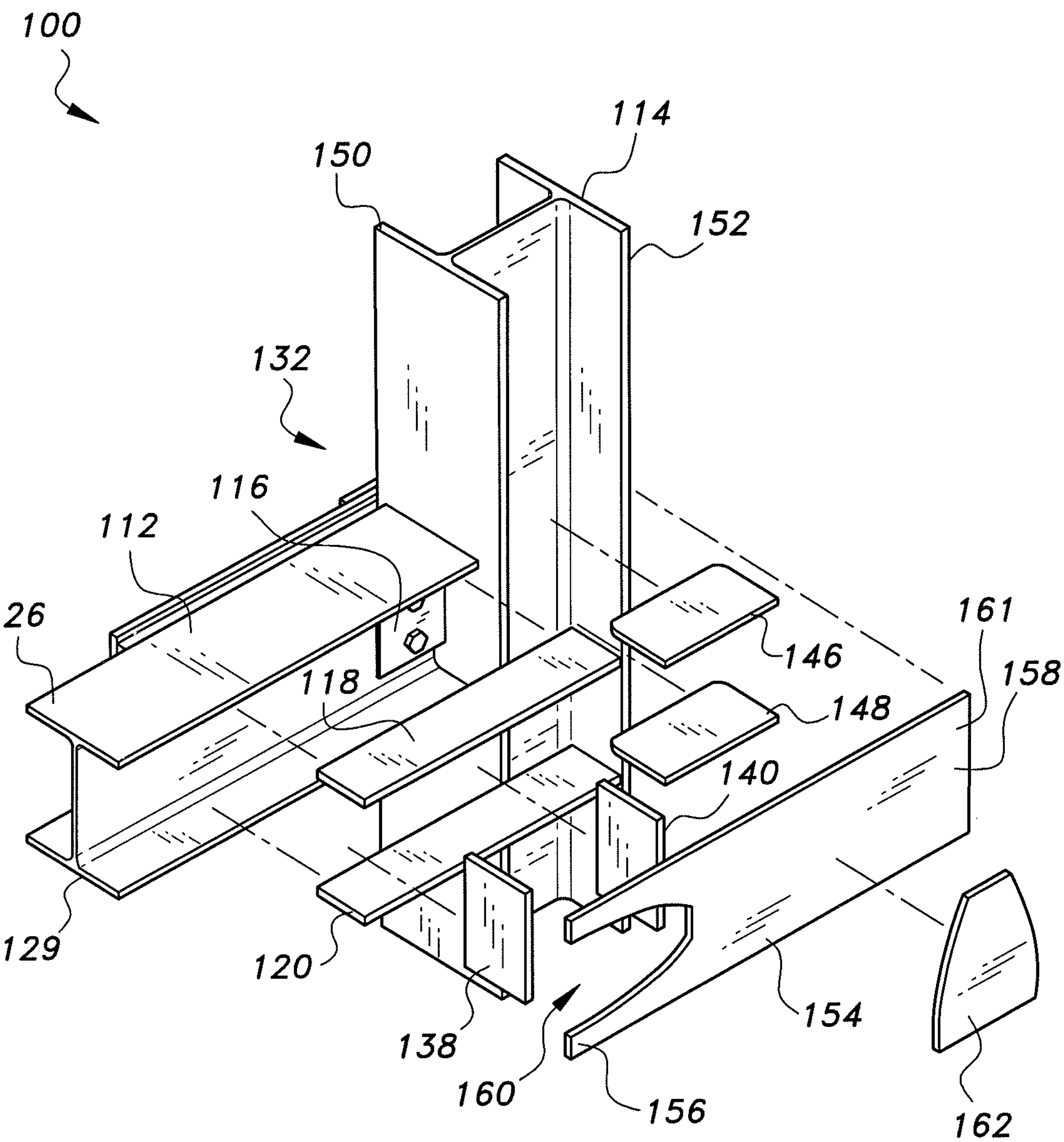
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FIG. 5

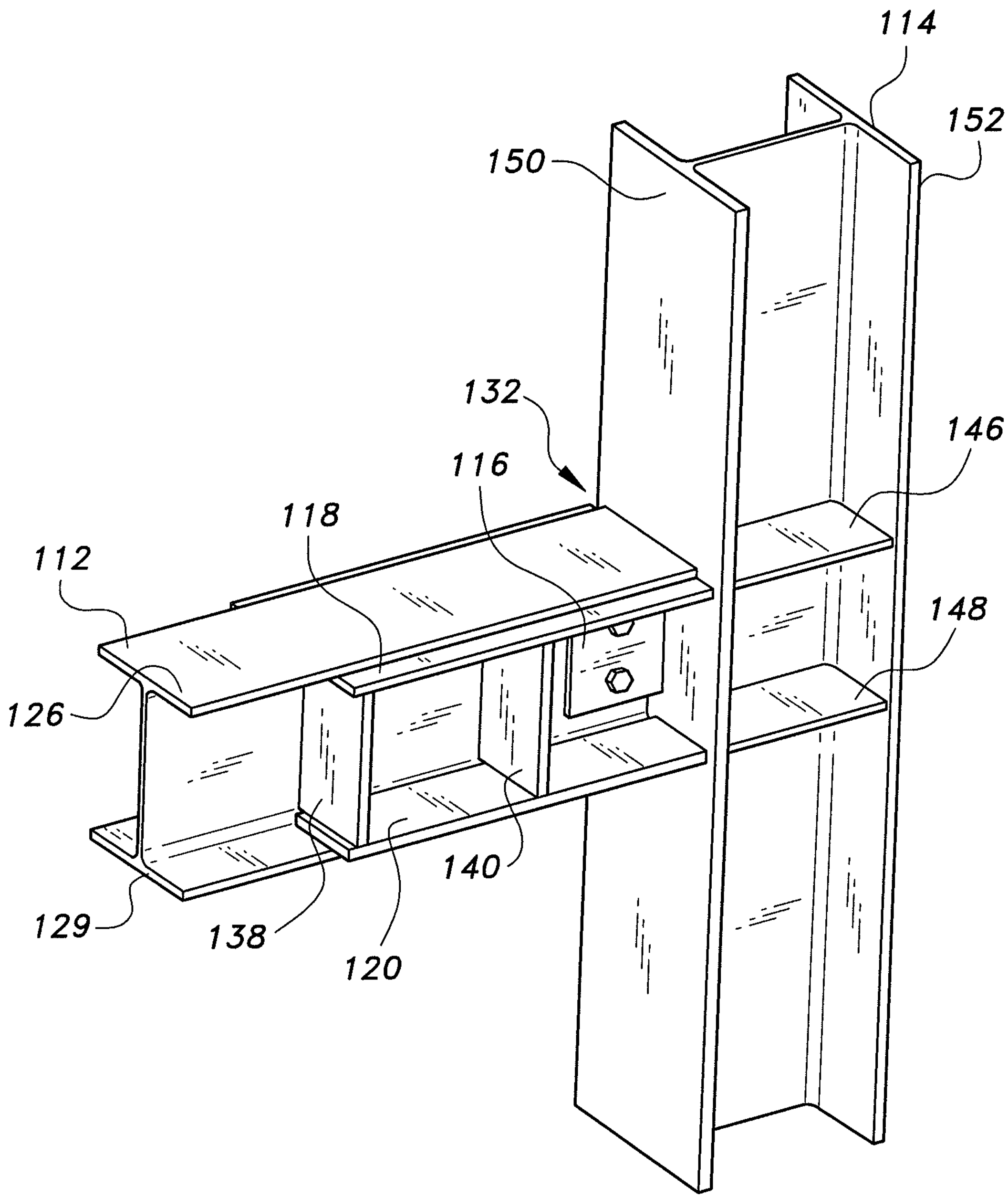

FIG. 6

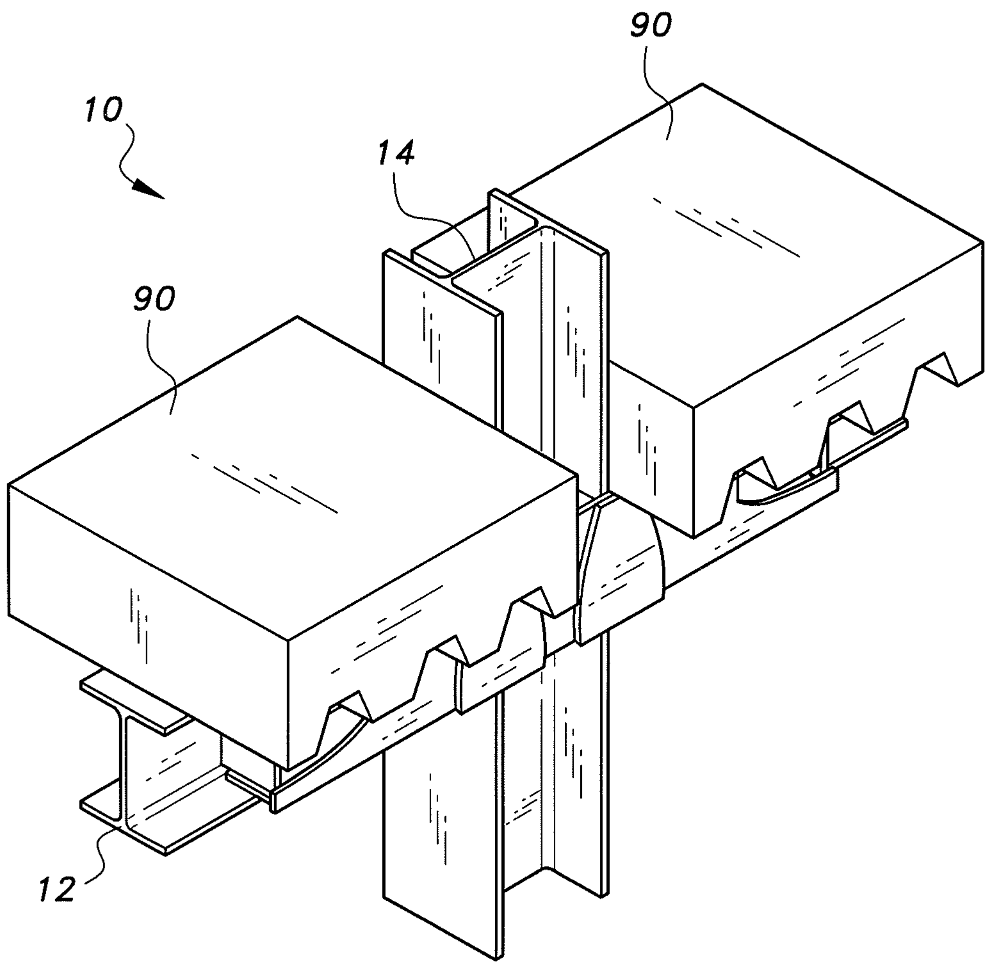

FIG. 7

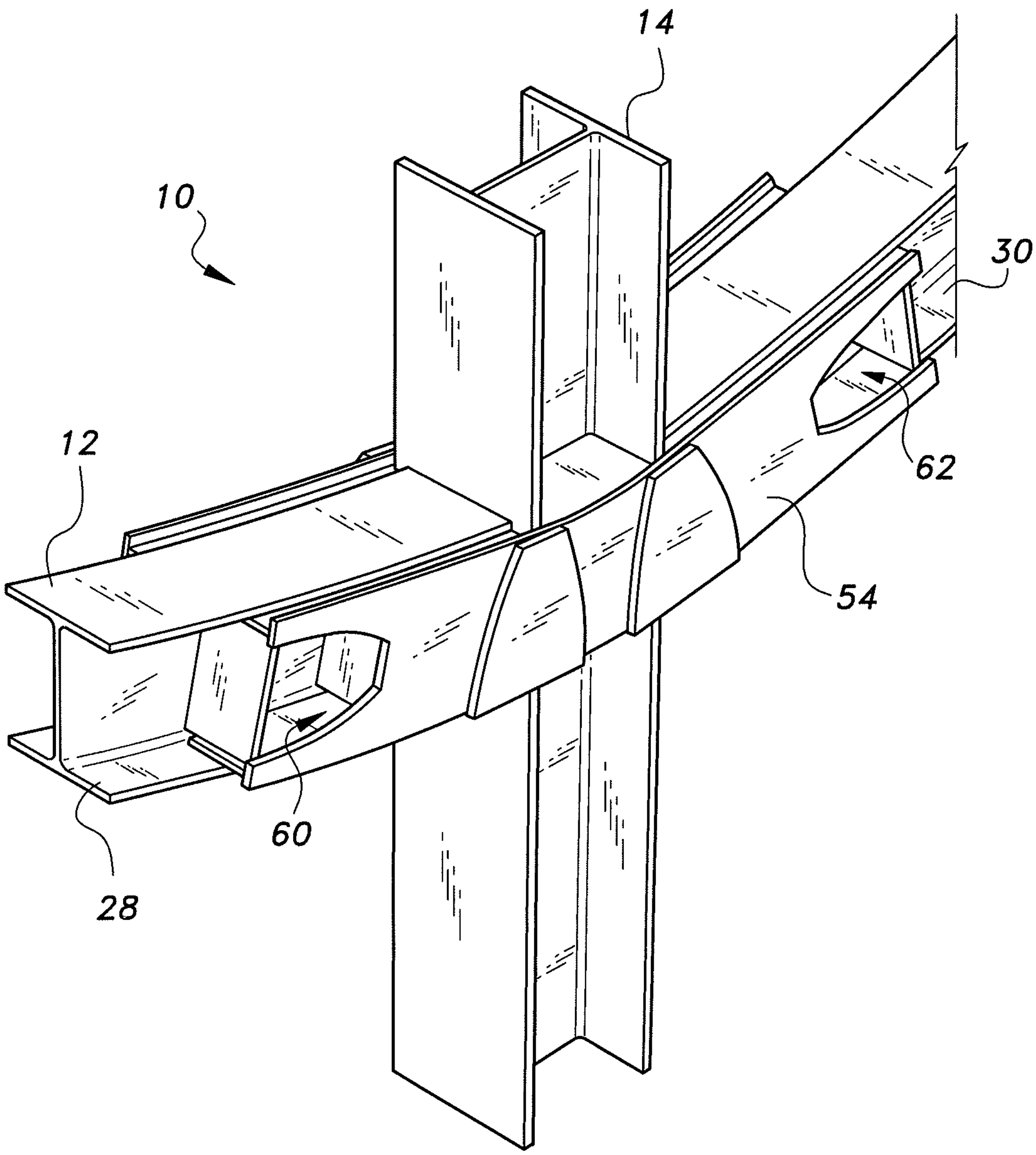

FIG. 8

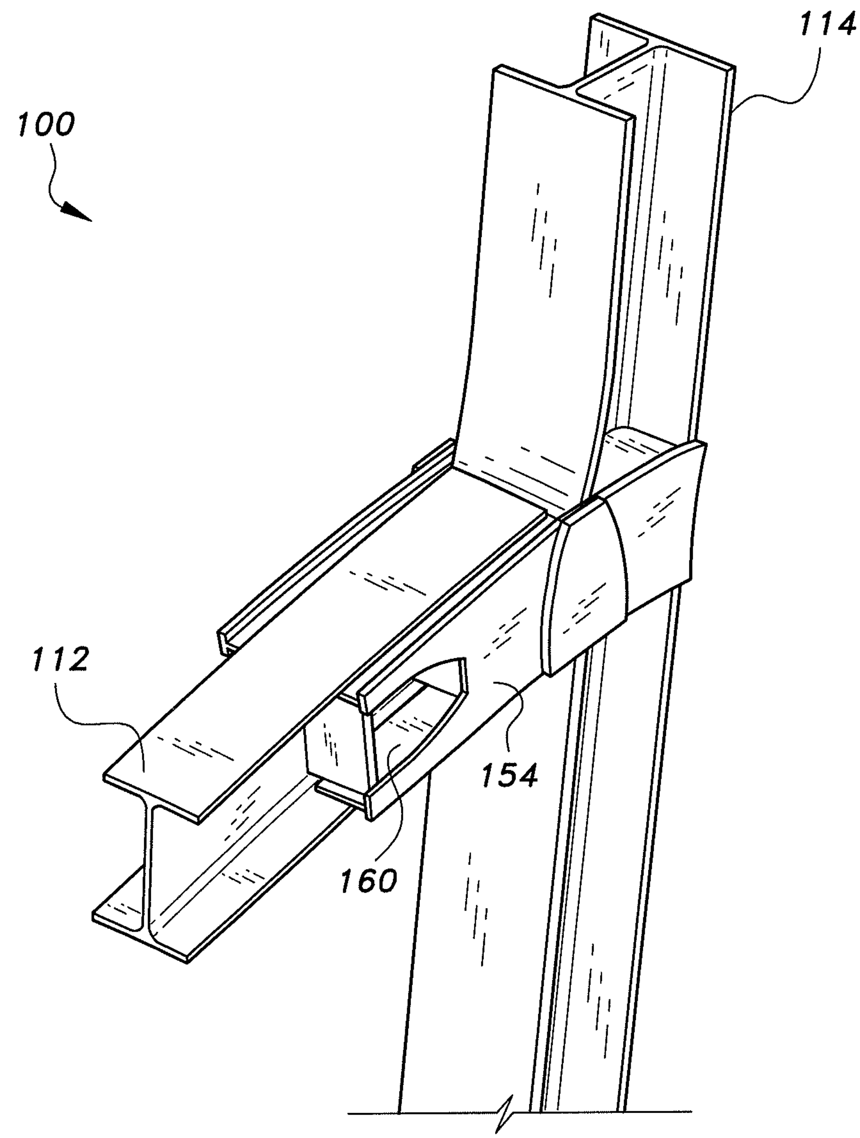

FIG. 9

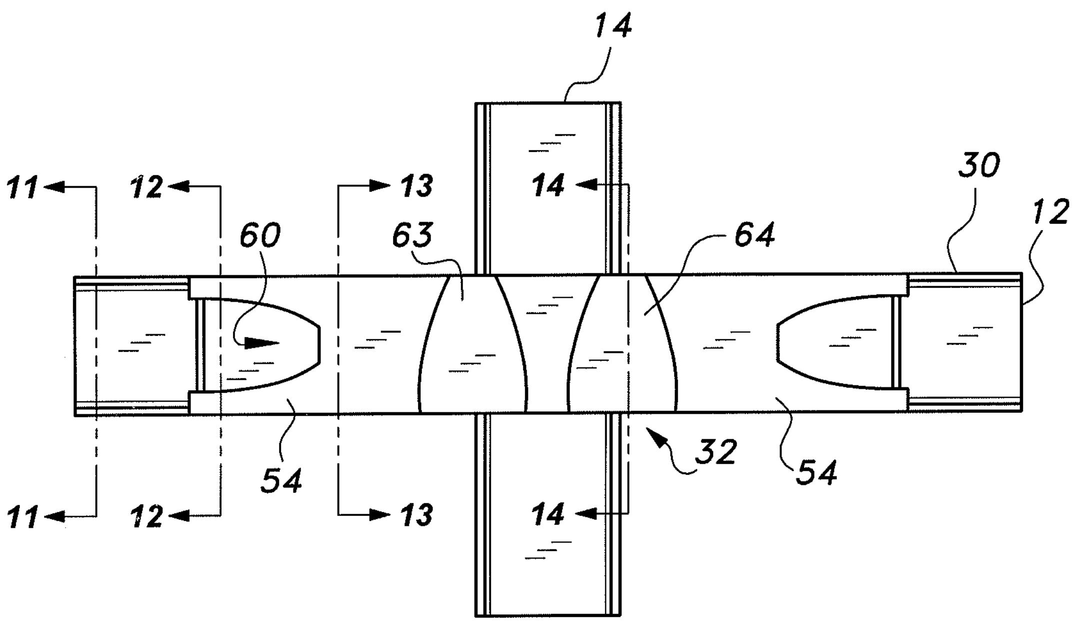

FIG. 10

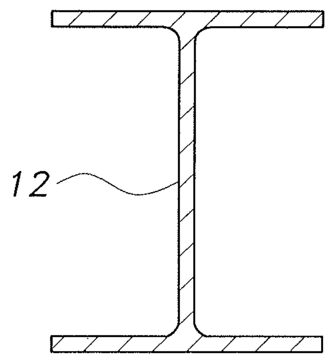

FIG. 11

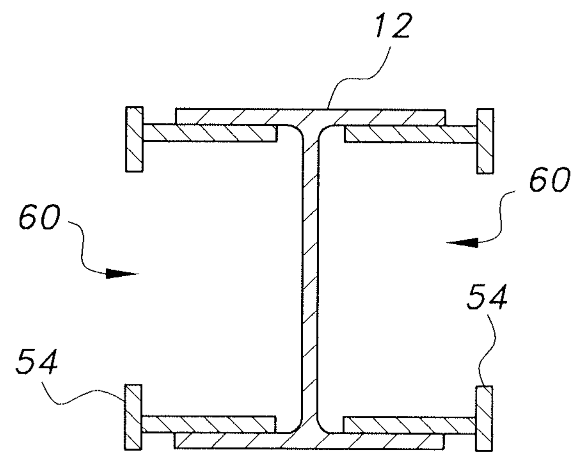

FIG. 12

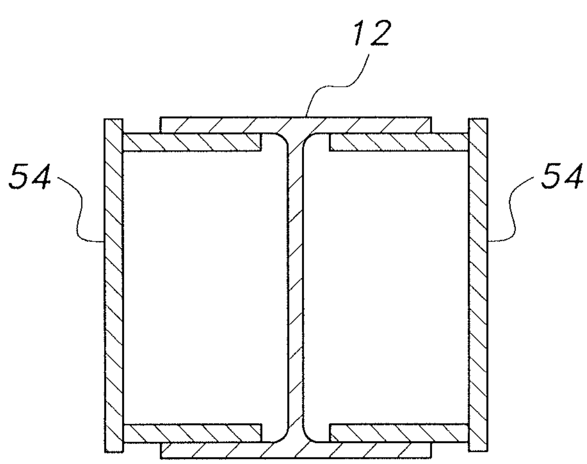

FIG. 13

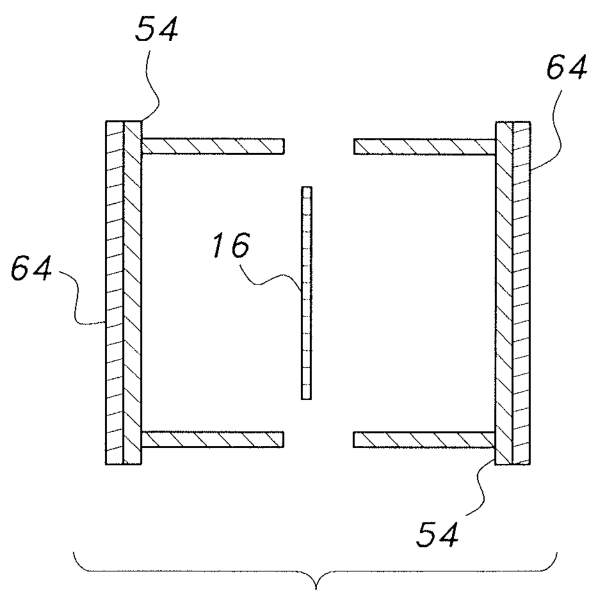

FIG. 14

REINFORCED JOINT FOR BEAM-COLUMN CONNECTION

BACKGROUND

1. Field

The disclosure of the present patent application relates to structural joints, and particularly to a reinforced joint for beam-column connection in a steel frame building that uses steel plates welded in the area about the beam-column connection to develop catenary action in the beams in the event of column failure.

2. Description of the Related Art

Building frames, such as typical steel building frames, are often exposed to extreme load events, such as those caused by large wind forces, earthquakes, vehicle crashes and blast loads. The ability of steel to yield under external forces is one of the reasons that steel is seen as an ideal building material for structural frames. However, steel buildings are still susceptible to progressive collapse under extreme conditions due to exposure to blast loads. The performance of steel-framed buildings primarily depends on the behavior of the frame's beam-column joints. The properties of the joints are crucial in a steel-framed building, since they determine the constructability, stability, strength, flexibility, residual forces, and ductility of the overall structure.

Progressive collapse is the propagation of an initial local failure from one part of the building to the adjoining parts, resulting in the eventual collapse of the entire building, or at least large parts thereof. In order to resist progressive collapse of buildings, the "alternate path" method is typically employed in the design. In this method, alternate paths are available for load transfer if one critical component, such as a column, fails, thus preventing progressive collapse. If a column of a building frame fails (due to a blast or seismic forces, for example), steel-framed buildings should have well-defined redundancies so that alternative load paths are available via the formation of catenary action. Unfortunately, effective alternative load paths via catenary action are frequently lacking in present building designs.

Thus, a reinforced joint for beam-column connection solving the aforementioned problems is desired.

SUMMARY

The reinforced joint for a beam-column connection is provided for improving the resistance of steel-framed buildings against progressive collapse, such as may be caused by damage to one or more columns as a result of exposure to blast loads or other extreme loads. In one embodiment, in which the reinforced joint for a beam-column connection is used as an internal joint in the building frame, first upper and lower flange stiffening plates are respectively attached to inner faces of the upper and lower flanges of a first structural beam (as well as being connected to a column flange). Similarly, second upper and lower flange stiffening plates are respectively attached to inner faces of upper and lower flanges of a second structural beam (as well as being connected to an opposed column flange), where the first and second structural beams extend in opposite directions from a column at the center of a connection joint between the first and second structural beams and the column.

At least one first beam web stiffener is attached to and extends between the first upper and lower flange stiffening plates, and at least one second beam web stiffener is attached to and extends between the second upper and lower flange stiffening plates. Upper and lower column web stiffeners are also attached to and extend between first and second flanges of the structural column. The upper and lower column web stiffeners are respectively aligned with the first and second upper flange stiffening plates and with the first and second lower flange stiffening plates. A cover stiffening plate is attached to the upper and lower column web stiffeners, the first and second upper flange stiffening plates, and the first and second lower flange stiffening plates. The cover stiffening plate extends between the at least one first beam web stiffener and the at least one second beam web stiffener.

In an alternative embodiment, in which the reinforced joint for a beam-column connection is used as an external joint in the building frame, upper and lower flange stiffening plates are respectively attached to inner faces of upper and lower flanges of a structural beam. The upper and lower flange stiffening plates are positioned adjacent a connection joint between the structural beam and a structural column. At least one beam web stiffener is attached to, and extends between, the upper and lower flange stiffening plates.

Additionally, upper and lower column web stiffeners are attached to and extend between first and second flanges of the structural column. The upper and lower column web stiffeners are aligned with the upper and lower flange stiffening plates, respectively. A cover stiffening plate is attached to the upper and lower column web stiffeners and the upper and lower flange stiffening plates. The cover stiffening plate extends between the at least one beam web stiffener and the second flange of the structural column. The stiffeners and stiffening plates are preferably attached to the corresponding flanges and web by welding.

These and other features of the present disclosure will become readily apparent upon further review of the following specification and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partial perspective view of a reinforced joint for beam-column connection for an interior beam-column joint in a steel frame building.

FIG. **2** is a partially exploded perspective view of the reinforced joint of FIG. **1**.

FIG. **3** is a partial perspective view of the reinforced joint of FIG. **1**, shown without the longitudinal cover plate.

FIG. **4** is a partial perspective view of a reinforced joint for beam-column connection for an exterior beam-column joint in a steel frame building.

FIG. **5** is a partially exploded perspective view of the reinforced joint of FIG. **4**.

FIG. **6** is a partial perspective view of the reinforced joint of FIG. **4**, shown without the longitudinal cover plate.

FIG. **7** is an environmental partial perspective view of the reinforced joint of FIG. **1**, shown with the beams supporting slabs of reinforced concrete.

FIG. **8** is a partial perspective view of the reinforced joint of FIG. **1**, shown in use during progressive collapse.

FIG. **9** is a partial perspective view of the reinforced joint of FIG. **4**, shown in use during progressive collapse.

FIG. **10** is a front view of the reinforced joint of FIG. **1**.

FIG. **11** is a section view along lines **11-11** of FIG. **10**.

FIG. **12** is a section view along lines **12-12** of FIG. **10**.

FIG. **13** is a section view along lines **13-13** of FIG. **10**.

FIG. **14** is a section view along lines **14-14** of FIG. **10**.

Similar reference characters denote corresponding features consistently throughout the attached drawings.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. **1-3**, a reinforced joint for beam-column connection **10** is provided for improving the resistance of steel-framed buildings against progressive collapse, such as may be caused by damage to one or more columns as the result of exposure to blast loads or other extreme loads. In FIGS. **1-3**, the reinforced joint for a beam-column connection **10** is used as an internal joint in the building frame. As shown, first upper and lower flange stiffening plates **18**, **20** are attached to inner faces of upper and lower flanges **26**, **29**, respectively, of a first structural beam **28** of a set **12** of structural beams. The first upper and lower flange stiffening plates **18**, **20** may be welded to the inner faces of the upper and lower flanges **26**, **29** of the first structural beam **28**. The set **12** of structural beams also includes a second structural beam **30**. Second upper and lower flange stiffening plates **22**, **24** are attached to inner faces of upper and lower flanges **34**, **36**, respectively, of the second structural beam **30**. The second upper and lower flange stiffening plates **22**, **24** may be welded to the inner faces of the upper and lower flanges **34**, **36** of the second beam **30**. As shown, the first and second structural beams **28**, **30**, respectively, of the set **12** of structural beams extend in opposite directions from a column **14** at the center of a connection joint **32** between the first and second structural beams **28**, **30** and the column **14**. It will be understood that the column **14** and the beams **28**, **30** are not drawn to scale in the drawings, but each have a much greater length, the stiffening plates **18**, **20**, **22**, **24** only being attached to the column **14** and beams **28**, **30** in the region immediately adjacent the beam-column joint **32**.

Each of the flange stiffening plates **18**, **20**, **22**, **24** may have a length of k D_b+g, a width of $(B_{f,c}-_{wr,b})/2$ and a thickness greater than or equal to $t_{f,b}$, where k=2 to 2.5, D_b is the depth of each of the structural beams of set **12**, g is the gap between the end of each of the structural beams of set **12** and the face of the structural column **14**, $B_{f,c}$ is the width of the flanges of the structural column **14**, $t_{w,b}$ is the thickness of the web of each of the structural beams of set **12**, and $t_{f,b}$ is the thickness of each flange of each of the structural beams of set **12**. Each of the flange stiffening plates **18**, **20**, **22**, **24** may have chamfered or filleted corners. Further, each of the flange stiffening plates **18**, **20**, **22**, **24** may be formed from steel or the like. Additionally, it should be understood that the connection between the first and second structural beams **28**, **30** and structural column **14** shown in FIGS. **1-3** is shown for exemplary purposes only, and that the reinforced joint **10** may be applied to any suitable type of beam-joint connection, such as, but not limited to, simple (i.e., pinned) connections, semi-rigid connections, and moment connections.

In reference to FIGS. **1-3**, the reinforced joint **10** is shown and described with respect to only the front side of the joint **32** between the first and second structural beams **28**, **30** and structural column **14** (i.e., the side facing the viewer in the orientation of FIGS. **1-3**). It should be understood that this is for purposes of illustration and simplifying the drawings only, and that an identical structure is also mounted on the rear side of the joint **32**. Further, it should be understood that for purposes of illustration and clarity, FIG. **3** does not include cover stiffening plate **54** (shown in FIGS. **1** and **2**). FIG. **7** illustrates the reinforced joint for a beam-column connection **10** in use, with the set of structural beams **12** being shown supporting slabs of reinforced concrete **90**. It should be understood that the slabs of reinforced concrete **90** are shown for exemplary purposes only.

As shown in FIGS. **2** and **3**, the first upper and lower flange stiffening plates **18**, **20** are positioned adjacent the structural column **14** on the first structural beam **28**, and the second upper and lower flange stiffening plates **22**, **24** are positioned adjacent the structural column **14** on the second structural beam **30**. As best seen in FIGS. **2** and **3**, each set of upper and lower flange stiffening plates may be placed adjacent and contiguous to a corresponding shear plate **16**. The shear plates **16** are typically bolted to the beams **28**, **30** on either side of the structural column **14** in a conventional, non-reinforced beam-column joint. Each of the flange stiffening plates **18**, **20**, **22**, **24** is attached by welding or the like to one of the corresponding flanges **50**, **52** of structural column **14**.

As discussed above, although the reinforced joint **10** is only described above with reference to the structure on one side of joint **32**, this is solely for purposes of simplification and illustration and, in practice, an identical structure is formed on the rear side of joint **32**. Thus, as an alternative, the upper flange stiffening plates **18**, **22** may each be replaced by wider plates mounted on the exterior faces of flanges **26**, **34**, extending across the entire width of each flange. Similarly, the lower flange stiffening plates **20**, **24** may each be replaced by wider plates mounted on the exterior faces of flanges **29**, **36**, extending across the entire width of each flange. The width of each of these alternative plates would match the width of the flanges **50**, **52** of structural column **14**. As a further alternative, both interior and exterior flange stiffening plates may be used in combination.

At least one first beam web stiffener is secured to, and extends between, the first upper and lower flange stiffening plates **18**, **20**, and at least one second beam web stiffener is secured to, and extends between, the second upper and lower flange stiffening plates **22**, **24**. In FIGS. **2** and **3**, two such first beam web stiffeners **38**, **40** and two such second beam web stiffeners **42**, **44** are shown, although it should be understood that any suitable number of beam web stiffeners may be used. Web stiffeners **38**, **40**, **42**, **44** may be welded to their respective flange stiffening plates. As shown, each of first beam web stiffeners **38**, **40** preferably extends orthogonally with respect to the first upper and lower flange stiffening plates **18**, **20**. Similarly, each of second beam web stiffener **42**, **44** preferably extends orthogonally with respect to the first upper and lower flange stiffening plates **22**, **24**. Each of the web stiffeners **38**, **40**, **42**, **44** may have a length of $D_b-2t_{f,b}-2t$, a width of $(B_{f,c}-t_{w,b})/2$ and a thickness of t, where D_b is the depth of each beam of the set of structural beams **12**, $B_{f,c}$ is the width of the flanges of structural column **14**, and $t_{w,b}$ is the thickness of the web of each beam of the set of structural beams **12**. D_b is taken as the depth measured between the outer faces of the beam flanges. Further, each of the web stiffeners **38**, **40**, **42**, **44** may be formed from steel or the like.

Upper and lower column web stiffeners **46**, **48**, respectively are also attached to and extend between first and second flanges **50**, **52**, respectively, of the structural column **14**. The upper and lower column web stiffeners **46**, **48** may be welded to first and second flanges **50**, **52**. The upper and lower column web stiffeners **46**, **48** are respectively aligned with and coplanar to the first and second upper flange stiffening plates **18**, **22** and with and coplanar to the first and second lower flange stiffening plates **20**, **24**. Each of the column web stiffeners **46**, **48** may have a length of $D_c-2t_{f,c}$, a width of $(B_{f,c}-t_{w,b})/2$ and a thickness of t, where D_c is the depth of structural column **14**, $B_{f,c}$ is the width of the flanges of structural column **14**, and t is the thickness of the web stiffeners **38**, **40**, **42**, **44**. Further, each of the column web stiffeners **46**, **48** may be formed from steel or the like.

A longitudinal cover stiffening plate **54** is attached to the upper and lower column stiffeners **46**, **48**, the first and second upper flange stiffening plates **18**, **22**, and the first and second lower flange stiffening plates **20**, **24** by welding or the like. The cover stiffening plate **54** extends between the at least one first beam web stiffener and the at least one second beam web stiffener. In the exemplary embodiment of FIGS. **1-3**, in which two beam web stiffeners **38**, **40** are mounted on the first structural beam **28**, and two beam web stiffeners **42**, **44** are mounted on the second structural beam **30**, the cover stiffening plate **54** extends between the two outermost beam web stiffeners **38**, **44**. The cover stiffening plate **54** may have a length of $2(kD_b+g)+D_c$, a width of D_b, and a thickness oft, where k=2 to 2.5, D_b is the depth of each beam of the set of structural beams **12**, D_c is the depth of structural column **14**, and t is the thickness of the web stiffeners **38**, **40**, **42**, **44** and the column web stiffeners **46**, **48**. The cover stiffening plate **54** may be formed from steel or the like. Thus, for an interior joint, the cover stiffening plate **54** extends across the column **14** of the beam-column joint **32**, and is indirectly attached to the beams **28**, **30** on opposite sides of the joint by welding to the corresponding stiffeners.

As shown in FIGS. **1** and **2**, the cover stiffening plate **54** may have truncated semi-elliptical recesses **60**, **62** formed in opposed first and second ends **56**, **58** thereof. The recesses **60**, **62** expose the two outermost beam web stiffeners **38**, **44**, and the two innermost beam web stiffeners **40**, **42** being covered. The recesses **60**, **62** are provided to avoid sudden changes in the moment of inertia of the set of structural beams **12**. Additionally, first and second recesses **60**, **62** are helpful for welding the flange stiffening plates and the beam web stiffeners with the cover stiffening plate in the accessible zone during installation.

Further, as shown, at least one exterior stiffening plate may be secured to an exterior face **61** of the cover stiffening plate **54** opposite the column flanges by welding or the like. In FIGS. **1** and **2**, two such exterior stiffening plates **63**, **64** are shown. However, it should be understood that any suitable number of exterior stiffening plates may be used. Each exterior stiffening plate **63**, **64** may have a semi-elliptical contour. The exterior stiffening plates **63**, **64** may be the material removed from the cover stiffening plate **54** during the formation of recesses **60**, **62**, thus recycling waste material into material useful for providing additional strengthening to the connection joint. Each of the exterior stiffening plates may have a length of D_b, a minor elliptical diameter of $0.8D_b$ to $0.9D_b$, and a thickness equal to that of the web stiffeners **38**, **40**, **42**, **44** and the column web stiffeners **46**, **48**, where D_b is the depth of each beam of the set of structural beams **12**. The width of each exterior stiffening plate at the top may be between 5 cm and 15 cm.

With reference to FIGS. **10-14**, FIG. **11** shows the I-beam cross section of the beams **28**, **30** of the set of structural beams **12**. As discussed above, the reinforced joint **32** is shown in FIG. **10**, and described above, with respect to only one side of the joint **32** between the set of structural beams **12** and structural column **14** (i.e., the front side facing the viewer in the orientation of FIG. **10**). It should be understood that this is for purposes of illustration and simplifying the drawings only, and that an identical structure is also mounted on the rear side of the joint **32**. Thus, FIGS. **11-14** also show portions of this identical structure. FIG. **12** is a section view taken within the region of the recess **60** of the cover stiffening plate **54**. FIG. **13** is a section view taken within the solid portion of the cover stiffening plate **54**. FIG. **14** is a section view taken within the gap between the end of the second structural beam **30** and the face of the structural column **14**, showing one of the flange stiffening plates **16**, also shown in FIG. **2**.

Table 1, below, shows the enhancement of the moment of inertia and shear area in each of these regions, before reinforcement (i.e., without the reinforced joint **10**) and with reinforcement (i.e., with the reinforced joint **10**). In Table 1, I_b is the moment of inertia of each beam of the set **12** of structural beams, A_w is the shear area of each beam of the set **12** of structural beams, and α and β are the moment and shear enhancement factors, respectively. As can be seen in Table 1, the shear capacity is more than doubled in the connection zone. The increase in moment of inertia causes a proportionate increase in the elastic moment of resistance. However, the enhancement in the ultimate moment of resistance will be much higher due to the presence of strain hardening in the stress-strain behavior of steel beams. The enhancement in the moment and shear capacity of the joint not only helps to increase the load-resisting capacity of the frame, but also helps in the development of the catenary mechanism in the event of column loss, thereby enhancing the progressive collapse resistance of the frame.

TABLE 1

Enhancement in Moment of Inertia and Shear Area in the Connection Zone

	Moment of Inertia = αI_b		Shear Area = βA_w	
Region of Connection Zone	Before reinforcement	After reinforcement	Before reinforcement	After reinforcement
Section 11-11, FIG. 11	$\alpha = 1$	$\alpha = 1$	$\beta = 1$	$\beta = 1$
Section 12-12, FIG. 12	$\alpha = 1$	$\alpha > 2$	$\beta = 1$	$\beta > 1$ to $\beta > 3$
Section 13-13, FIG. 13	$\alpha = 1$	$\alpha > 2$	$\beta = 1$	$\beta > 3$
Section 14-14, FIG. 14	$\alpha = 0$	$\alpha > 1$	$\beta \approx 1$	$\beta > 2$

FIGS. **4-6** show a reinforced joint for a beam-column connection **100** that is used as an external joint in the building frame. The upper and lower flange stiffening plates **118**, **120** are attached to inner faces of the upper and lower flanges **126**, **129**, respectively, of structural beam **112**, e.g., by welding. The upper and lower flange stiffening plates **118**, **120** are positioned adjacent a connection joint **132** between the structural beam **112** and a structural column **114**. In reference to FIGS. **4-6**, the reinforced joint **100** is shown and described with respect to only the front side of the joint **132** between the structural beam **112** and the structural column **114** (i.e., the side facing the viewer in the orientation of FIGS. **4-6**). It should be understood that this is for purposes of illustration and simplifying the drawings only, and that an identical structure is also mounted on the rear side of the joint **132**. Further, it should be understood that for purposes of illustration and clarity, FIG. **6** does not include the longitudinal cover stiffening plate **154** (shown in FIGS. **4** and **5**). Each of the flange stiffening plates **118**, **120** may have a length of $k\,D_b+g$, a width of $(B_{f,c}-t_{w,b})/2$ and a thickness greater than or equal to $t_{f,b}$, where k=2 to 2.5, D_b

is the depth of structural beam **112**, g is the gap between the end of structural beam **112** and the face of structural column **114**, $B_{f,c}$ is the width of the flanges of structural column **114**, and $t_{w,b}$ is the thickness of the web of structural beam **112**. Each of the flange stiffening plates **118**, **120** may have chamfered or filleted corners. Further, each of the flange stiffening plates **118**, **120** may be formed from steel or the like.

As shown in FIGS. **4** and **6**, the upper and lower flange stiffening plates **118**, **120** may have respective widths greater than widths of the upper and lower flanges **126**, **129** of the structural beam **12**. Thus, the upper and lower flange stiffening plates **118**, **120** extend beyond the upper and lower flanges **126**, **129** of the structural beam **112**. At least one beam web stiffener is attached to and extends between the upper and lower flange stiffening plates **118**, **120**. FIGS. **5** and **6** show a pair of such beam web stiffeners **138**, **140**, although it should be understood that any suitable number of beam web stiffeners may be used. As shown, the beam web stiffeners **138**, **140** preferably extend orthogonally with respect to the upper and lower flange stiffening plates **118**, **120**. Each of the web stiffeners **138**, **140** may have a length of $D_b-2_{f,b}-2t$, a width of $(B_{f,c}-t_{w,b})/2$ and a thickness of t, where D_b is the depth of structural beam **112**, $B_{f,c}$ is the width of the flanges of structural column **114**, $t_{f,b}$ is the thickness of the flange of structural beam **112**, and $t_{w,b}$ is the thickness of the web of structural beam **112**. Further, each of the web stiffeners **138**, **140** may be formed from steel or the like.

Additionally, upper and lower column web stiffeners **146**, **148** are attached to and extend between the first and second flanges **150**, **152** of the structural column **114**. The upper and lower column web stiffeners **146**, **148** are aligned with and coplanar to the upper and lower flange stiffening plates **118**, **120**, respectively. Each of the column web stiffeners **146**, **148** may have a length of $D_c-2t_{f,c}$, a width of $(B_{f,c}-t_{w,b})/2$ and a thickness of t, where D_c is the depth of structural column **114**, $B_{f,c}$ is the width of the flanges of structural column **114**, $t_{f,c}$ is the thickness of the flange of structural column **114**, $t_{w,b}$ is the thickness of the web of structural beam **112** and t is the thickness of the web stiffeners **138**, **140**. Further, each of the column web stiffeners **146**, **148** may be formed from steel or the like.

A longitudinal cover stiffening plate **154** is attached to the upper and lower column stiffeners **146**, **148** and the upper and lower flange stiffening plates **118**, **120**. The cover stiffening plate **154** extends between the at least one beam web stiffener and the second flange **152** of the structural column **114**. In the exemplary embodiment of FIGS. **4-6**, the cover stiffening plate **154** extends between the outermost beam web stiffener **138** and second flange **152**, i.e., the longitudinal cover stiffening plate **154** extends across the beam-column joint **132**.

As shown in FIGS. **4** and **5**, the longitudinal cover stiffening plate **154** may have a truncated semi-elliptical recess **160** formed in a first end **156** thereof. The first end **156** is positioned opposite a second end **158**, which is mounted adjacent the second flange **152** of the structural column **114**. The recess **160** may expose the outermost beam web stiffener **138**, and the innermost beam web stiffener **140** being covered. Further, at least one exterior stiffening plate **162** may be attached to an exterior face **161** of the cover stiffening plate **154**. The exterior stiffening plate **162** may be a semi-elliptical, and may be formed from the material removed to defing the recess **160**. Unlike the previous embodiment, the cover stiffening plate **154** may have a length of $(k\,D_b+g)+D_c$, a width of D_b, and a thickness of t, where k=2 to 2.5, D_b is the depth of structural beam **112**, g is the gap between the end of structural beam **112** and the face of structural column **114**, D_c is the depth of structural column **14**, and t is the thickness of the web stiffeners **138**, **140** and the column web stiffeners **146**, **148**.

FIGS. **8** and **9** show the reinforced joints **10**, **100**, respectively, in use during progressive collapse. As shown, the reinforced joints **10**, **100** provide alternative load transfer paths during progressive collapse, and further aid in the development of catenary action in the beams **12**, **112**, respectively, connected to the joint of the damaged column **14**, **114**, respectively. As shown in FIG. **8**, the catenary action develops due to the connection of the two sides **28**, **30** of structural beam **12** through the longitudinal cover stiffening plate **54**. The longitudinal cover stiffening plate **154** in FIG. **9** performs a similar function with regard to structural beam **112**. These cover stiffening plates **54**, **154** also enhance the shear capacity of the beams **12**, **112**, respectively. The beam flange stiffening plates **18**, **20**, **22**, **24** of reinforced joint **10** and the beam flange stiffening plates **118**, **120** of reinforced joint **100** help in improving the moment of resistance, whereas the beam web and column web stiffeners **38**, **40**, **42**, **44**, **46**, **48** of reinforced joint **10** and **138**, **140**, **146**, **148** of reinforced joint **100** help in resisting the buckling of the respective beam and column webs. The recesses **60**, **62** in cover stiffening plate **54** and recess **160** in cover stiffening plate **154** not only help in welding the otherwise inaccessible areas of reinforced joints **10**, **100**, but also provide a smooth transition in the enhancement of the moment resisting capacity in the connection region.

It is to be understood that the beam-column connections for steel framed buildings is not limited to the specific embodiments described above, but encompasses any and all embodiments within the scope of the generic language of the following claims enabled by the embodiments described herein, or otherwise shown in the drawings or described above in terms sufficient to enable one of ordinary skill in the art to make and use the claimed subject matter.

We claim:

1. A reinforced joint for a beam-column connection of a steel frame structure, comprising:

a steel column having a pair of spaced flange plates and a web plate joining the spaced flange plates, the column having an I-shape in section, the web plate having a front face and a rear face defining a front and a rear of the joint, the column extending vertically;

a first beam and a second beam connected to and extending normal from the column, the second beam extending from the column opposite the first beam, the beam-column connection being an interior beam-column joint in a steel frame structure, each of the beams having a pair of spaced flange plates and a web plate joining the spaced flange plates, each of the beams having an I-shape in section, wherein each of the spaced flange plates have inner faces and outer faces, the web plate having a front face and a rear face, the column and the first and second beams defining a beam-column connection;

on both the front and the rear of the joint, an upper flange stiffening plate and a lower flange stiffening plate attached directly to the inner faces of each of the flange plates of each of the beams, respectively, adjacent to the web plate of the beams and adjacent to the beam-column connection so that the upper and lower flange stiffening plates face each other;

at least one web stiffening plate attached to and extending between the upper and lower flange stiffening plates and extending normal to the web plate of each of the beams;

an upper web stiffening plate and a lower web stiffening plate attached to and extending between the flanges of the column, the upper web stiffening plate being coplanar with the upper flange stiffening plate of each beam and the lower web stiffening plate being coplanar with the lower flange stiffening plate of each beam; and

a longitudinal cover stiffening plate extending across the flanges of the column and attached to and covering edges of the web stiffening plates of the column and edges of the flange stiffening plates of the first and second beams.

2. The reinforced joint according to claim **1**, wherein said at least one web stiffening plate of each said beam comprises a first web stiffening plate disposed adjacent said column and a second, outermost web stiffening plate, said longitudinal cover stiffening plate having a length extending at least as far as the outermost web stiffening plate of each of said beams.

3. The reinforced joint according to claim **1**, wherein said longitudinal cover stiffening plate extends across the flanges of the column and is attached to and covers edges of the web stiffening plates of the column and edges of the flange stiffening plates of both the first beam and the second beam.

4. The reinforced joint according to claim **1**, wherein said longitudinal cover stiffening plate has opposing ends, each of the ends having a semi-elliptical recess defined therein.

5. The reinforced joint according to claim **1**, wherein said longitudinal cover stiffening plate has an external surface, the reinforced joint further comprising first and second external stiffening plates attached to the external surface of said longitudinal cover stiffening plate opposite the flanges of said column, respectively.

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