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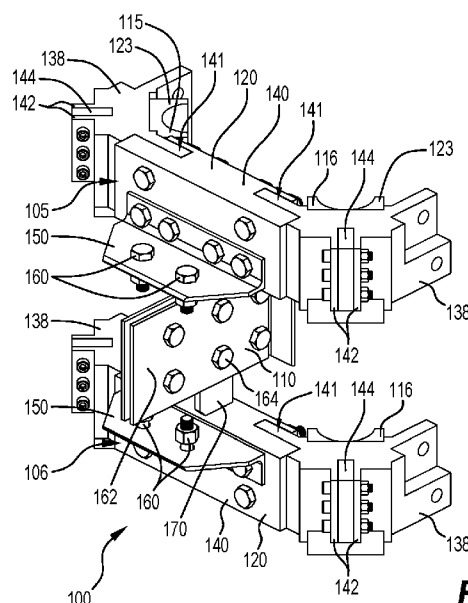


Figure 1

(57) Abstract: A connection arrangement for connecting a cross-member to a vertical member comprising: at least one pair of spaced apart mounting fixtures, each mounting fixture being securable to a vertical member at a selected height spaced apart from the adjoining mounting fixture of the pair of spaced apart mounting fixtures, each mounting fixture including a support engagement formation; and at least one cross-support configured to be secured between a pair of spaced apart mounting fixtures, the cross-support including at least two mount engagement formations which are configured to cooperatively engage with the support engagement formations of the respective pair of spaced apart mounting fixtures to mount the cross-support onto the respective mounting fixture, the cross-support also including a beam securing formation for securing a portion of a cross-member to the cross-support.

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CONNECTION ARRANGEMENT FOR CONNECTING A CROSS-MEMBER TO A VERTICAL MEMBER

PRIORITY CROSS-REFERENCE

[001] The present application claims priority from Australian Provisional Patent Application No. 2016903472 filed 31 August 2016 the contents of which is to be considered to be incorporated into this specification by this reference.

TECHNICAL FIELD

[002] The present invention generally relates to connection arrangement for connecting a cross-member to a vertical member, such as a beam to a column. The invention is particularly applicable to bi-lateral connection between a beam and a hybrid fabricated column and it will be convenient to hereinafter disclose the invention in relation to that exemplary application. However, it should be appreciated that the connection arrangement could be used to interconnect any type of structural members.

BACKGROUND OF THE INVENTION

[003] The following discussion of the background to the invention is intended to facilitate an understanding of the invention. However, it should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was published, known or part of the common general knowledge as at the priority date of the application.

[004] Moment-resisting frames are rectilinear assemblages of beams and columns, with the beams rigidly connected to the columns. Resistance to lateral forces is provided primarily by rigid frame action-that is, by the development of bending moment and shear force in the frame members and joints. By virtue of the rigid beam-column connections, a moment frame cannot displace laterally without bending the beams or columns depending on the geometry of the connection. The bending rigidity and strength of the frame members is therefore the primary source of lateral stiffness and strength for the entire frame.

[005] A number of innovative fabricated members have been developed during the past two decades. One type of innovative column of interest is a hybrid fabricated column which consists of a rectangular cross-sectioned column comprising four corner steel tubes spaced apart and interconnected by mild steel plates welded at each end to spaced apart pairs of corner tubes, for example as taught in international patent publication No. WO2014/127401A1, the contents of which should be understood to be incorporated into this specification by this reference, and as shown in Figure 3. The column face could be flat or corrugated which in both cases is made of thin plates (Figure 3 and 9(a)). This type of hybrid fabricated column benefits from the ductility of steel plate and strength of corner tubes. Use of these types of columns in a moment-resisting frame requires a connection to be developed which provides an optimal bi-lateral connection between a beam and that column.

[006] Conventional types of beam to column connections usually use the column flat face and end of the beam as the interaction surfaces connected together using end plates or reverse channels or similar interconnecting members attached to the column face and beam end. These interconnecting members are usually anchored to the corresponding beam/column using weld or bolts. In the case of a hybrid fabricated column with thin face thicknesses, these connections may cause problems such as local buckling, bolt punch shear or distortion caused by welding of the interconnecting member to the face of the column. These connections may not be able to effectively transfer the load from the beam to the hybrid fabricated column elements, and therefore may result in undesirable force transfer and/or deformation of the beam or column when loaded.

[007] It would therefore be desirable to provide a new connection arrangement or system useful for connecting a beam to a hybrid fabricated column. The new connection arrangement could be preferably used in constructing moment-resisting frames within a structure or building.

SUMMARY OF THE INVENTION

[008] A first aspect of the present invention provides a connection arrangement for connecting a cross-member to a vertical member, comprising:

at least one pair of spaced apart mounting fixtures, each mounting fixture being securable to a vertical member at a selected height spaced apart from the adjoining mounting fixture of the pair of spaced apart mounting fixtures, each mounting fixture including a support engagement formation; and

at least one cross-support configured to be secured between a pair of spaced apart mounting fixtures, the cross-support including at least two mount engagement formations which are configured to cooperatively engage with the support engagement formations of the respective pair of spaced apart mounting fixtures to mount the cross-support onto the respective mounting fixture, the cross-support also including a beam securing formation for securing a portion of a cross-member to the cross-support.

[009] The present invention provides a new connection arrangement for connection of a cross-member to a vertical member. The connection arrangement of the present invention uses an advantageous attachment arrangement comprising fixing mounting fixtures to the vertical member that can then be used to support a cooperating cross-support which is connected to the cross-member. This allows for simplified construction of the connection arrangement on site.

[010] The vertical member of application to this connection arrangement include but are not limited to innovative load bearing elements, referred to herein, as hybrid fabricated columns (HFC). In embodiments, the HFCs consist of mild steel plates which are welded to either mild-steel, high strength steel or ultra-high strength steel tubular pillar corners. The HFC benefits from the ductility of steel plate and strength of corner tubes. For this specific application and due to the special geometry of the column, the conventional types of cross-member connections cannot effectively serve as interconnecting devices between cross-member and the HFC.

[011] For HFC's, the connection arrangement of the present invention uses an advantageous attachment arrangement comprising the cooperating mounting

fixtures and cross-support for mounting the cross-member to a vertical member mounting face configuration. This type of connection advantageously utilizes the vertical pillars as the medium to apply the loads transferred from the beam. In a framework, preferably a moment-resisting frame, arrangement of the connection and the way it transfers load from the cross-member to the vertical members leads to a well distributed load across all the vertical members in the structure that keeps all the loads on vertical members well below their capacities and reduces the risk of applying a high local load on a single vertical members. Moreover, the material properties of the vertical pillars and connecting plate can be fully utilised.

[012] The mount engagement formation and support engagement formation can have any suitable configuration. The mount engagement formation and the support engagement formation preferably comprise co-operating formations which releasably secure the cross-support with each of the mounting fixtures. A variety of cooperating formations could be used, for example hook and opening, rod and opening, clamps, clips or the like. In some embodiments, one of the mount engagement formations and the support engagement formations comprises a mounting recess and the other of the mount engagement formations and the support engagement formations comprises a fixing member configured to be captured in the mounting recess. This enables the cross-support to be seated on each cooperating mounting fixture. In a preferred embodiment, the mount engagement formation comprises a mounting recess and the support engagement formations comprise a fixing member configured to be captured in the mounting recess of a cooperating mounting fixture.

[013] The mounting recess can have any suitable configuration. In embodiments, the mounting recess comprises a slot or channel formed in each mounting fixture. This form of the mounting recess preferably comprises a top or upwardly orientated opening into which the fixing member is received. Moreover, the mounting recess can have any suitable form and shape. In some embodiments, the mounting recess comprises a U or V shaped slot or channel.

[014] It is preferable that the cross-support is securely fastened on the mounting fixture. The cross-support therefore may also include at least one

securing arrangement for fastening a portion of the mounting fixture thereto. In some embodiments, the securing arrangement comprises at least one flange configured to overlie a co-operating securing portion of the mounting fixture, the flange and securing portion of the mounting fixture including at least one complementary aperture into which a fastener can be mounted to secure the flange and securing portion together. Any number of co-operating arrangements could be used. In some embodiments, the securing arrangement comprises two spaced apart flanges defining a slot therebetween configured to receive therebetween the co-operating securing portion of the mounting fixture.

[015] The mount engagement formation can have any suitable configurations. In some embodiments, the mount engagement formation comprises body including at least one fixing section configured to be received and seated within the mounting recess. The fixing section preferably includes a cross-member configured to be seated on and within the mounting recess. The fixing section may have a slotted configuration in some embodiments.

[016] Each mounting fixture preferably includes an engagement section for engagement to a portion of the vertical member. The engagement section typically has a co-operating (and preferably complementary) shape to the portion of the vertical member to which it is to be fixed. For example, where the vertical member has a curved shape (for example an HFC where the pillar has a round cross-section – as discussed below), the engagement section will therefore have a complementary and cooperating curved shape. Where the vertical member has a polygonal cross-sectional shape (such as triangular, square, hexagonal or the like), the engagement section will therefore have a complementary and cooperating shape to that portion of the polygon it engages. For example, where the mounting fixture is fitted to the corner of a square or rectangular post, the engagement section will comprise a complementary right angled shape (for example two panels perpendicularly orientated to each other to fit that corner). The engagement section can have any suitable form. In some embodiments the engagement section comprises at least one of a sleeve, flange, arm, panel, groove, channel or the like.

[017] The mounting fixture can be attached to the vertical member using any suitable means or arrangement. In some embodiments, the mounting fixture is fixedly attached to a portion of the vertical member using an energetic bond. In preferred embodiments, each mounting fixture is fixedly secured, preferably welded, into position on the respective vertical member.

[018] Any number of connection arrangements can be secured around the periphery of the vertical member. In some embodiments the vertical member includes two connection arrangements of the present invention. These two connection arrangements may be orientated at right angles to each other on the vertical member, or on opposite sides (around 180 degrees apart) around the vertical member. In embodiments, four connection arrangements are used. This typically involves installing four mounting fixtures are welded to the vertical member to form a rectangular mounting arrangement on the vertical member. The connection arrangement therefore provides the opportunity to mount beams to all four sides of this type of vertical member without need to make any modifications in the structure of the vertical member.

[019] The cross-support is preferably formed from a plurality of interconnected elements. In embodiments, the cross-support is formed from at least two spaced apart end elements interconnected by a cross-element, each of the end elements including a mount engagement formation and the cross-element including at least one beam securing formation. The length of the cross-element can be varied to match the dimensions of the vertical support to which the connection arrangement is being attached. In some embodiments, the elements are designed to be fastened together using fasteners, preferably cooperating bolts and nuts. The end sections are typically formed of a standard configuration which can be connected using fasteners to the requisite cross-element. Any suitable fastener can be used, for example a plurality of threaded joints, clamp joints, U-bolts, bolts, rods, threaded body, flange, or a combination thereof.

[020] The beam securing formation of the cross-support is preferably configured to fasten a portion of an end of the cross-member to the cross-support. A number of suitable beam securing formation arrangements can be

used. In some embodiments, the beam securing formation includes at least one flange configured to extend over and interconnect to a portion of an end of the cross-member to the cross-support. Fasteners, such as cooperating bolts and nuts, are preferably used to secure the at least one flange to the end portion of the cross-member. The beam securing formation is releasably secured to the cross-support using at least one fastener. In each case the fasteners similarly can have any suitable configuration. In some embodiments, the fasteners comprise a plurality of threaded joints, clamp joints, U-bolts, bolts, rods, threaded body, flange, or a combination thereof.

[021] Embodiments of the invention can include at least two pairs of spaced apart mounting fixtures. Each pair of spaced apart mounting fixtures are securable to adjoining vertical pillars of a vertical member at a selected height and being vertically spaced apart on the vertical member, each pair of mounting fixtures including a cooperating cross-support. In these embodiments, a portion of the cross-member, typically an end portion of the cross-member is preferably secured between two vertically spaced apart cross-members.

[022] The connection arrangement preferably comprises a modular construction. In such embodiments, the connection arrangement is preferably constructed from a number of standard parts that are secured together using fasteners, such as cooperative bolts and nuts. The connection arrangement is preferably configured from at least two releasably engagable sections which enable the connection to be deconstructed, and thus disassembled and in some cases used in new construction.

[023] This modular construction advantageously reduces the need to weld to a minimum level. In embodiments, the mounting fixtures are preferably welded to their respective mounting locations on the vertical member. Similarly, the beam securing formations may also be welded to the cross-member in some embodiments. A number of the parts of the connection arrangement are preferably constructed to be attached together using fasteners such as bolts/nuts etc. The cross-member is preferably configured to be attached to the connection arrangement using fasteners. This means that the majority of the parts of the connection arrangement of the present invention are reusable such

that after the structure lifetime or in case of extreme actions impacting on the structural elements, they can easily be disassembled and used in new construction. This connection arrangement therefore provides the possibility of disassembling the constituting frame members or replacing the possibly damaged vertical or cross-members non-destructively where required.

[024] The proposed modular connection components of the connection arrangement are geometrically identical which reduces the fabrication cost and makes the mass production of them economically more feasible while in the conventional connections different components have their own specific shape which is different from other parts. The factory made parts are made with high precision and therefore can provide better construction tolerances making construction and finishing trade works easier and faster.

[025] The mounting fixtures are attachable to any suitable portion of the vertical member. In embodiments, the mounting fixtures are attachable to or proximate to adjoining corners of the vertical member. Moreover, as discussed above, the vertical member can comprise a hybrid fabricated columns (HFC) in some embodiments. In these types of columns, the vertical member preferably has a mounting face having two spaced apart vertical pillars interconnected by a panel. Each mounting fixture of a pair of spaced apart mounting fixtures is therefore preferably securable to adjoining vertical pillars of a vertical member at a selected height.

[026] The connection arrangement of the present invention may also include a panel engagement section comprising a panel mounting fixture secured to a portion of a panel, and a beam connection arrangement which connects a portion of the end of the cross-member to the panel mounting fixture. This enables the panel of the mounting face of the vertical member to also contribute to load transfer and/or ductility of the connection arrangement. The panel mounting fixture is preferably attached to the cross-member using bolted side plates. The panel mounting fixture is preferably located centrally between at least one pair of mounting fixtures.

[027] The connection arrangement can also further comprise a connector member, preferably flange connected between the two vertically spaced apart cross-supports. The connector member is preferably secured to the beam connection arrangement.

[028] A second aspect of the present invention provides a connection arrangement for connecting a cross-member to a vertical member, the vertical member having a mounting face having two spaced apart vertical pillars interconnected by a panel, the connection arrangement comprising:

- at least one pair of spaced apart mounting fixtures, each mounting fixture of a pair of spaced apart mounting fixtures being securable to adjoining vertical pillars of a vertical member at a selected height, each mounting fixture including a support engagement formation; and

- at least one cross-support configured to be secured between a pair of spaced apart mounting fixtures, the cross-support including at least two mount engagement formations which are configured to cooperatively engage with the support engagement formations of the respective pair of spaced apart mounting fixtures to mount the cross-support onto the respective mounting fixture, the cross-support also including a beam securing formation for securing a portion of a cross-member to the cross-support.

[029] It should be appreciated that this second aspect of the present invention can include any of the features detailed above in relation to the first aspect of the present invention.

[030] A third aspect of the present invention provides a connection arrangement for connecting a cross-member to a vertical member, the connection arrangement comprising:

- a vertical member;

- a cross-member;

- at least one pair of spaced apart mounting fixtures, each mounting fixture being securable to a vertical member at a selected height spaced apart from the adjoining mounting fixture of the pair of spaced apart mounting fixtures, each mounting fixture including a support engagement formation; and

at least one cross-support configured to be secured between a pair of spaced apart mounting fixtures, the cross-support including at least two mount engagement formations which are configured to cooperatively engage with the support engagement formations of the respective pair of spaced apart mounting fixtures to mount the cross-support onto the respective mounting fixture, the cross-support also including a beam securing formation for securing a portion of the cross-member to the cross-support.

[031] It should be appreciated that this third aspect can include any of the features detailed above in relation to the first or second aspect of the present invention. Similarly, it should be appreciated that the first aspect of the present invention can include any of the features discussed in relation to this third aspect of the present invention.

[032] The cross-member can comprise any suitable cross-member including, but not limited to a beam, girder, joist, pillar, plank, pole, shaft, timber, axle, boom, brace, crossbar, crosspiece, lintel, post, prop, rafter, rail, stake, reach, stanchion, stay, stringer, strip, strut, or stud. Similarly, the vertical member can comprise any suitable vertical structural member including, but not limited to a column, pillar, pedestal, girder, colonnade, mast, obelisk, pier, pilaster, piling, pole, post, prop, shaft, stanchion, support, tower, or upright. In preferred embodiments, the cross-member comprises a beam, strut or bar and the vertical member comprises a post, pillar or column.

[033] In embodiments, the cross-member and the vertical member comprise structural members, preferably load bearing structural members. Preferably, the cross-member and vertical member comprise part of a moment-resisting frame. During the construction phase of the frame, the majority of the connection parts are preferably assembled in a factory prior to shipment of the cross-members and vertical members to the site. This therefore introduces high precision factory standard welding instead of on-site welding to the construction and installation process. It can also reduce the safety concerns about welding in a construction site, in particular in higher levels of the frame.

[034] As noted above, the vertical member preferably comprises a hybrid fabricated columns (HFC). More particularly, the HFC form of vertical member preferably comprises a column consists of at least three spaced elongate tubes spaced apart around a central axis, each elongate tube being interconnected to an adjoining elongate tube by a panel. In embodiments, the elongate tubes are substantially parallel to each other. The elongate tubes can also be substantially cylindrical.

[035] The panels can have any suitable form. In some embodiments, at least one of the panels is planar. In some embodiments, at least one of the panels is shaped, for example corrugated. The panels are preferably energetically bonded, preferably welded to the elongate tubes.

[036] In preferred embodiments, the panels are formed of material having a lower yield stress than the material of which the elongate tubes are formed. For example, in some embodiments, the panels can be formed from mild steel and the elongate tubes can be formed from high strength steel, ultra-high strength steel or stainless steel. As discussed above, the HFC benefits from the ductility of steel plate and strength of corner tubes.

[037] In some embodiments, the vertical member may further include a filling material within the elongate volume, wherein at least the panels define an outer periphery of the filling material. In some embodiments, the filling material includes an elongate cavity within the filling material and running longitudinally along the elongate volume. The filling material can include aggregate in some embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[038] The present invention will now be described with reference to the figures of the accompanying drawings, which illustrate particular preferred embodiments of the present invention, wherein:

[039] Figure 1 is a front perspective view of one embodiment of the connection arrangement according to the present invention.

[040] Figure 2 is a rear perspective view the connection arrangement shown in Figure 1.

[041] Figure 3 illustrates the cross-sectional configuration of two examples of a hybrid fabricated columns (HFC) with (a) Flat Face Plate and (c) Corrugated Face Plate on to which the connection arrangement shown in Figures 1 and 2 can attach.

[042] Figure 4 is a perspective view of a hybrid fabricated column with four mounting fixtures of the connection arrangement shown in Figure 1 welded into position.

[043] Figure 5 provides a perspective view of the various section of the connection arrangement of Figure 1 used to connect a beam to a hybrid fabricated column.

[044] Figure 6 provides a perspective view of the final assembled connection between the beam and the hybrid fabricated column shown in Figure 5.

[045] Figure 7 illustrates the steps in assembling the connection arrangement between the beam to the hybrid fabricated column shown in Figures 5 and 6.

[046] Figure 8 shows the connection model configuration for each of the comparative connection arrangements, showing (a) Extended end-plate; (b) Flush end plate; (c) Reverse Channel (d) connection arrangement according to embodiments of the present invention.

[047] Figure 9 provides the parametric dimensions of (a) and (b) fabricated of hybrid fabricated columns (HFC); (c) extended end-plate connection; (d) flush end-plate connection; and (e) reverse channel connection.

[048] Figure 10 provides a plot showing a comparison of moment-rotation curves of extended and flush end-plate connections with mild steel (MS) and ultra-high strength steel (UHSS) corner tube materials of hybrid fabricated columns (HFC) shown in Figure 9(a).

[049] Figure 11 provide a plot showing a comparison of moment-rotation curves of reverse channel connection with MS and UHSS corner tube materials of hybrid fabricated columns (HFC) shown in Figure 9(a).

[050] Figure 12 provides a plot showing a comparison of moment-rotation curves of innovative modular connection with MS and UHSS corner tube materials of hybrid fabricated columns (HFC) shown in Figure 9(a).

[051] Figure 13 provides von Mises stress distribution on ultra-high strength steel corner tubes of hybrid fabricated columns (HFC) shown in Figure 9(a) for (a) Flush end-plate connection; (b) Extended end-plate connection; (c) Reverse channel connection; and (d) connection arrangement of the present invention.

DETAILED DESCRIPTION

[052] It should be understood that various directions such as “upper”, “lower”, “bottom”, “top”, “left”, “right”, and so forth are made only with respect to explanation in conjunction with the drawings, and that the components may be oriented differently, for instance, during transportation and manufacturing as well as operation. Because many varying and different embodiments may be made within the scope of the inventive concept(s) herein taught, and because many modifications may be made in the embodiments described herein, it is to be understood that the details herein are to be interpreted as illustrative and non-limiting.

[053] The present invention provides a structural connection between a beam and a column that can be used in some embodiments in moment resistant frames. Again it should be appreciated that the vertical member 200 of application to this connection arrangement includes but are not limited to innovative load bearing elements, referred to herein, as hybrid fabricated columns (HFC).

[054] Figures 1 and 7 show one embodiment of the connection arrangement 100 according to the present invention. This new connection arrangement 100 is configured to connect a cross-member, such as I-beam 220 (Figure 5 and 6)

to a hybrid fabricated column type vertical member 200 (Figure 5 and 6). One particular embodiment of hybrid fabricated column 200 that the connection arrangement 100 is configured to attach to is shown in Figures 2, 5 and 6.

[055] As shown in these Figures, the hybrid fabricated column 200 consists of four parallel spaced apart elongate tubes 205 spaced apart around a central axis, each elongate tube 205 being interconnected to an adjoining elongate tube 205 by a panel 207. The panels 207 typically comprise mild steel plates which are welded between corner tubes 205. The face of each plate 207 could be flat or corrugated which in both cases is made of thin plates (Figure 2). The corner tubes 205 are usually formed from mild-steel, high strength steel or ultra-high strength steel tubes. The hybrid fabricated column 200 benefits from the ductility of steel panels 207 and the strength of corner tubes 205. Each side of the hybrid fabricated column 200 provides a mounting face having two spaced apart vertical tubes 205 interconnected by a panel 207. The connection arrangement 100 advantageously utilizes the vertical tubes 205 as the medium to apply loads transferred from the cross-member 220.

[056] The illustrated connection arrangement 100 is formed from a plurality of interconnected elements connected together using fasteners. In the illustrated embodiment, cooperating nut and bolt fasteners are used to join the underjoining and interconnection parts of the connection arrangement 100 together. The illustrated connection arrangement 100 is composed of eleven separate interconnected parts. However, it should be appreciated that this number of parts may vary in other embodiments, depending on the particular constructional arrangement selected for that particular connection arrangement 100.

[057] The illustrated connection arrangement comprises two vertically spaced apart collars 105 and 106 which are vertically connected by panel connector 110. Each of the collars 105 and 106 are formed from two main interconnecting sections, comprising:

- a one pair of spaced apart mounting fixtures 115 and 116; and
- a cross-support 120 configured to be secured between the pair of spaced apart mounting fixtures 115 and 116.

[058] The mounting fixtures 115 and 116 provide the support for the whole connection assembly 100 and transfer the load from the connection parts to the corner tubes 205 of the vertical member 200. The mounting fixtures 115 and 116 are fixedly attached, preferably welded to the corner tubes 205 of the vertical member 200. The corner tubes 205 of the vertical member 200 have the same or preferable have a higher strength compared to panels 207 of the vertical member 200. The mounting fixtures 115 and 116 thus provide the mounting points on the vertical member 200 on which each of the collars 105 and 106 are seated and secured. This gravity connection removes the need to weld connection parts at the construction site and improves build quality and construction time.

[059] Each mounting fixture 115 and 116 includes an engagement section, in this form of engagement flange 125 configured for abutting engagement to a portion of the respective corner tubes 205 of the vertical member 200. The engagement flange 125 has a co-operating shaped engagement face to the portion of the vertical pillar to which it is to be fixed. In the illustrated embodiment, the corner tubes 205 have a round cross-section, and thus the engagement flange 125 has a complementary and cooperating curved shape.

[060] Each mounting fixture 115, 116 also include a support engagement formation 125 which releasably secure the cross-support 120 with each of the mounting fixtures 115, 116. In the illustrated embodiment, the support engagement formation 125 comprises a mounting recess 130 (Figure 4) configured to receive and seat a portion of the cross-support 120 therein. The mounting recess 130 comprises a top or upwardly orientated slot or channel formed in each mounting fixture 115, 116.

[061] The illustrated cross-support 120 is formed from two spaced apart end 138 elements interconnected by a cross-element 140.

[062] Each of the end elements 138 are configured to be seated within the mounting recess 130. Each end element 138 also includes two spaced apart flanges 142 defining a slot therebetween configured to receive therebetween

the co-operating securing portion 144 of the mounting fixture 115, 116. The flanges 142 and securing portion 144 of the mounting fixture 115, 116 including three complementary apertures into which nut and bolt fasteners can be mounted to secure flanges 142 and securing portion 144 together. The end sections 138 are typically formed of a standard configuration which can be interchangeably used with different configured cross-elements 140.

[063] The cross-element 140 comprises an elongate member configured to span the width of the vertical member 200 between each of the end elements 138. The end elements 138 and cross-element 140 include cooperating connection sections 141 (Figures 1 and 2), in this case connection flanges configured to overlap and interconnect using fasteners (nut and bolt fasteners in the illustrated embodiments). These flanges may be keyed or include complementary steps (as illustrated) to interlock the elements together. It should be appreciated that the length of the cross-element 140 can be varied to match the dimensions of the vertical support 200 to which the connection arrangement 100 is being attached. The cross-element 140 includes on a rear face a beam securing formation 150 which connects the cross-support 120 to the respective cross-member 220. The illustrated beam securing formation 150 comprises a flange or bracket with apertures designed to overlay the top of I-beam cross-member 220 (see Figures 5 and 6) and be fastened onto the end of that cross-member 220 using nut and bolt fasteners (for example fasteners 160 in Figure 1). It should be appreciated that in other embodiments the beam securing formation 150 could be fastened to the top of the I-beam cross-member 220 using other fastening means, for example welding or the like.

[064] As shown in Figures, the two spaced apart collars 105 and 106 are secured to the respective corner tubes 205 of the vertical member 200 using two vertically spaced apart pairs of mounting fixtures 115, 116 (Figure 4). Each pair of spaced apart mounting fixtures 115, 116 are secured to the respective corner tubes 205 of the vertical member 200 at a selected height. An end portion 225 of the cross-member 220 is preferably secured between the two vertically spaced apart cross-supports 120 through fastening between and to beam securing formations 150 of each cross-support 120. Again, it should be

appreciated that in other embodiments the beam securing formation 150 could be fastened to the top of the I-beam cross-member 220 using other fastening means, for example welding or the like.

[065] The illustrated connection arrangement 100 also include a panel mounting fixture 160 secured to a portion of a panel 207 of the vertical member 200, comprising a perpendicularly extending flange welded into place at a central location between the spaced apart pairs mounting fixtures 115 and 116. A cooperating beam connection arrangement 162 is also provided which connects a portion of the end 225 of the cross-member 220 to the panel mounting fixture 160. The beam connection arrangement 162 comprises a pair of plates 164 which are fastened using nuts and bolt fasteners mounted through apertures extending through the plates 164 and an end portion 225 of the cross-member 220 and also fastened to the panel mounting fixture 160 again using nut and bolt fasteners extending through cooperating apertures in the overlapping parts. This enables the panel 207 of the vertical member 200 to also contribute to load transfer and/or ductility of the connection arrangement 100.

[066] A connector flange 170 is also located between the two vertically spaced apart cross-supports 120. The connector member is also secured between the plates 164 of the beam connection arrangement 162.

[067] Referring now to Figure 7 where the construction cycle of the connection arrangement 100 is illustrated:

Stage 1: Firstly, the various parts of the connection arrange 100 are manufactured in a factory and then transported to the construction site.

Stage 2: The connection arrangement 100 can then be constructed by firstly welding the mounting fixtures 115, 116 onto the corner tubes 205 of the vertical member 200 and the panel mounting fixture 160 onto the face of the panel 207 of the vertical member 200. Collars 105 and 106 can be preconstructed offsite (in a workshop or similar) prior to transportation to the construction site. The collars 105 and 106 are constructed from the interconnected elements (two end

138 elements and a cross-element 140 – see Figure 1 and 2). Similarly, beam securing formation/ brackets 150 could be fastened to the top of the I-beam cross-member 220 using fastening means, welding or the like prior to transportation to site.

Stage 3: The lower collar 106 is then lowered onto the lower pair of mounting fixtures 115, 116 and bolted into place.

Stage 4: The top collar 105 is attached to the cooperating beam securing formations/ brackets 150. Again, this can be conducted in a workshop/ offsite prior to transportation to site.

Stage 5: The cross-member 220 is lowered into place, with the top collar 105 lowered onto the top pair of mounting fixtures 115, 116, and the I-beam cross-member 220 and beam securing formation/ brackets 150 are lowered to be seated onto the lower collar 106 and bolted into place. The top collar 105 and pair of mounting fixtures 115, 116 are then secured together, for example through fasteners or other suitable attachment means.

[068] As indicated above, the top collar 105, beam securing formation/ brackets 150 and I-beam 220 assembly from stage 4 can be assembled prior to being transported to site. Similarly, the lower collar 106 can be assembled prior to being transported to site. These parts can then be simply constructed as indicated to form the connection arrangement 100.

[069] Advantageously, all of the components are lowered into place and gravity-held. This provides for safe onsite installation where all parts are held in place purely by gravity allowing for simple and safe installation

[070] It should be appreciated that lowering the cross-member 220 using the gravity and placing the cross-member 220 in place makes a fully moment-connection from the very beginning moment of construction of a frame structure which includes the vertical member 200 and cross-member 220. This interlocking and integration between connection components happens without

need for any additional fastening devices and can avoid unwanted movement of the frame members in extreme conditions. This makes the whole assembly a robust moment connection.

[071] It should also be appreciated that during the construction phase of the frame, the majority of the connection parts are preferably assembled in a factory prior to shipment of the cross-members 220 and vertical members 200 to the site. High precision factory standard welding can be used instead of on-site welding. This can reduce the safety concerns about welding, especially in higher levels of the comprising frame.

[072] Whilst an I-beam and HFC are illustrated in the Figures, it should be appreciated that the connection arrangement 100 could be used to interconnect a variety of cross-members 220 and vertical members 200. The cross-member 220 can comprise any suitable cross-member including, but not limited to a beam, girder, joist, pillar, plank, pole, shaft, timber, axle, boom, brace, crossbar, crosspiece, lintel, post, prop, rafter, rail, stake, reach, stanchion, stay, stringer, strip, strut, or stud. Similarly, the vertical member 200 can comprise any suitable vertical structural member including, but not limited to a column, pillar, pedestal, girder, colonnade, mast, obelisk, pier, pilaster, piling, pole, post, prop, shaft, stanchion, support, tower, or upright. It should be appreciated that the cross-member 220 and vertical member 200 may comprise part of a moment-resisting frame.

[073] For example, the vertical member may comprise a rectangular post or column (not illustrated). The mounting fixtures of the connection arrangement would be welded onto the corners of the rectangular vertical member and the connection arrangement would then be constructed as described above with the cross-element supported between those mounting fixtures. A similar arrangement could also be configured for a round cross-section pole or column (not illustrated), where the mounting fixtures were fixed, welded to that column at spaced apart locations, typically 90 to 180 degrees apart and the connection arrangement would then be constructed as described above with the cross-element supported between those mounting fixtures.

[074] It should also be appreciated, that whilst a number of the illustrated parts of the connection arrangement 100 are taught as being fastened together using nut and bolt fasteners, those parts could equally be secured or fastened together using other means, for example welding or the like.

EXAMPLE

1. SIMULATED MECHANICAL BEHAVIOUR OF A CONNECTION ARRANGEMENT

[075] In this Example, the behaviour of the type of I-beam- to-fabricated column connection 100 shown in Figures 1 to 7 and 8(d) is investigated under monotonic loading using a numerical finite element study. The overall performance of this connection is compared with three conventional types of connections (i.e. extended end-plate connection, flush end-plate connection and reverse-channel connection) widely used to make a connection between I-beams and rectangular hollow sections. For each case a detailed 3-D finite element model was developed under monotonic loading using ABAQUS in which contact elements, damage to elements, and non-linearity in both material and geometry are considered. The initial stiffness, moment capacity, and rotation capacity of the proposed connection are extracted from the moment-rotation curves and compared with those of conventional connections, including extended end-plate, flush end-plate, and reverse channel connections, which are widely used for I-beams to rectangular hollow-section columns connections

2. FINITE ELEMENT MODELLING

2.1 *Geometry*

[076] The innovative column used in this simulation is 1 m in height and has a cross-section with the shapes and sizes depicted in Figure 9. The corresponding values of the parametric dimensions of the flush end-plate, extended end-plate, and reverse channel connections shown in Figure 9 can be found in Table 1.

[077] Table 1: Dimensions of the column and connections

	Symbol	Value mm		Symbol	Value mm
Column	W_1	286		T_1	3
	W_2	286		T_2	32
	$H1$	1000		R_1	34.85
Extended End-plate	W_3	160		T_3	6
	W_4	435		R_2	11
Flush End-plate	W_3	160		T_3	6
	W_5	365		R_2	11
Reverse Channel	W_6	296		T_4	10
	W_7	90		R_3	15
	W_8	400			

2.2 Element type and meshing

[078] The type of elements used for meshing the connection assembly is C3D8R. These elements are recommended for use in models that include very large mesh distortions (large strain) problems. Since the problem under investigation has a similar nature, this element may be a good choice. In combination with proper meshing, this element can give accurate results at a reasonable computational cost (ABAQUS 2014).

[079] Meshing of the model parts has been performed based on two strategies. The first is the use of the tie feature in attaching adjacent zones with different mesh densities to avoid applying very fine meshes in areas where it is not necessary. An example of this approach is in the zone where the corner tubes are connected to the side-walls of the plates or in the zone where the beam is attached to the connection.

[080] The second strategy is the use of sections. Creating appropriate sections on different zones of each part helps achieve a well-shaped and more controllable mesh in terms of density and shape. In some parts, structured

meshing is not possible using brick elements (C3D8R) without using appropriate sectioning.

2.3 *Contacts*

[081] Contact modelling is of great importance in modelling bolted connection problems. Although the accuracy of the results depends on the level of detail implemented in the model, there should be a balance between details and computational cost. For that reason, bolt and nut threads have not been modelled, since this could lead to more complex contact definition, a longer solution time due to smaller time steps, and may also affect the loading conditions of the model because of the need to apply torque on the bolt-nut assembly instead of using the predefined bolt load implemented in ABAQUS. Another compromise is combining the bolt and nut, and treating them together as a single part.

[082] Contact formulation is based on finite slide with surface-to-surface discretization. Contact behaviour in normal direction has been modelled using hard contact, and tangential contact behaviour has been modelled with consideration of friction between the relevant parts. The selection of slave or master surfaces should be done with extra care, since it can seriously impact the contact behaviour and even lead to solution divergence. Tie constraint has been used to define attachment between the beam and the adjacent connection part and also between the front corner tubes and the adjoining plates.

2.4 *Material model*

[083] One of the influential parameters that can noticeably affect the results is how closely the material model used in the model represents the actual material behaviour. A challenging part of this task is modelling the material behaviour after the point of ultimate tensile strength, where necking initiates in ductile materials.

[084] In this simulation, this behaviour has been modelled by using the ductile damage definition and damage evolution laws in ABAQUS. The corresponding constants and formulations have been obtained for each material that has been

used here. Material types used in this simulation include ultra-high strength steel (UHSS) and mild steel (MS). UHSS was used for the corner tubes while MS was used for all other parts of the connection. The fastener (bolt-nut combination) material is high strength steel and modelled based on a bilinear model definition.

2.5 Boundary conditions

[085] As shown in Figure 8(a), quasi-static displacement load is monotonically applied at free end of the beam. The free end of the beam is constrained in lateral direction to avoid beam torsion. The column is under constant compressive axial load of 50 kN. The bottom of the column is encastered and the top is constrained in all directions, except in the vertical direction. Fasteners are preloaded. Displacement load has been applied in a separate step to ensure that the contacts, axial load and bolt preload have been applied correctly in advance. Similar boundary conditions were used for the flush end plate model and Reverse Channel model shown in Figures 8(b) and 8(c), and the connection arrangement of the present invention shown in Figure 8(d).

3. RESULTS

[086] In this section the results of simulations based on the specifications described in the previous section are presented. The beam used in the simulations is a 360UB56.7 (AS/NZS 3679.1) on which the load is applied at a point 1 m from the connection end (Figure 8).

3.1 Extended and flush end-plate connections

[087] In these types of connections, a flat plate is welded to the beam end and then bolted to the column face. As shown in Figures 8 (a) and (b), the difference between flush end-plate and extended end-plate connections, as the name implies, is the extension of the flat plate welded to the beam in the extended end-plate connection.

[088] The results in Figure 10 suggest that the use of the ultra-high strength material for corner tubes may slightly enhance the connection performance in

terms of load-carrying capacity in extended end-plate connections, while this effect is not observed in flush end-plate connections, especially with increasing rotation. In the case of flush end-plate connection and at 0.12 rad rotation of the beam this improvement is about 2%, while this improvement for extended endplate is about 10%. This is indicative of the fact that the flush and extended end-plate connections cannot fully utilise the mechanical properties of the UHSS.

[089] At the time which solution has been finished investigating the damage index in column face shows that the material in the region around the point of interaction of the fasteners with the plate has much higher index value than other parts of the assembly. Therefore, the failure mode in this type of connection for this configuration may be face punch and tearing of the face plate at those points.

3.2 *Reverse channel connection*

[090] This connection consists of a C-shaped member (Figures 8(c) and 9(e)) welded to the front corner tubes. A group of holes, matching those of the flush end-plate connection, has been created on this member so that the beam that is welded to the end-plate can be bolted to the C-shaped member. The major difference between this connection and those previously discussed is that the load from the beam is transferred to the column through the corner tubes. The results of the loading on this connection with the corner tubes made of UHSS and MS corner tubes are presented in Figure 11.

[091] This connection shows more ductility compared to the flush and extended end-plate connections, which is favourable. In addition, the effect of material property on increasing the capacity of the connection before failure is more significant. At 0.23 rad rotation of the beam capacity has increased by 11 percent.

3.3 *Innovative modular connection*

[092] For this connection (Figure 8(d)) each flange of the beam is connected to one of the collars (Parts 1, 5) of the connection and the beam web is welded to an extension part (Part 4). This extension is itself welded to the top and bottom

collars at both ends. Assuming this combination to be a single part, it is bolted to intermediate parts (Parts 3, 6, 9, 11), which are then bolted to the corner parts (Parts 2, 7, 8, 10). Under loading this assembly works as a robust connection. A beam web is also connected to the column face using two thin plates to ensure that the connection also uses the column face ductility.

[093] The results in Figure 12 show that the moment capacity of the connection has been increased by a great extent. Comparison of the connection stiffness with that of conventional connections indicates that the proposed connection has more stiffness and also shows high ductility under similar loading conditions. The combination of high ductility and high moment capacity makes this connection a good candidate for use in high-rise buildings. In addition, the influence of the corner tube material is shown to be more effective in this case compared to conventional connections.

[094] In terms of load distribution on the corner tubes and taking advantage of their superior material properties, the von Mises stress distribution on the UHSS corner tube is compared in Figure 13(a) to (c) for three conventional connections.

[095] It can be observed that for reverse channel connection, compared to the other two conventional cases, stress contours are more distributed and a larger segment of the tubes has undergone higher levels of stress. This is a sign of better load transfer from beam to column and greater utilization of the superior material properties of the tube.

[096] However, as depicted in Figure 13(d), the stress distribution for the modular connection is such that a larger portion of the tube is under higher stress levels and load distribution is towards more utilization of superior material properties, which is favourable.

4. CONCLUSIONS

[097] The innovative modular connection exhibits more ductility and moment capacity than the conventional connections. It also has the advantage of

utilising a higher portion of the material properties of the ultrahigh strength corner tubes.

[098] The proposed connection can be used along with the fabricated columns and will perform as a reliable robust connection in high-rise buildings. In addition to having superior performance, this connection has other benefits for the construction industry, such as shorter construction times on-site because of the modular construction feature. It removes the need for a great amount of on-site welding and preparation. In addition, due to having factory-built connection parts and welds, overall construction quality may be significantly improved. Although the connection has been shown to have convincing performance, more simulations and experimental work are required to prove the concept.

[099] The described connection arrangement therefore provides one or more of the following advantages:

- Connection between a cross-member to a hybrid fabricated column;
- Increased stiffness as well as ductility compared to conventional beam connections to rectangular columns;
- Can be removed and reapplied;
- Dimensions and configuration can be varied according to beam size;
- Possible to be installed with minimal or no onsite welding; and
- Faster and safer installation.

[100] Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is understood that the invention includes all such variations and modifications which fall within the spirit and scope of the present invention.

[101] Where the terms "comprise", "comprises", "comprised" or "comprising" are used in this specification (including the claims) they are to be interpreted as specifying the presence of the stated features, integers, steps or components, but not precluding the presence of one or more other feature, integer, step, component or group thereof.

CLAIMS

1. A connection arrangement for connecting a cross-member to a vertical member comprising:

at least one pair of spaced apart mounting fixtures, each mounting fixture being securable to a vertical member at a selected height spaced apart from the adjoining mounting fixture of the pair of spaced apart mounting fixtures, each mounting fixture including a support engagement formation; and

at least one cross-support configured to be secured between a pair of spaced apart mounting fixtures, the cross-support including at least two mount engagement formations which are configured to cooperatively engage with the support engagement formations of the respective pair of spaced apart mounting fixtures to mount the cross-support onto the respective mounting fixture, the cross-support also including a beam securing formation for securing a portion of a cross-member to the cross-support.

2. A connection arrangement according to claim 1, wherein the mount engagement formations are releasably securable to the support engagement formations.

3. A connection arrangement according to claim 1 or 2, wherein one of the mount engagement formations and the support engagement formations comprises a mounting recess and the other of the mount engagement formations and the support engagement formations comprises a fixing member configured to be captured in the mounting recess.

4. A connection arrangement according to claim 3, wherein the mounting recess comprises a slot or channel formed in each mounting fixture.

5. A connection arrangement according to claim 3 or 4, wherein the mounting recess comprises a top or upwardly orientated opening into which the fixing member is received.

6. A connection arrangement according to claim 3, 4 or 5, wherein the mounting recess comprises a U or V shaped slot or channel.

7. A connection arrangement according to any preceding claim, wherein the cross-support includes at least one securing arrangement for fastening a portion of the mounting fixture thereto.

8. A connection arrangement according to claim 7, wherein the securing arrangement comprises at least one flange configured to overlie a co-operating securing portion of the mounting fixture, the flange and securing portion of the mounting fixture including at least one complementary aperture into which a fastener can be mounted to secure the flange and securing portion together.

9. A connection arrangement according to claim 7 or 8, wherein the securing arrangement comprises two spaced apart flanges defining a slot therebetween configured to receive therebetween the co-operating securing portion of the mounting fixture.

10. A connection arrangement according to any preceding claim, wherein each mounting fixture includes an engagement section for engagement to a portion of the vertical member, the engagement section having a co-operating shape to the portion of the vertical member to which it is to be fixed.

11. A connection arrangement according to any preceding claim, wherein the cross-support comprises a plurality of interconnected elements.

12. A connection arrangement according to claim 11, wherein the cross-support is formed from at least two spaced apart end elements interconnected by a cross-element, each of the end elements including a mount engagement formation and the cross-element including at least one beam securing formation.

13. A connection arrangement according to any preceding claim, wherein the beam securing formation of the cross-support is configured to fasten a portion of an end of the cross-member to the cross-support.

14. A connection arrangement according to any preceding claim, wherein the beam securing formation includes at least one flange configured to extend over

and interconnect to a portion of an end of the cross-member to the cross-support.

15. A connection arrangement according to claim 14, wherein the beam securing formation are releasably secured to the cross-support using at least one fastener.

16. A connection arrangement according to claim 15, wherein the fasteners comprise a plurality of threaded joints, clamp joints, U-bolts, bolts, rods, threaded body, flange, or a combination thereof.

17. A connection arrangement according to any preceding claim, wherein the connection arrangement comprises a modular construction.

18. A connection arrangement according to any preceding claim, including at least two pairs of spaced apart mounting fixtures, each pair of spaced apart mounting fixtures being securable to a vertical member at a selected height and being vertically spaced apart on the vertical member, each pair of mounting fixtures including a cooperating cross-support.

19. A connection arrangement according to claim 18, wherein a portion of the cross-member, preferably an end portion of the cross-member, is secured between two vertically spaced apart cross-members.

20. A connection arrangement according to any one of claims 18 or 19, further comprising a connector member, preferably flange connected between the two vertically spaced apart cross-supports.

21. A connection arrangement according to any preceding claim, wherein the mounting fixtures are attachable to or proximate to adjoining corners of the vertical member.

22. A connection arrangement according to any preceding claim, wherein the vertical member has a mounting face having two spaced apart vertical pillars

interconnected by a panel, and each mounting fixture of a pair of spaced apart mounting fixtures is securable to adjoining vertical pillars of a vertical member at a selected height.

23. A connection arrangement according to claim 22, further including a panel engagement section comprising a panel mounting fixture secured to a portion of a panel, and a beam connection arrangement which connects a portion of the end of the cross-member to the panel mounting fixture.

24. A connection arrangement according to any preceding claim, configured from at least two releasably engagable sections which enable the connection to be deconstructed.

25. A connection arrangement for connecting a cross-member to a vertical member, the vertical member having a mounting face having two spaced apart vertical pillars interconnected by a panel, the connection arrangement comprising:

- at least one pair of spaced apart mounting fixtures, each mounting fixture of a pair of spaced apart mounting fixtures being securable to adjoining vertical pillars of a vertical member at a selected height, each mounting fixture including a support engagement formation; and

- at least one cross-support configured to be secured between a pair of spaced apart mounting fixtures, the cross-support including at least two mount engagement formations which are configured to cooperatively engage with the support engagement formations of the respective pair of spaced apart mounting fixtures to mount the cross-support onto the respective mounting fixture, the cross-support also including a beam securing formation for securing a portion of a cross-member to the cross-support.

26. A connection arrangement for connecting a cross-member to a vertical member, comprising:

- a vertical member;
- a cross-member;

at least one pair of spaced apart mounting fixtures, each mounting fixture being securable to a vertical member at a selected height spaced apart from the adjoining mounting fixture of the pair of spaced apart mounting fixtures, each mounting fixture including a support engagement formation; and

at least one cross-support configured to be secured between a pair of spaced apart mounting fixtures, the cross-support including at least two mount engagement formations which are configured to cooperatively engage with the support engagement formations of the respective pair of spaced apart mounting fixtures to mount the cross-support onto the respective mounting fixture, the cross-support also including a beam securing formation for securing a portion of the cross-member to the cross-support.

27. A connection arrangement according to any preceding claim, wherein the cross-member and the vertical member comprise structural members, preferably load bearing structural members.

28. A connection arrangement according to any preceding claim, wherein the cross-member comprises a beam, struts or bar and the vertical member comprises a post, pillar or column.

29. A connection arrangement according to any preceding claim, wherein the cross-member and vertical member comprise part of a moment-resisting frame.

30. A connection arrangement according to any preceding claim, wherein the vertical member comprises a column consists of at least three spaced elongate tubes spaced apart around a central axis, each elongate tube being interconnected to an adjoining elongate tube by a panel.

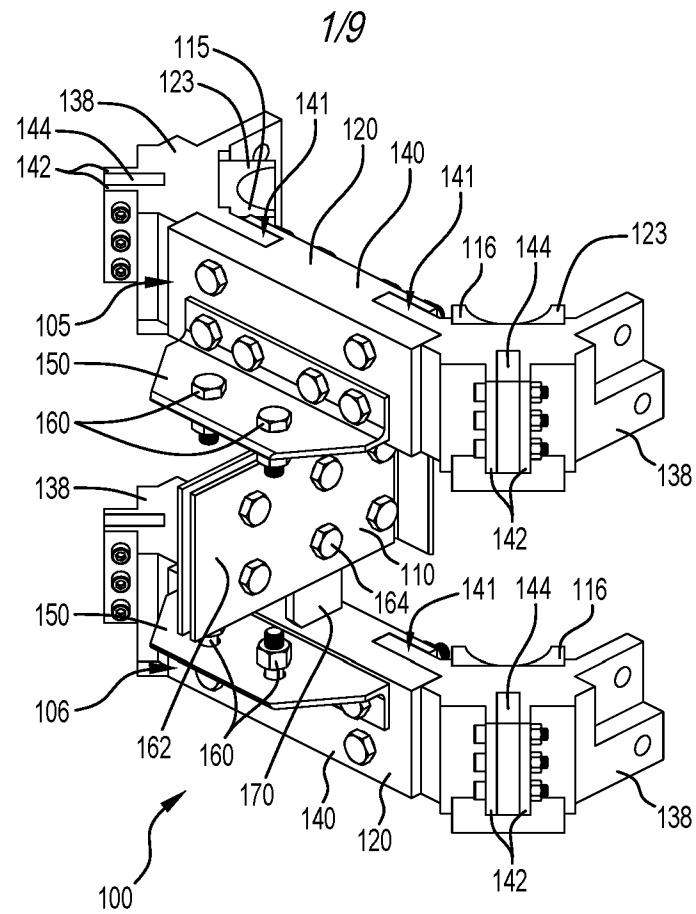


Figure 1

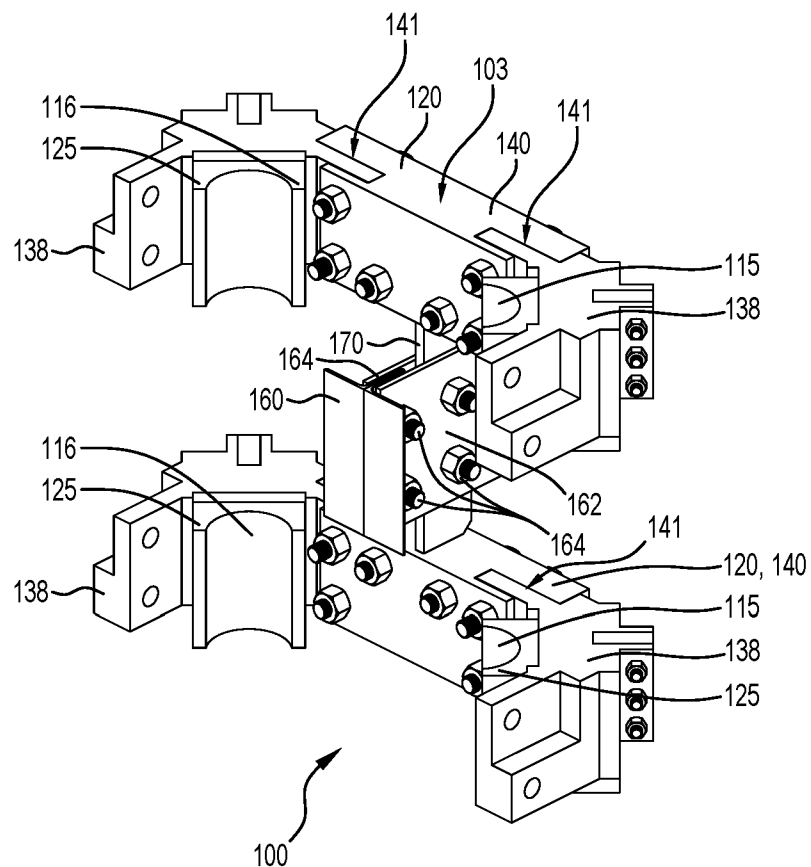


Figure 2

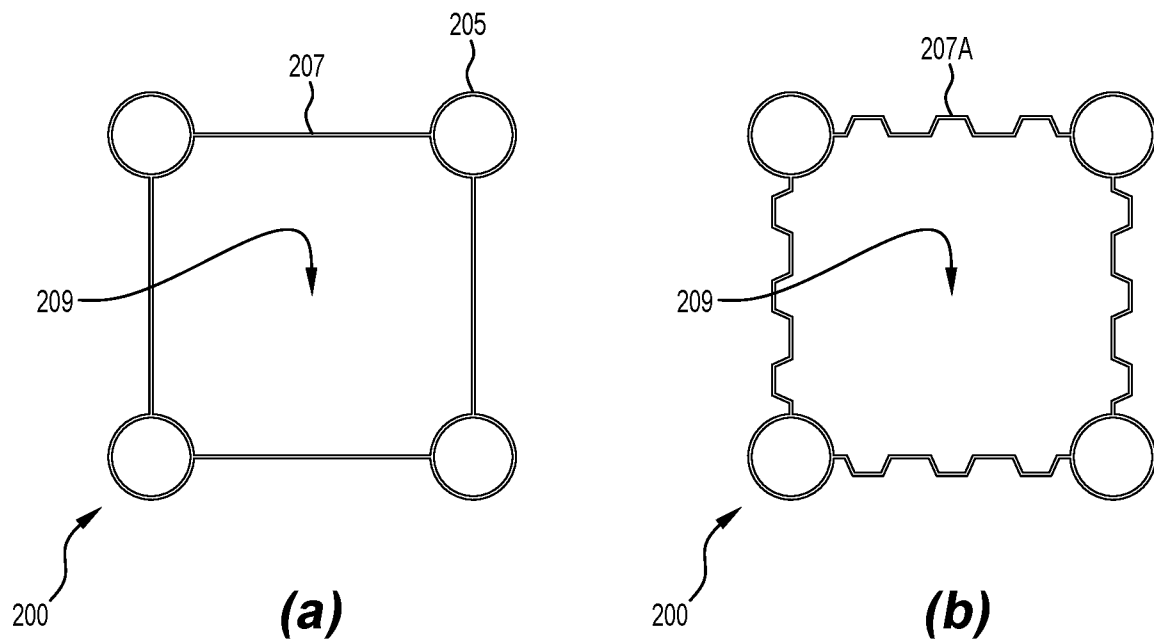


Figure 3

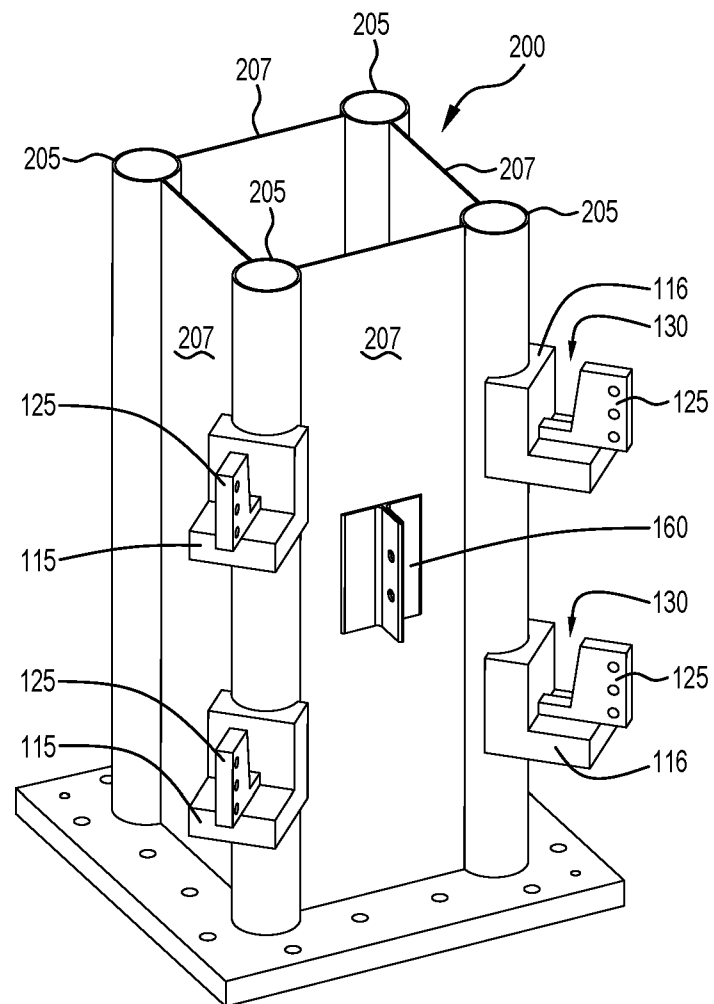


Figure 4

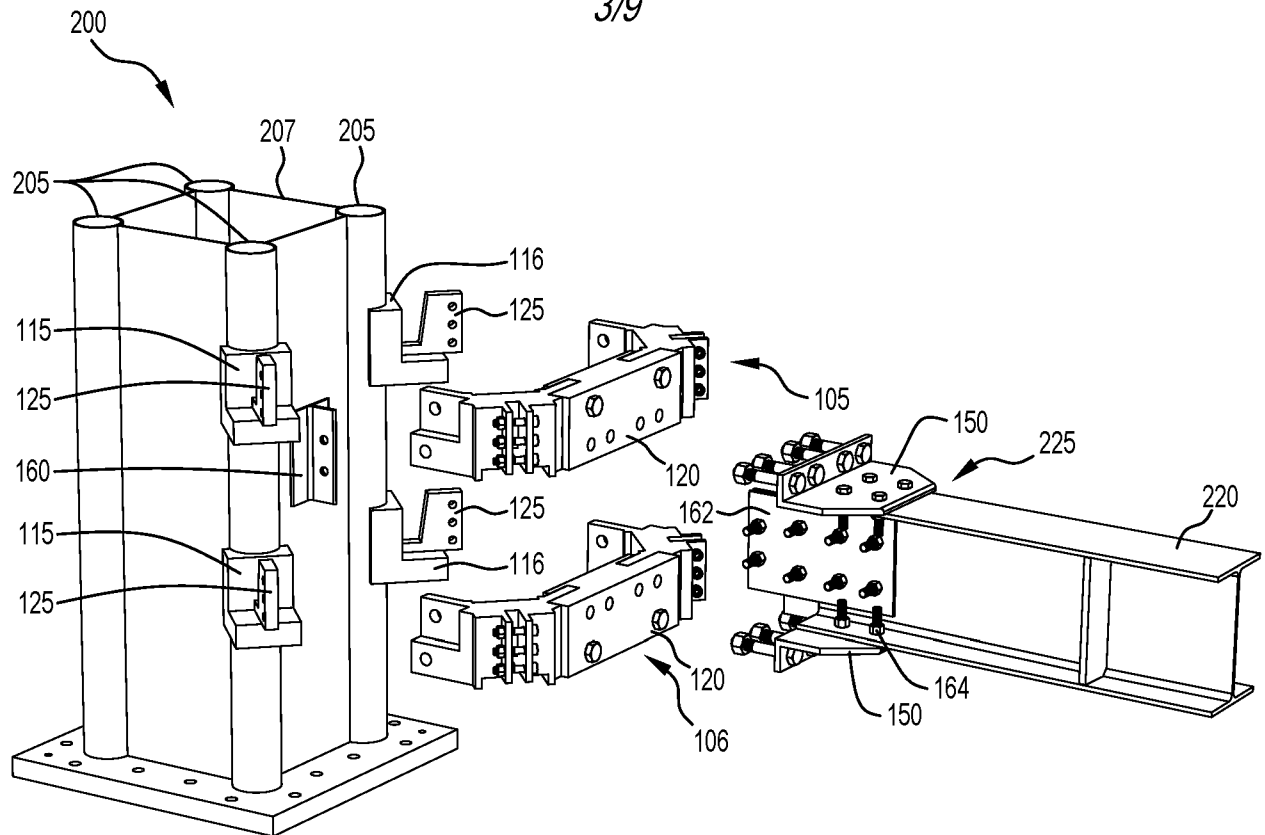


Figure 5

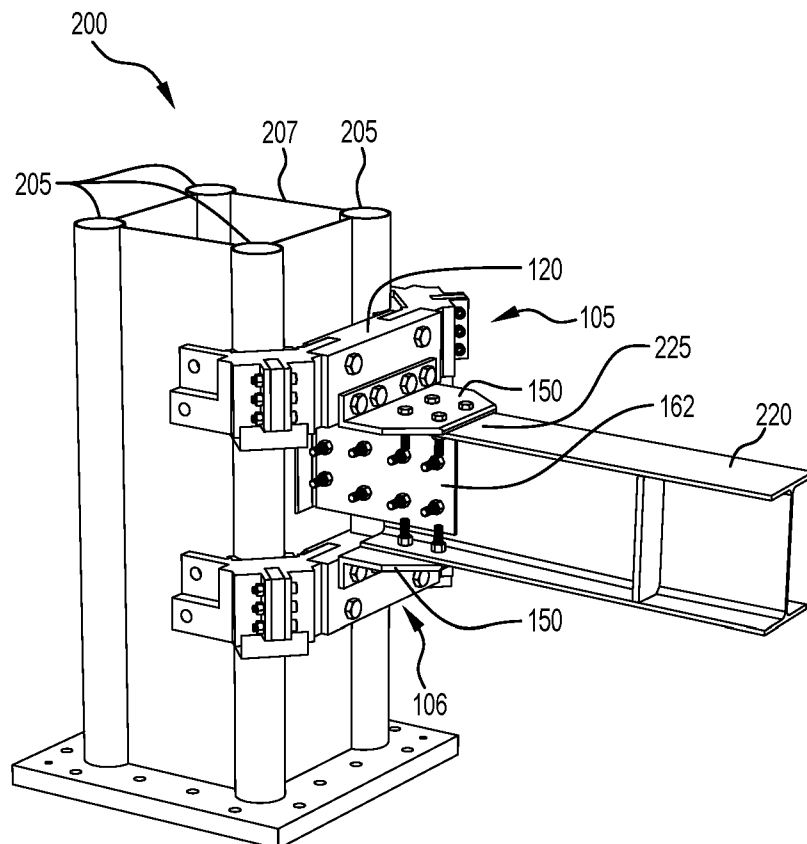
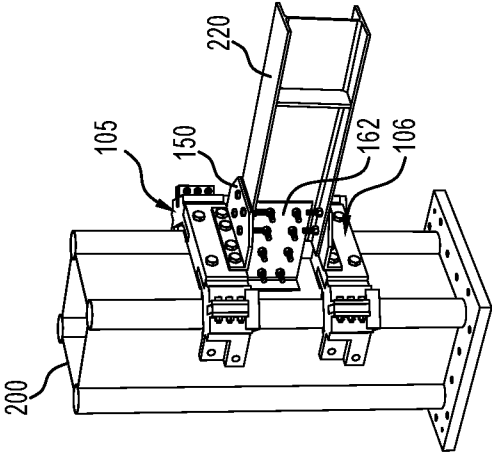
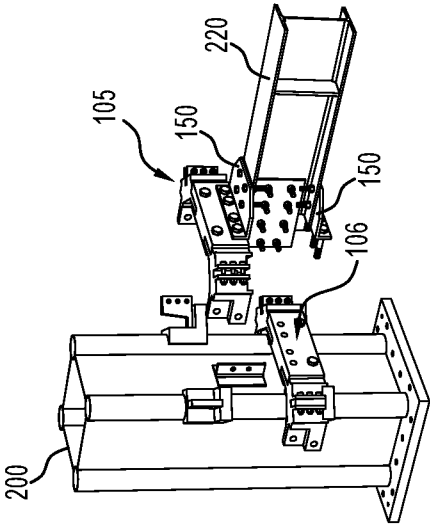


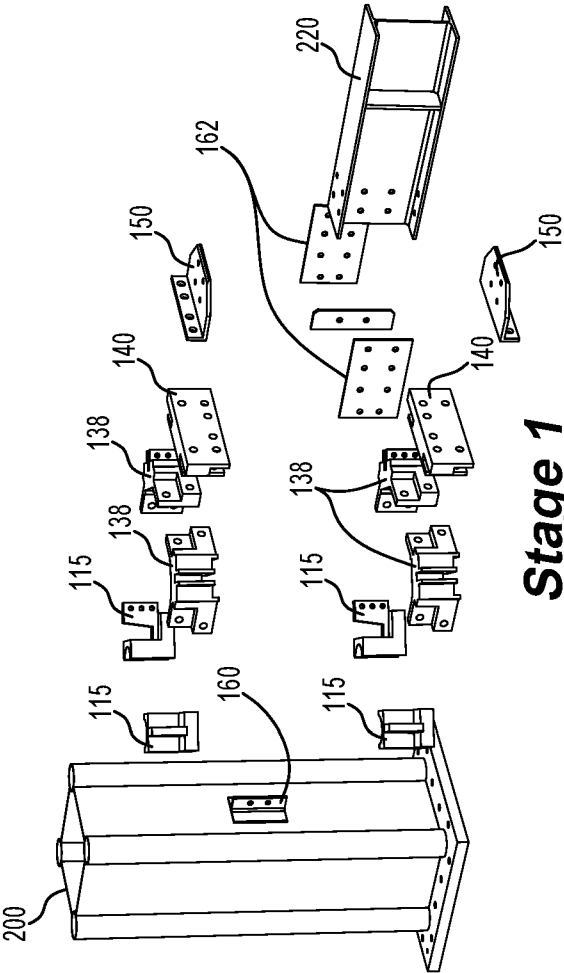
Figure 6



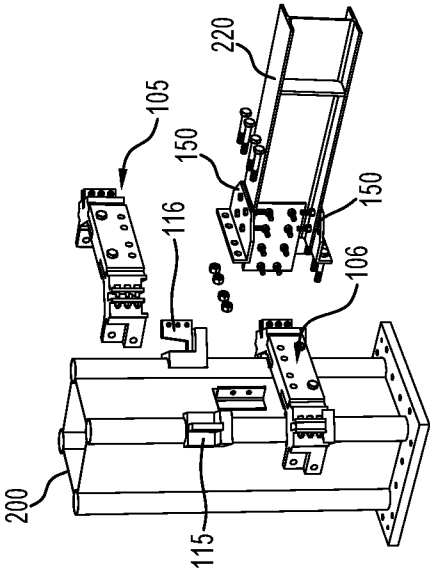
Stage 5



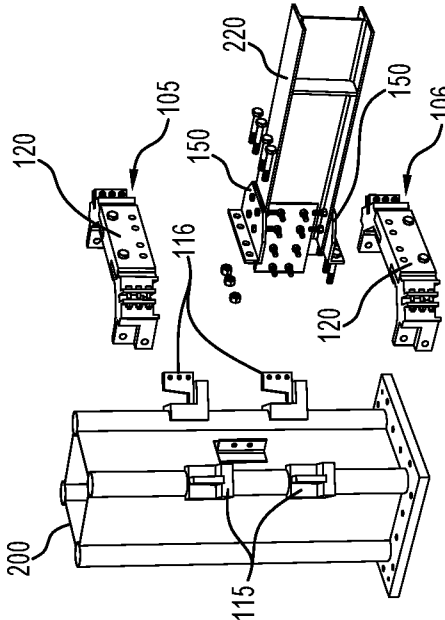
Stage 4



Stage 1

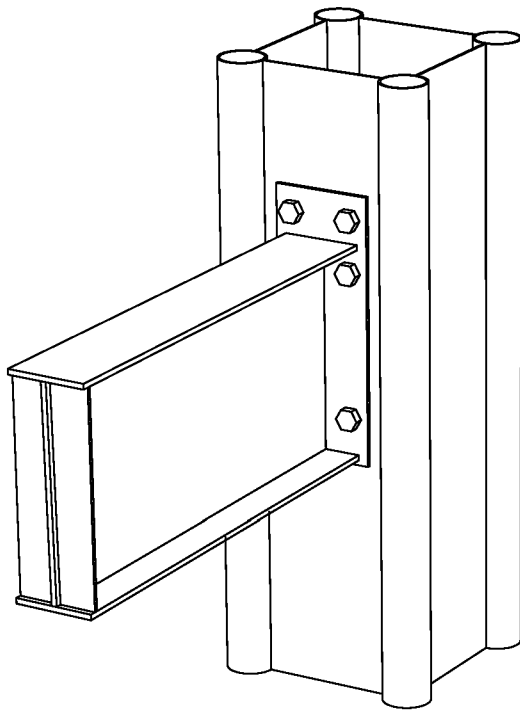


Stage 3

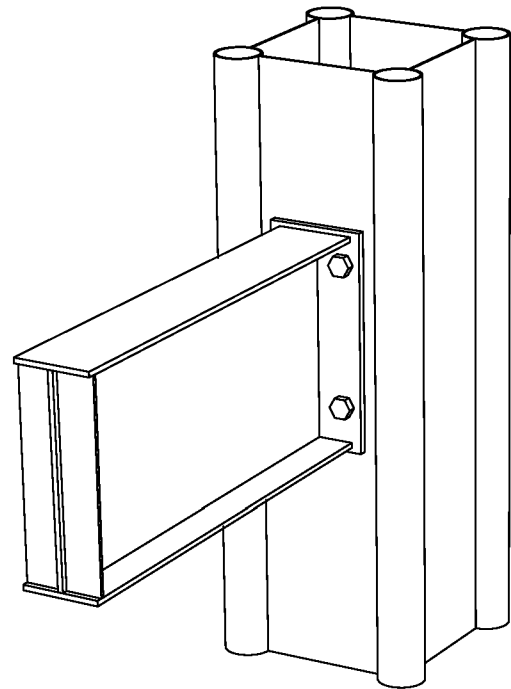


Stage 2

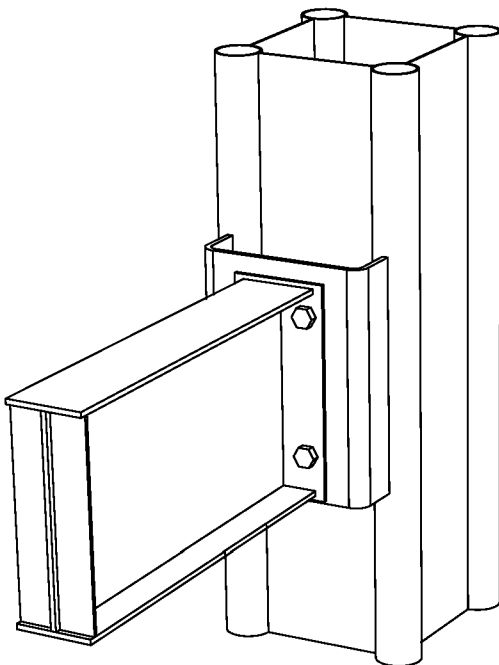
Figure 7



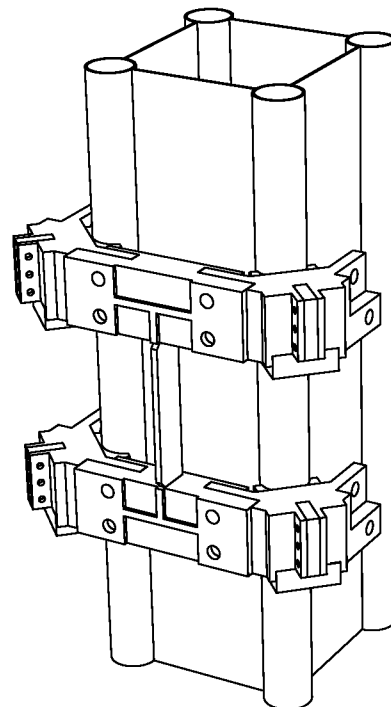
(a)



(b)



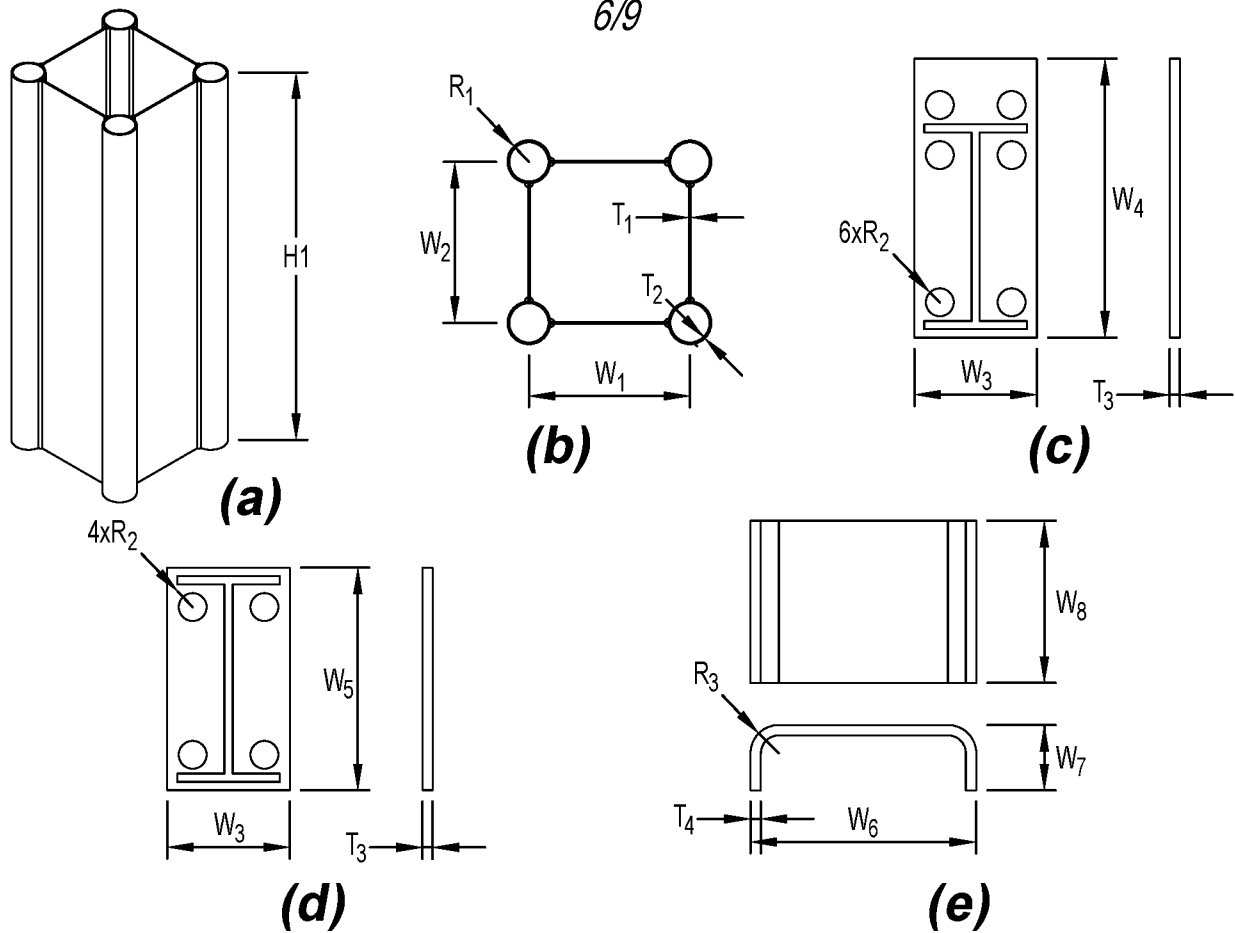
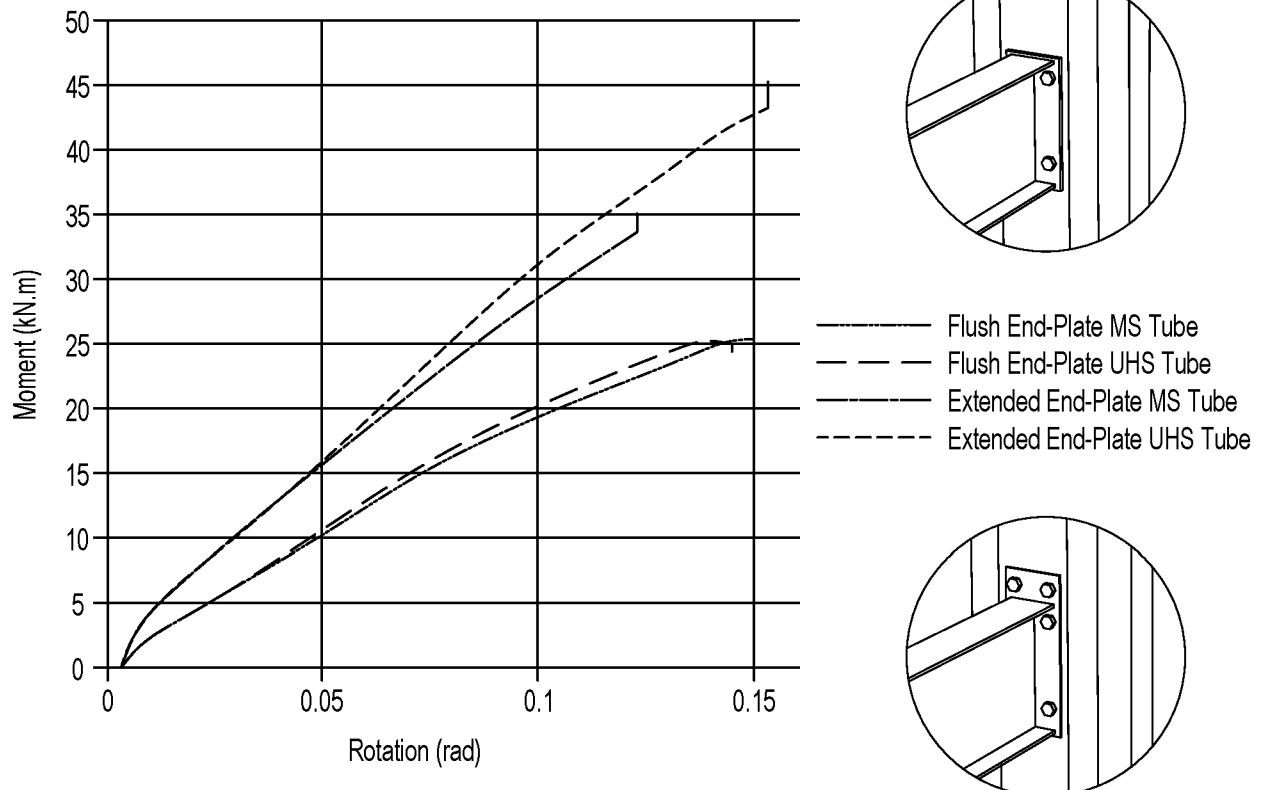
(c)



(d)

Figure 8

6/9

**Figure 9****Figure 10**

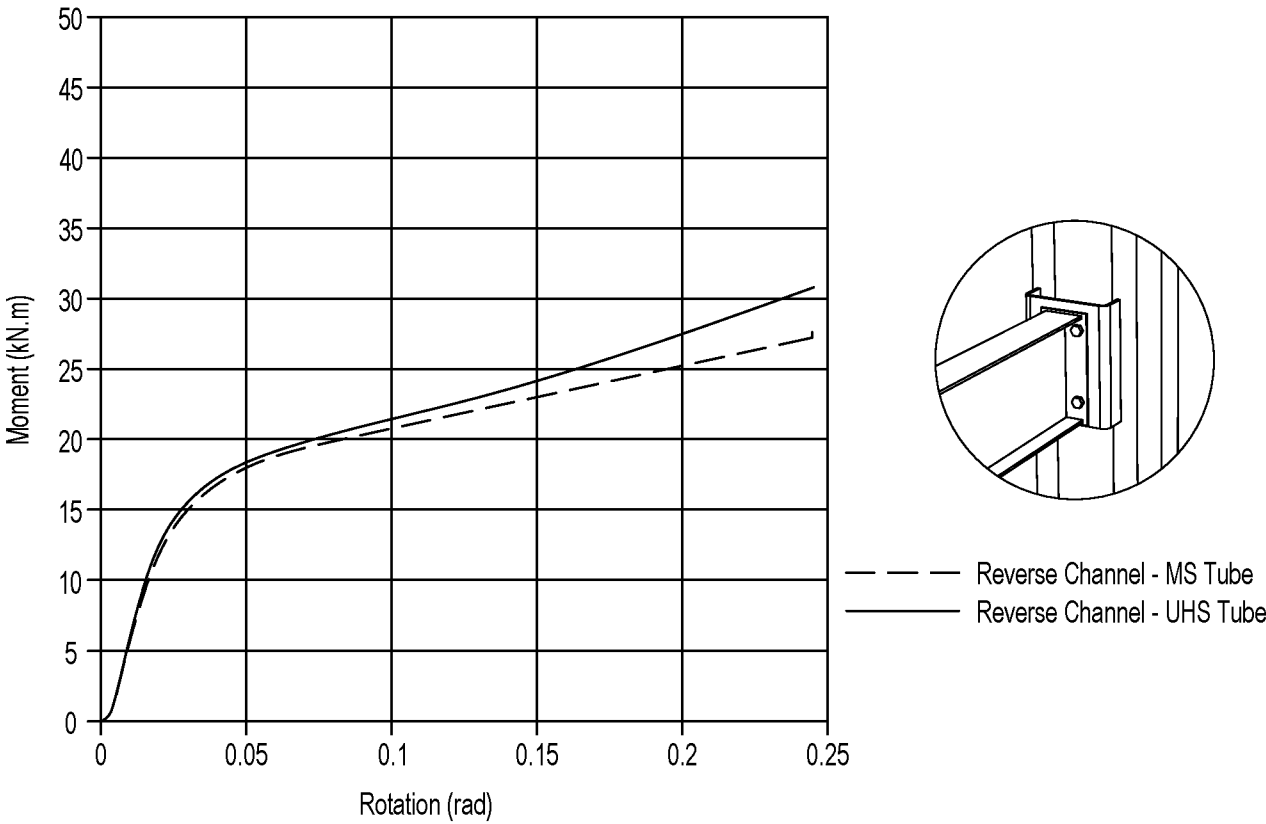


Figure 11

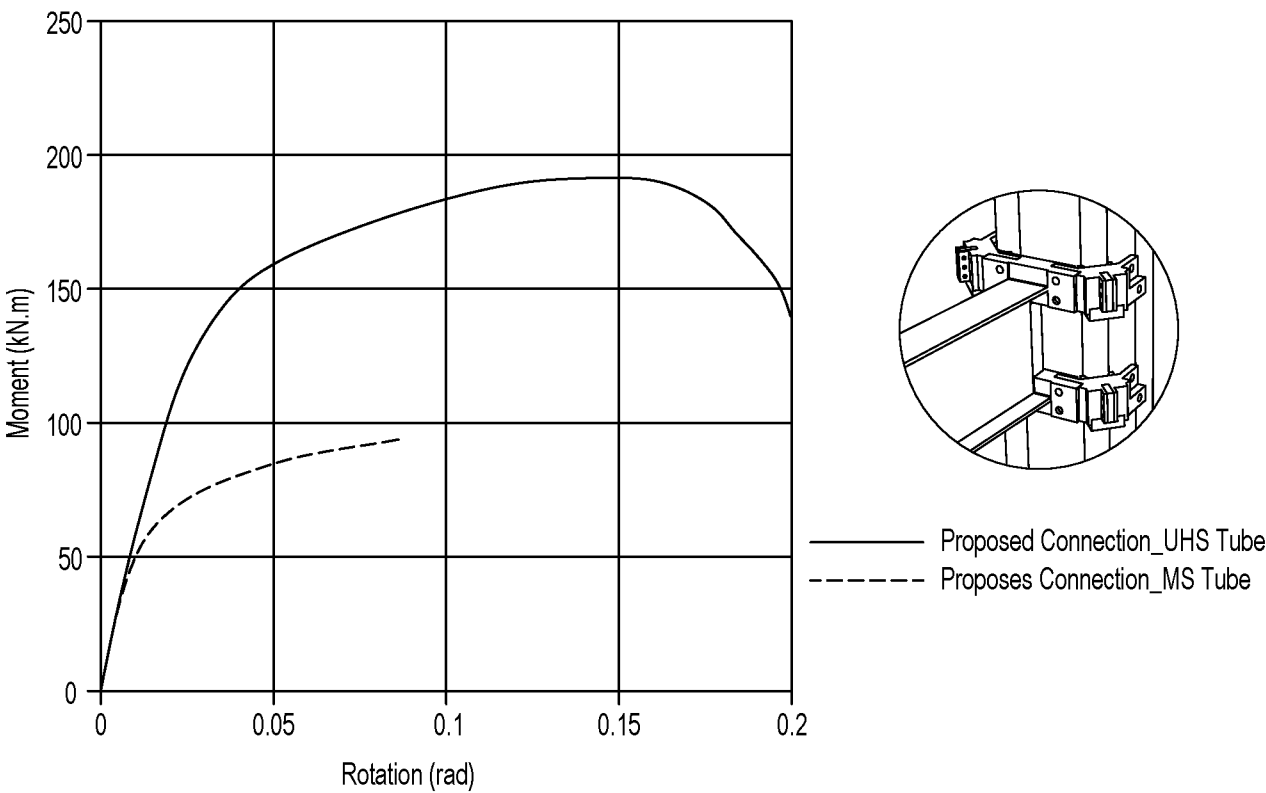


Figure 12

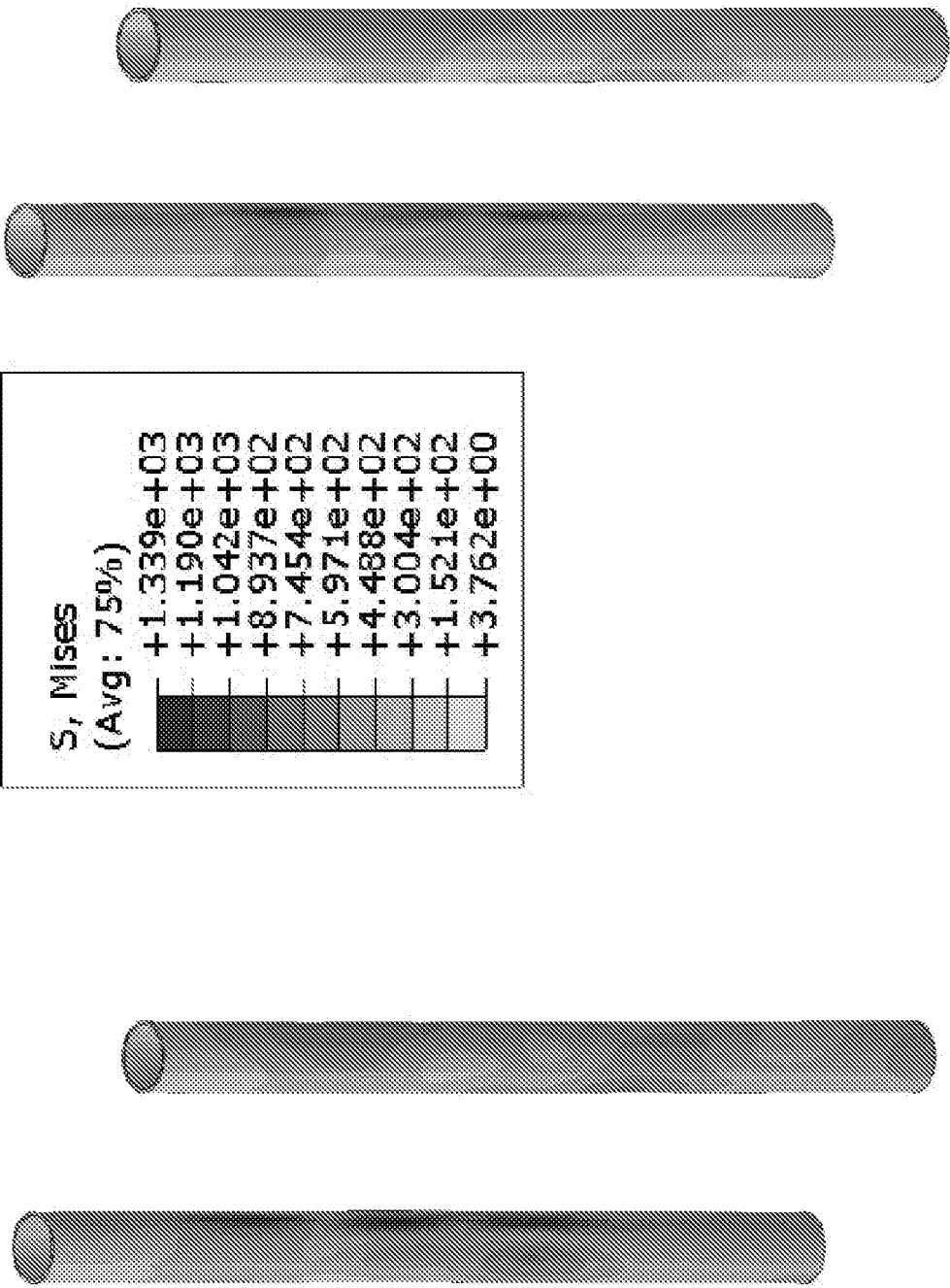


Figure 13 (b)

Figure 13 (a)

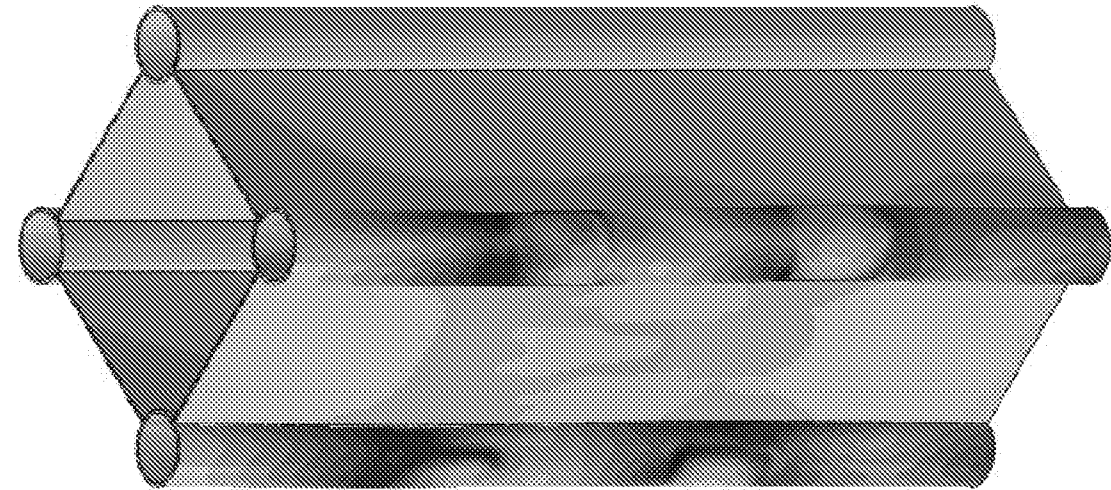


Figure 13 (d)

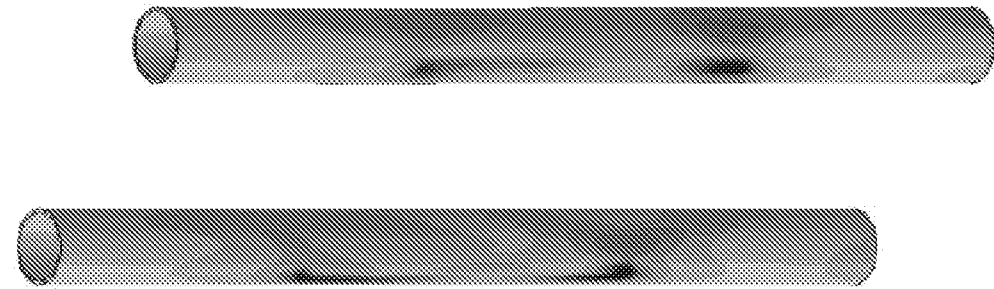
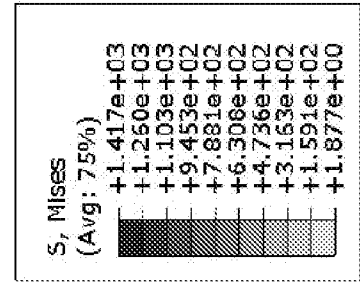
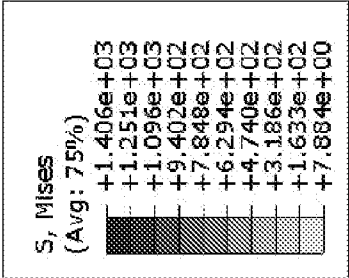


Figure 13 (c)



INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2017/050923

A. CLASSIFICATION OF SUBJECT MATTER

E04B 1/58 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: PATENW IPC/CPC E04B1/5812, E04B1/5831, E04B1/5806, E04B1/5825, E04B1/58 and keywords (connect, join, mount, bracket, column, pillar, mast, pole, post, vertical, upright, beam, cross, stud, second, pair, edge, corner, rectangular and like terms)

Applicant(s)/Inventor(s) name searched in internal databases provided by IP Australia, AusPat and Espacenet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

☒ Further documents are listed in the continuation of Box C☒ See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 30 October 2017		Date of mailing of the international search report 30 October 2017	
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustalia.gov.au		Authorised officer Leopold Filipovic AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61262832105	

INTERNATIONAL SEARCH REPORT		International application No.
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			