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(54) **CONNECTION SYSTEM FOR CONCRETE SECTIONS**

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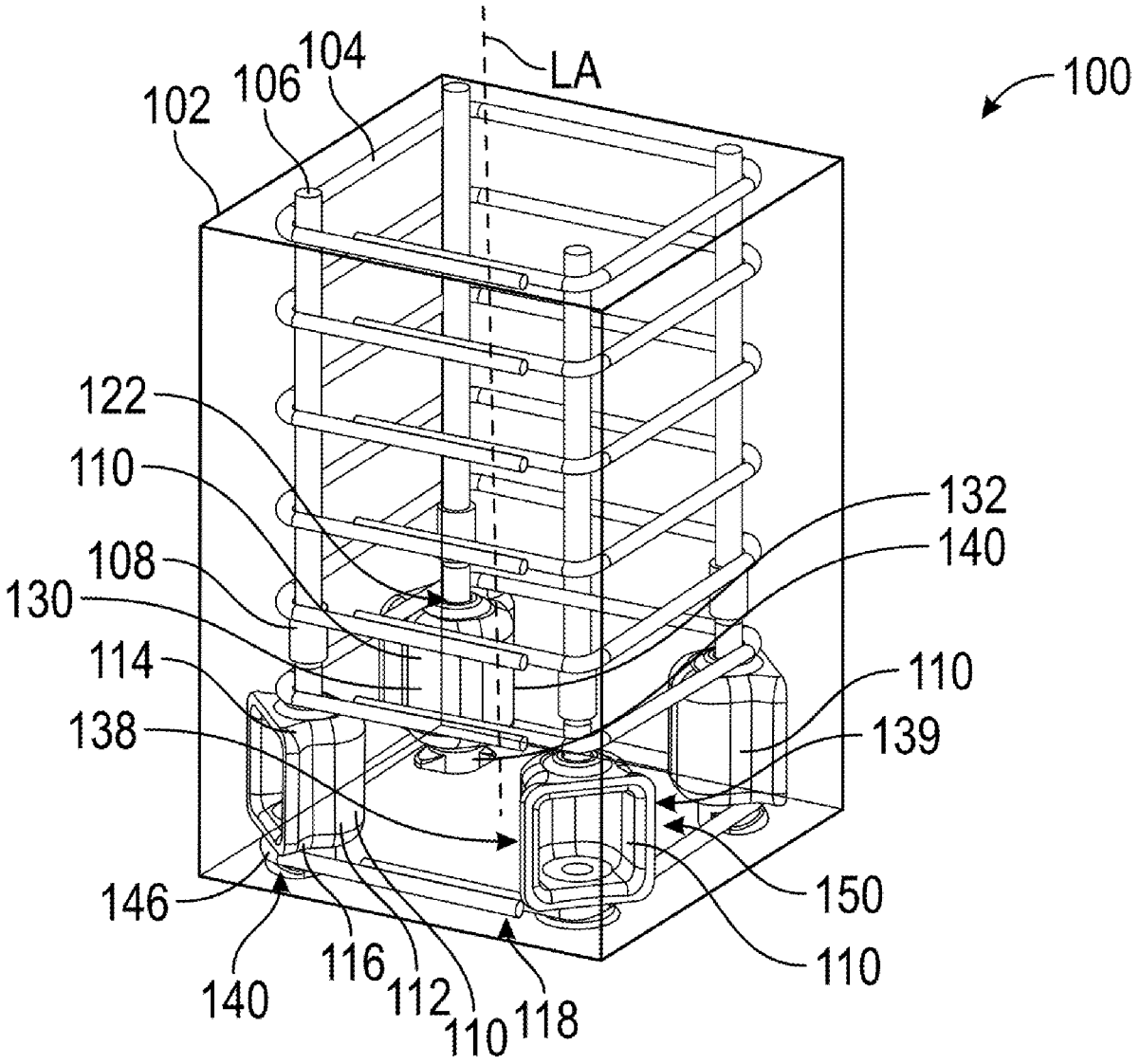
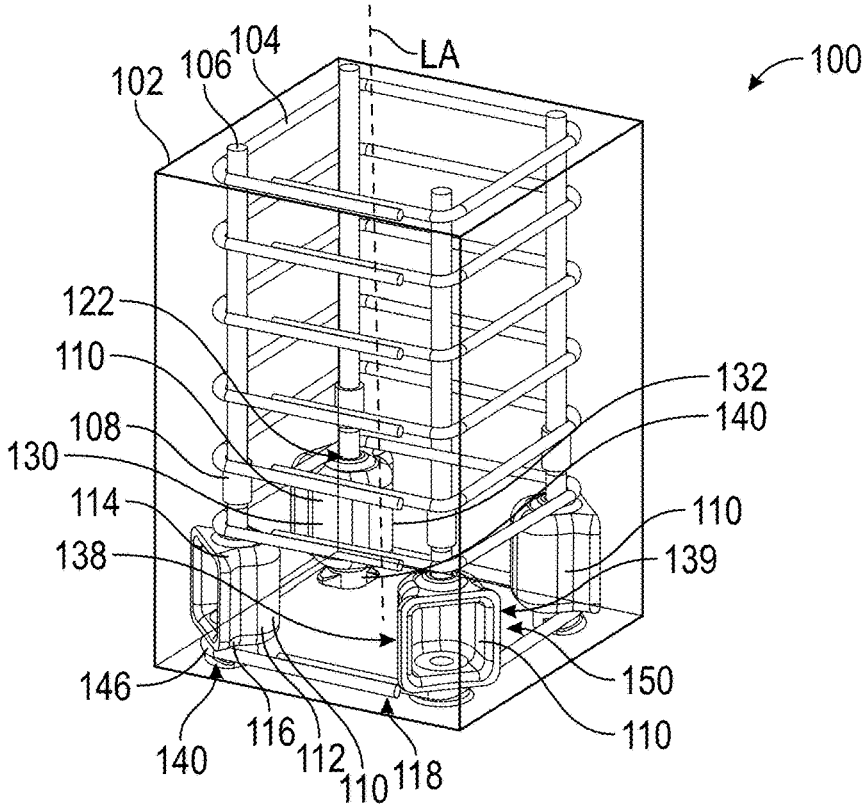
CPC ..... ***E04C 5/163*** (2013.01); ***E04C 5/0604*** (2013.01)

(57) **ABSTRACT**

A column shoe assembly can include a shoe body including an access opening and a lower rebar opening that defines a connection axis to receive a threaded rebar end. A lower protrusion or a vertical member can extend from shoe body to secure a rebar tie assembly to the shoe body.




LA
100
102
106
104
122
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114
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146
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116
112
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118
132
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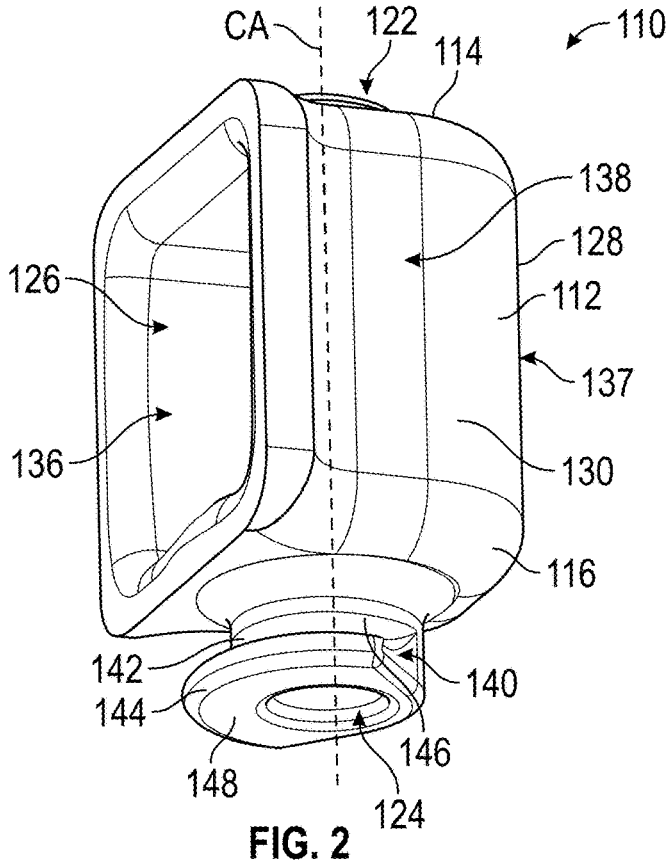
110
139
150
110

FIG. 1


CA
122
114
110
138
128
126
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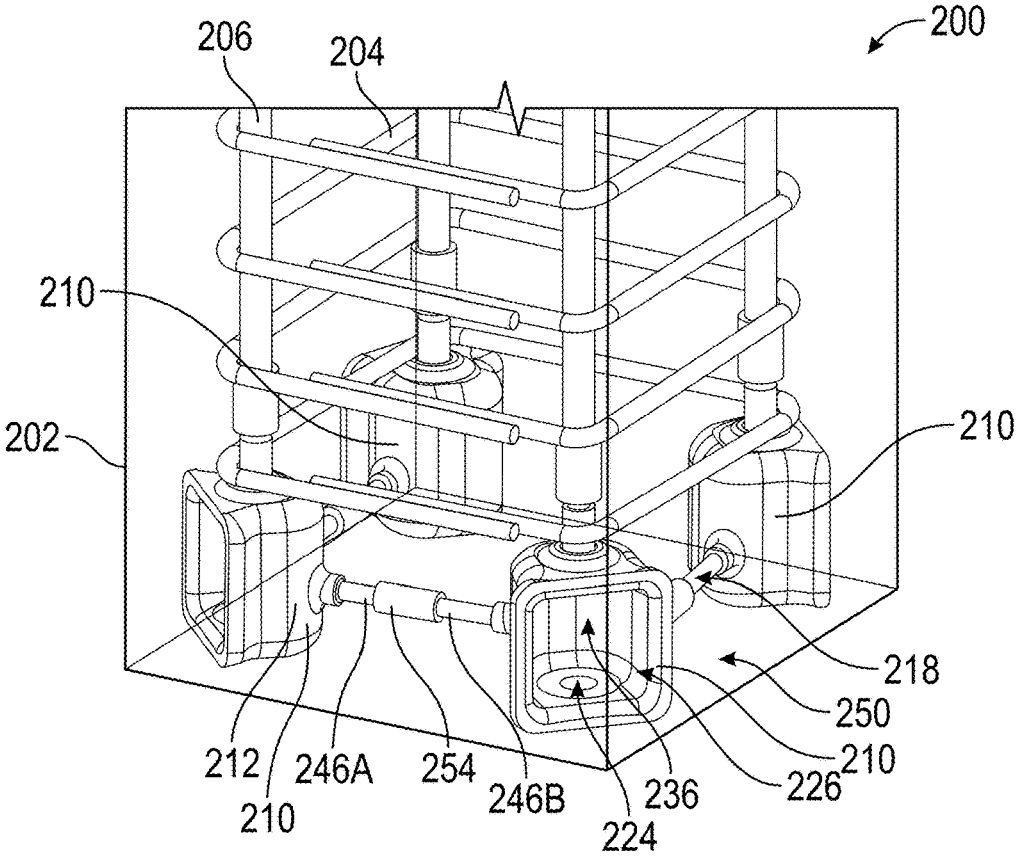
137
136
130
116
142
144
148
140
146
124

FIG. 2


200
206
204
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202
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218
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226
236
224
246B
254
246A
212
210

FIG. 3

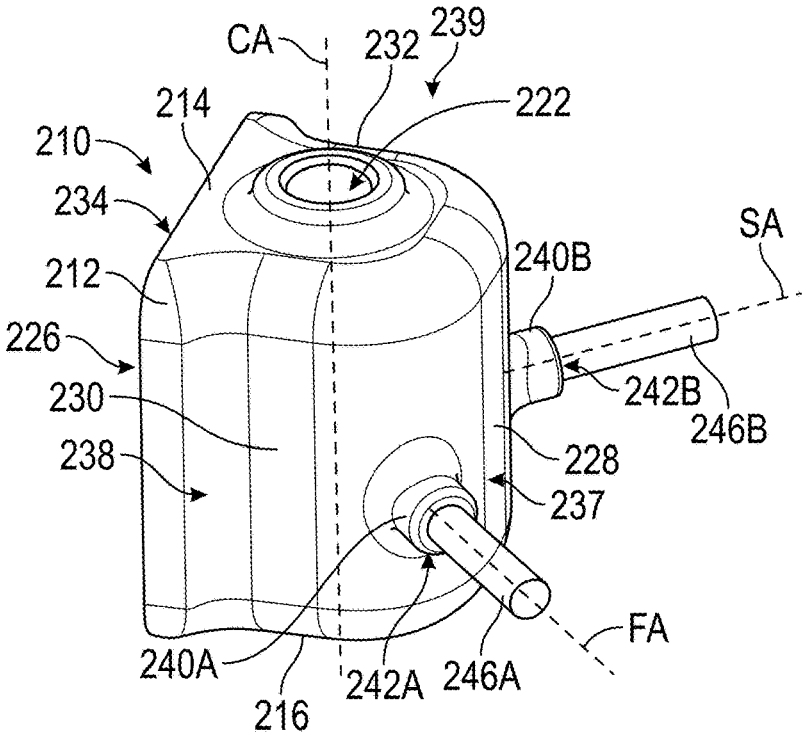
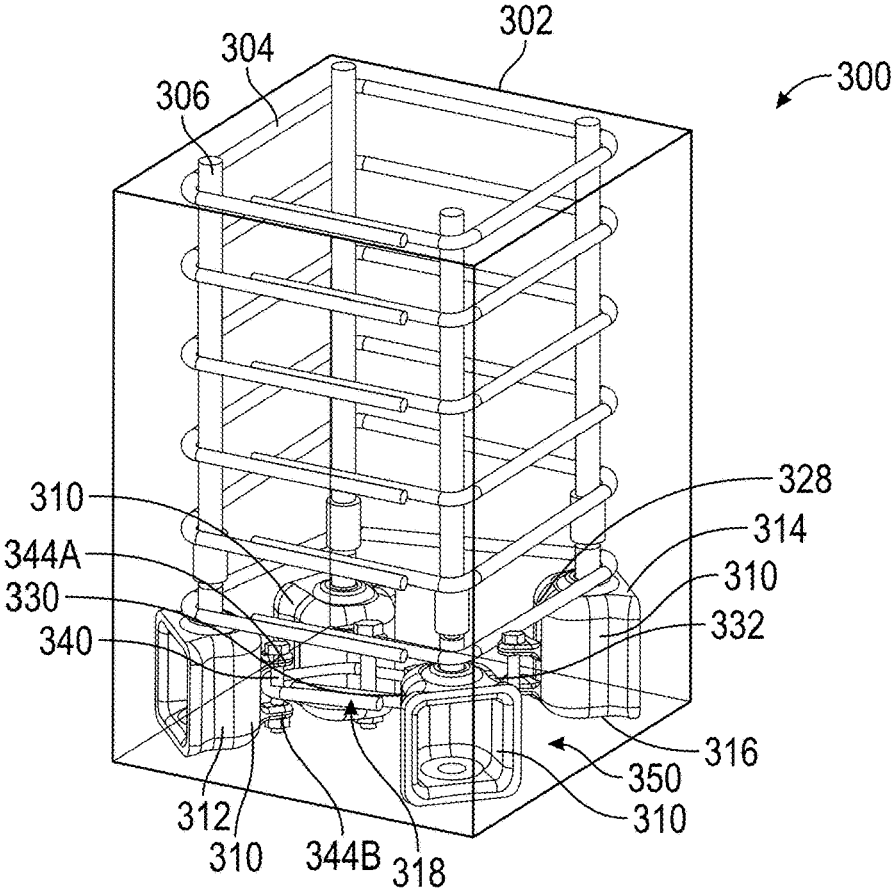

CA
232
239
222
214
210
234
212
240B
SA
226
242B
246B
230
228
238
237
FA
240A
242A
246A
216

FIG. 4


302
304
306
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344A
330
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328
314
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332
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312
310
344B
318

FIG. 5

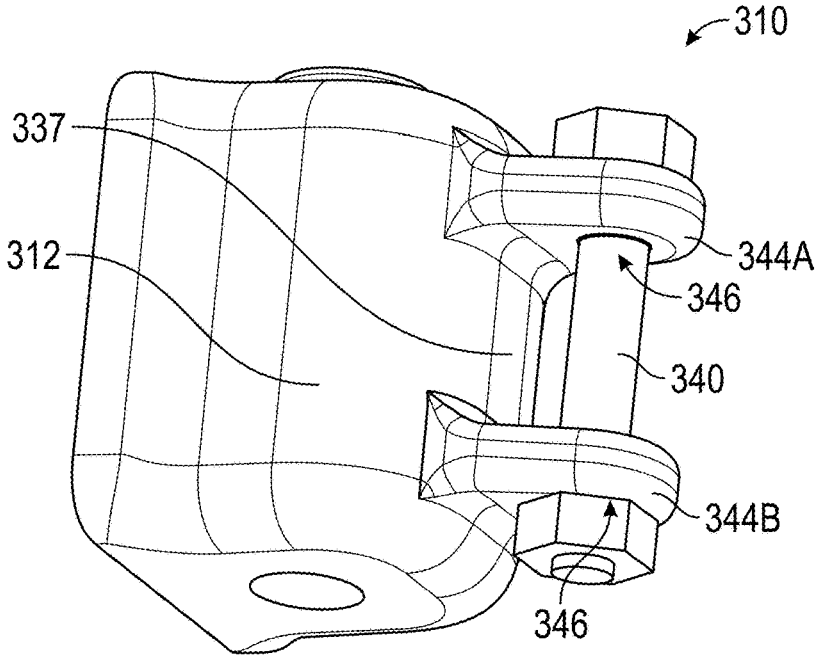
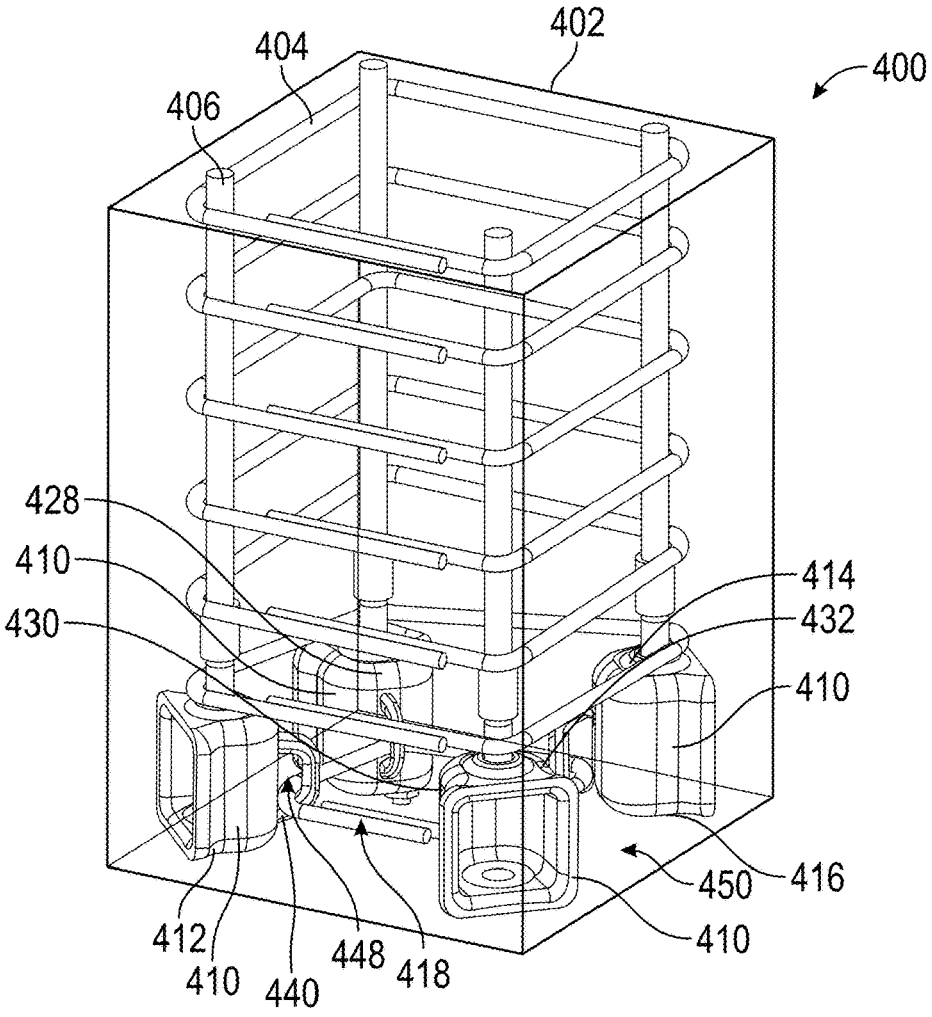

310
337
312
344A
346
340
344B
346

FIG. 6


402
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448
418

FIG. 7

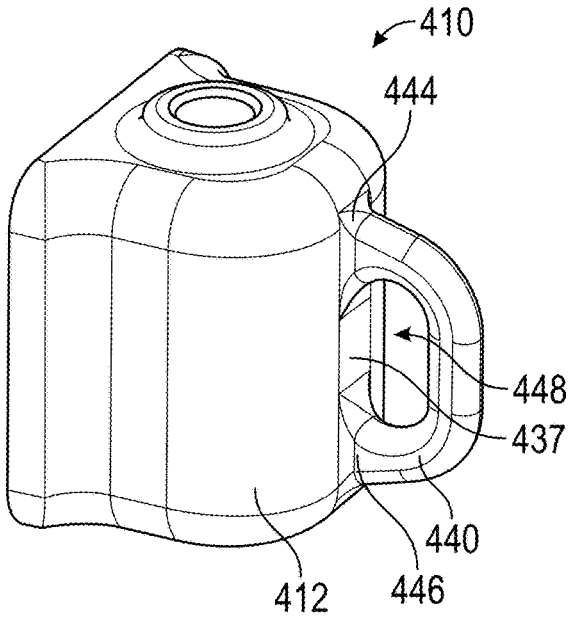
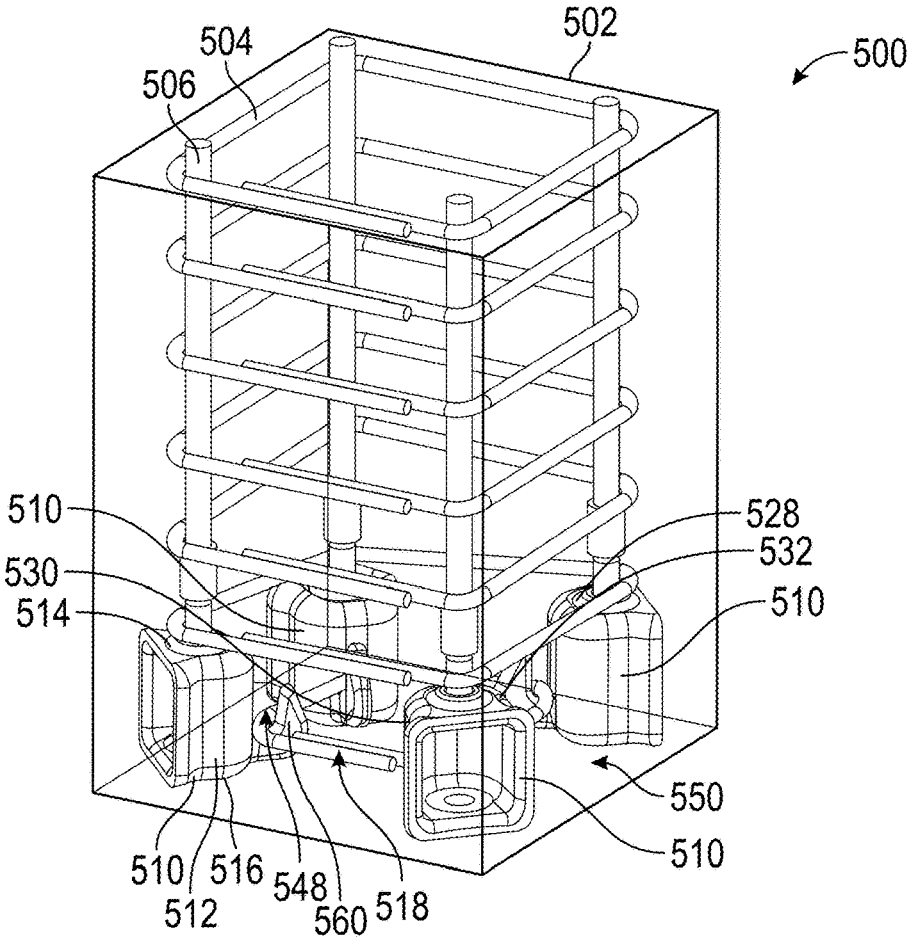

410
444
448
437
440
412
446

FIG. 8


500
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532
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510
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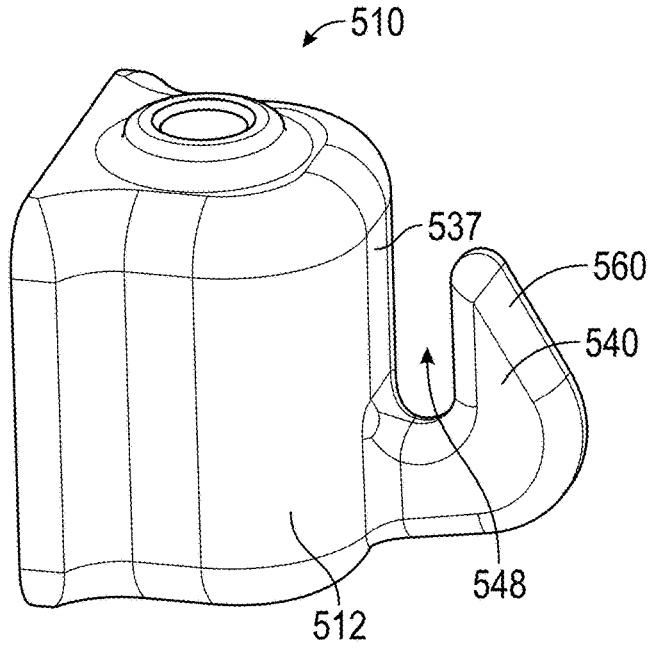
560
518

FIG. 9


510
537
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540
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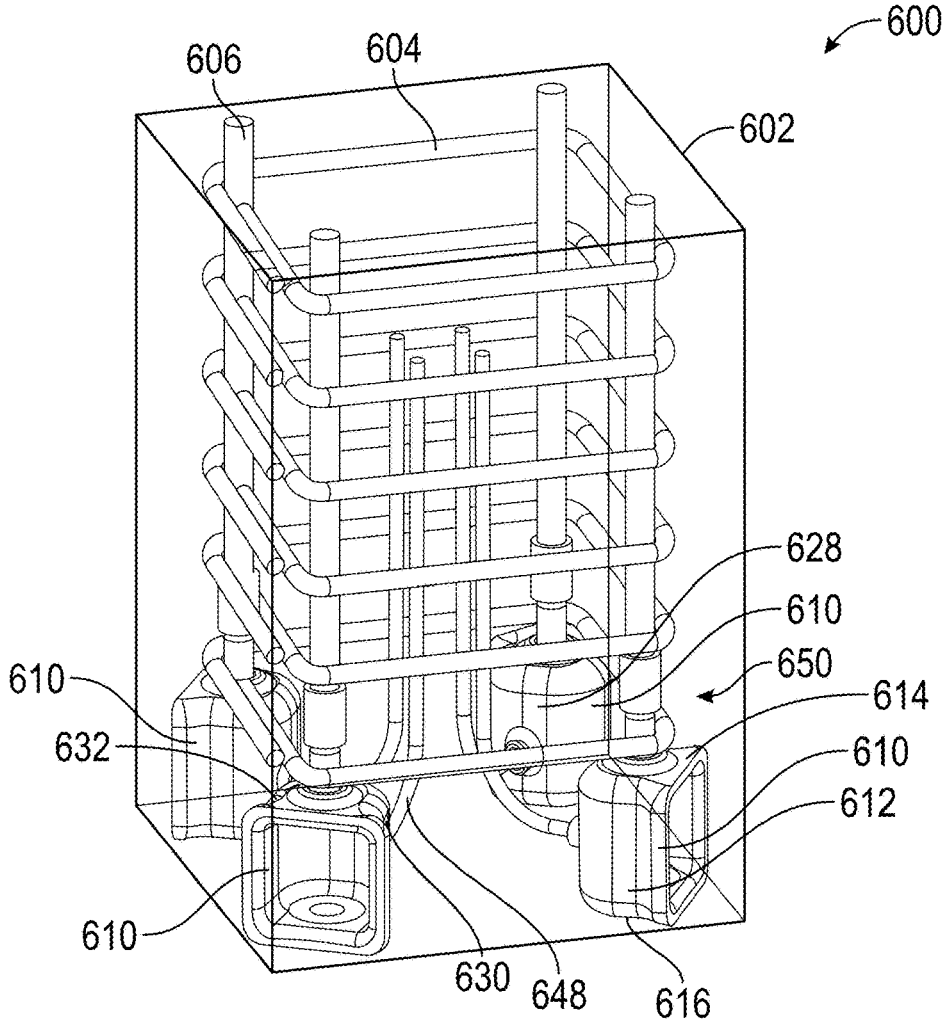
512

FIG. 10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606
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602
628
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632
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648
616

FIG. 11

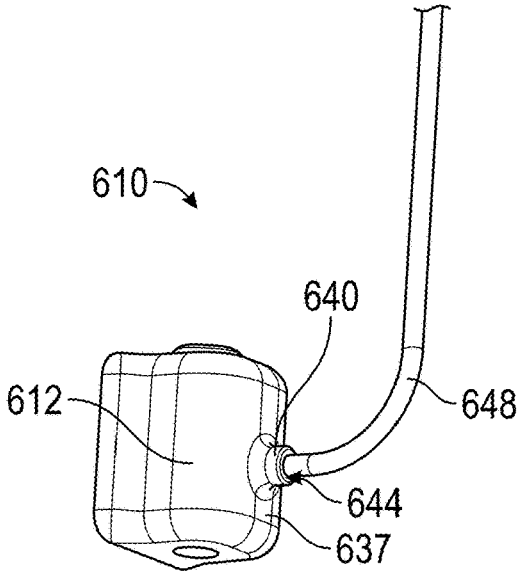
610
640
612
648
644
637

FIG. 12

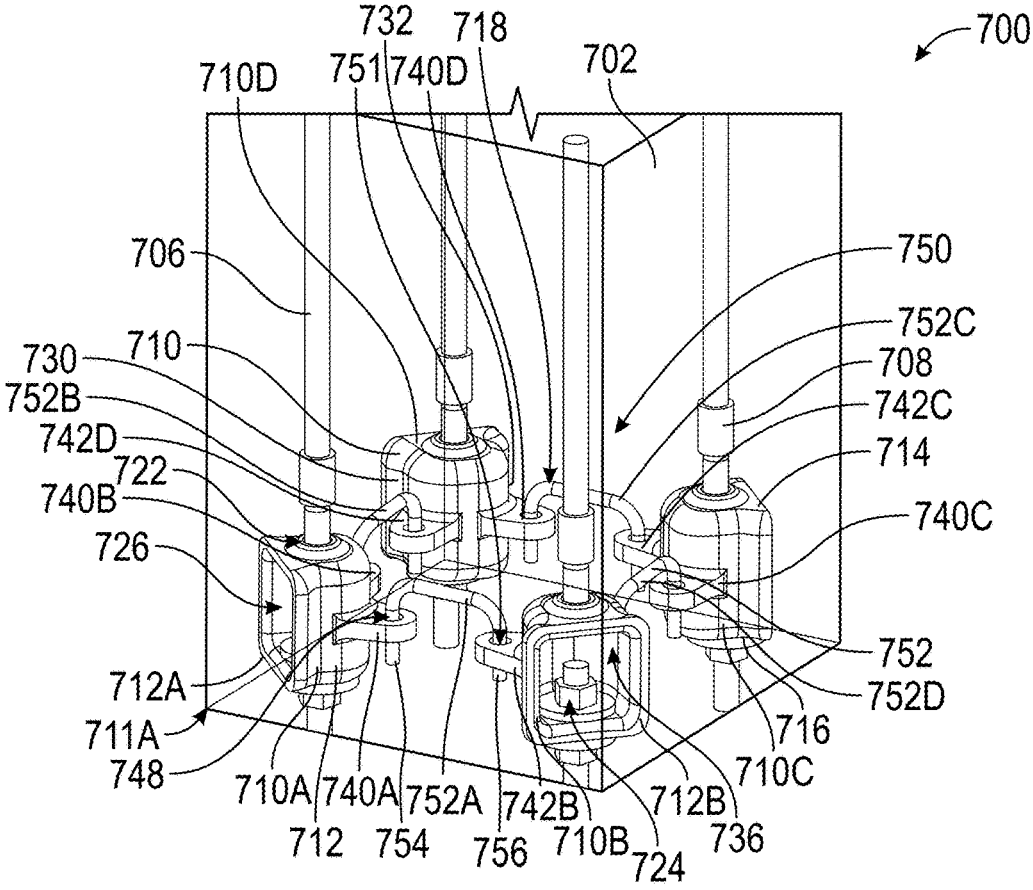
700
732
718
710D
751
740D
702
706
750
752C
730
710
708
752B
742C
742D
714
722
740B
740C
726
752
712A
752D
711A
716
748
710C
710A
740A
752A
742B
712B
712
754
756
710B
736
724

FIG. 13

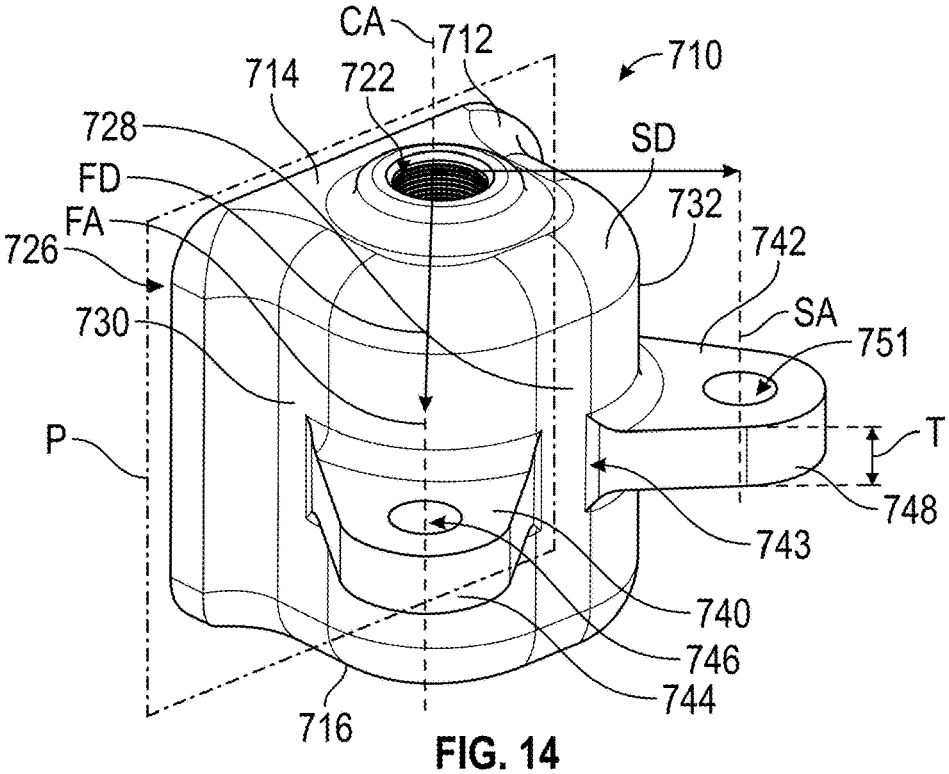
CA
712
710
714
722
728
SD
FD
732
FA
742
726
SA
730
751
T
P
748
743
740
746
744
716

FIG. 14

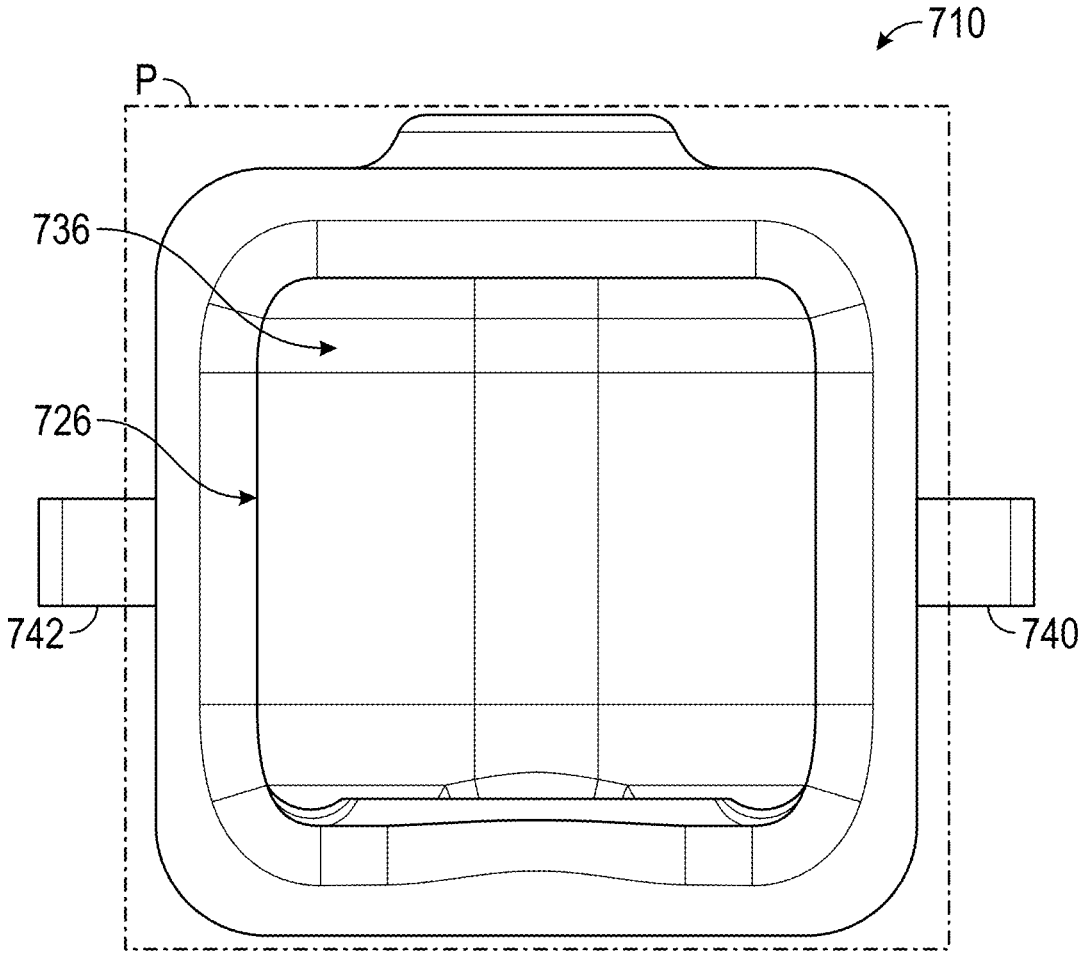


FIG. 15

# CONNECTION SYSTEM FOR CONCRETE SECTIONS

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims priority to and incorporates by reference U.S. Provisional Patent Application No. 63/500,185, filed May 4, 2023.

## BACKGROUND

**[0002]** Concrete is a mixture of cement, water, and aggregates. Known for its strength, durability, low maintenance, energy efficiency, and relatively low cost, concrete is one of the most frequently used building materials used for constructing buildings, bridges, roads, sidewalks and other structures. In some structures, concrete is used in combination with reinforcement bars (herein, rebars). The combination of concrete and rebars is known as reinforced concrete and is widely used to mitigate the weak tension of concrete by distributing the tensile forces evenly across the structure and support heavy loads.

## SUMMARY

**[0003]** Some embodiments of the invention provide a column shoe. A shoe body can include an access opening and a lower rebar opening that defines a connection axis to receive a threaded rebar end. A lower protrusion may extend from the lower end of the shoe body to secure a rebar tie assembly to the shoe body.

**[0004]** In some examples, an assembly can include a plurality of the column shoes. A rebar tie assembly can engage the lower protrusions of the column shoes to connect the column shoes together.

**[0005]** In some examples, a method of installing a rebar assembly can include arranging a plurality of the column shoes in a spaced array. A rebar tie assembly can be engaged with the lower protrusions of the column shoes to connect the column shoes together. Concrete can be poured to cover the column shoes and the rebar tie assembly.

**[0006]** Some embodiments of the invention provide a column shoe with a shoe body that includes an access opening and a lower end with a lower rebar opening that defines a connection axis to receive a threaded rebar end. A first threaded opening can be included on a first lateral side of the shoe body to secure a first threaded rebar of a rebar tie assembly to the shoe body. A second threaded opening can be included on a second lateral side of the shoe body to secure a second threaded rebar of the rebar tie assembly to the shoe body.

**[0007]** In some examples, an assembly can include a plurality of the column shoes. A rebar tie assembly can include threaded rebar segments that engage the first and second threaded openings of the column shoes to connect the column shoes together.

**[0008]** In some examples, a method of installing a rebar assembly can include arranging a plurality of the column shoes in a spaced array. A respective first rebar length can be engaged with each of first threaded openings of the plurality of column shoes and a respective second rebar length can be engaged with each of the second threaded openings of the plurality of column shoes. Sets of the first and second rebar lengths can be secured together with turnbuckles to connect the column shoes together. Concrete can be poured to cover the column shoes and the rebar tie assembly.

**[0009]** Some embodiments of the invention provide a column shoe with a shoe body that includes an access opening at a front side, and a lower end with a lower rebar opening that defines a connection axis to receive a threaded rebar end. A vertical member can extend at a back side of the shoe body to secure a rebar tie assembly to the shoe body.

**[0010]** In some examples, an assembly can include a plurality of the column shoes. A rebar tie assembly can engage the vertical members of the column shoes to connect the column shoes together.

**[0011]** In some examples, a method of installing a rebar assembly can include arranging a plurality of the column shoes in a spaced array. A rebar tie assembly can be engaged with the vertical members of the column shoes to connect the column shoes together. Concrete can be poured to cover the column shoes and the rebar tie assembly.

**[0012]** In some examples, an assembly for a concrete column can include a first shoe body and a second shoe body. Each of the first and second shoe bodies defines an internal cavity, a lower wall, an upper wall, an opening, a first lug, and a second lug, respectively. The internal cavity is closed continuously around a rear side and at opposite lateral sides by a rear wall, a first side wall, and a second side wall of the respective first or second shoe body. The lower wall can include a lower rod opening that defines a connection axis and receives a threaded end of a first length of rod into the internal cavity along the connection axis. The upper wall can secure a second length of rod opposite the lower rod opening. The opening opens into the internal cavity at a front side of the shoe body to provide access to secure the threaded end of the first length of rod within the internal cavity. The first lug protrudes from one or more of the first side wall or the rear wall. The second lug protrudes from one or more of the second side wall or the rear wall. A tie assembly can include a first tie that can be secured to, and extend between, the first lug of the first shoe body and the second lug of the second shoe body to secure the first and second shoe bodies together.

**[0013]** In some examples, an assembly for a concrete column can include a first shoe body, a second shoe body and a third shoe body. Each of the first shoe body, the second shoe body, and the third shoe body can include an internal cavity, a lower rod opening, an upper wall, a first lug and a second lug. The lower rod opening can receive a threaded end of a corresponding first length of rod into the internal cavity along a connection axis to be secured within the internal cavity. The upper wall can secure a corresponding second length of rod (e.g., opposite the lower rod opening). The first lug can protrude in a first direction away from the connection axis and the second lug can protrude in a second direction away from the connection axis. A tie assembly can include a first tie and a second tie. The first tie can extend between the first lug of the first shoe body and the second lug of the second shoe body to secure the first and second shoe bodies together. The second tie can extend between the second lug of the first shoe body and the first lug of the third shoe body to secure the first and third shoe bodies together.

**[0014]** In some examples, a method of forming a concrete column can include arranging a first shoe body and a second shoe body in a spaced array. Internal cavities of the first and second shoe bodies can be closed continuously around a rear side and at opposite lateral sides by a rear wall, a first side

wall, and a second side wall of the respective first or second shoe body. Lower rod openings can define connection axes to receive ends of first lengths of rod into the internal cavities. Openings into the internal cavity at front sides of the shoe bodies can provide access to the ends of the first lengths of rod within the internal cavities. First and second lugs can extend away from the corresponding connection axis. Second lengths of rod can be secured to upper ends of the first and second shoe bodies. A tie assembly can be engaged with the first and second shoe bodies, including: securing a first tie to the first lug of the first shoe body and to the second lug of the second shoe body to extend between, and secure together, the first and second shoe bodies. Concrete can be poured to cover the first and second shoe bodies and the tie assembly, with the lower rod openings and the openings at the front sides of the first and second shoe bodies remaining exposed to an exterior of the concrete.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0015]** The accompanying drawings, which are incorporated in and form a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of embodiments of the invention:

**[0016]** FIG. **1** is an isometric view of a connection system according to an embodiment of the invention, including a column shoe assembly within a concrete section (rendered transparently);

**[0017]** FIG. **2** is an axonometric view of a column shoe of the column shoe assembly of FIG. **1**;

**[0018]** FIG. **3** is an isometric view of a connection system according to another embodiment of the invention, including a column shoe assembly within a concrete section (rendered transparently);

**[0019]** FIG. **4** is an axonometric view of a column shoe and rebar sections of the column shoe assembly of FIG. **3**;

**[0020]** FIG. **5** an isometric view of a connection system according to another embodiment of the invention, including a column shoe assembly within a concrete section (rendered transparently);

**[0021]** FIG. **6** is an axonometric view of a column shoe of the column shoe assembly of FIG. **5**;

**[0022]** FIG. **7** is an isometric view of a connection system according to another embodiment of the invention, including a column shoe assembly within a concrete section (rendered transparently);

**[0023]** FIG. **8** is an axonometric view of a column shoe of the column shoe assembly of FIG. **7**;

**[0024]** FIG. **9** is an isometric view of a connection system according to another embodiment of the invention, including a column shoe assembly within a concrete section (rendered transparently);

**[0025]** FIG. **10** is an axonometric view of a column shoe of the column shoe assembly of FIG. **9**;

**[0026]** FIG. **11** is an isometric view of a connection system according to another embodiment of the invention, including a column shoe assembly within a concrete section (rendered transparently);

**[0027]** FIG. **12** is an axonometric view of a column shoe of the column shoe assembly of FIG. **11**;

**[0028]** FIG. **13** is an isometric view of a connection system according to another embodiment of the invention, including a column shoe assembly within a concrete section (rendered transparently);

**[0029]** FIG. **14** is an axonometric view of a column shoe of the column shoe assembly of FIG. **13**; and

**[0030]** FIG. **15** is a front elevation view of the column shoe of FIG. **14**.

## DETAILED DESCRIPTION

**[0031]** Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways.

**[0032]** The following discussion is presented to enable a person skilled in the art to make and use embodiments of the invention. Various modifications to the illustrated embodiments will be readily apparent to those skilled in the art, and the generic principles herein can be applied to other embodiments and applications without departing from embodiments of the invention. Thus, embodiments of the invention are not intended to be limited to embodiments shown, but are to be accorded the widest scope consistent with the principles and features disclosed herein. The following detailed description is to be read with reference to the figures, in which like elements in different figures have like reference numerals. The figures, which are not necessarily to scale, depict selected embodiments and are not intended to limit the scope of embodiments of the invention. Skilled artisans will recognize the examples provided herein have many useful alternatives and fall within the scope of embodiments of the invention.

**[0033]** In some construction operations, reinforced concrete is pre-cast at a prefabrication site (e.g., a dedicated facility) to form a section of a structure (e.g., walls or columns). Various sections can then be transported to an installation site to be joined together into a larger assembled structure, typically with various rebar connectors used to join the rebar of adjacent sections of the concrete.

**[0034]** Some concrete sections in particular can be configured as columns, to be stacked onto supporting foundations to assemble a larger structure (e.g., stacked onto a foundation provided by an earlier-installed column). However, a variety of section forms are possible. Correspondingly, discussion of columns in particular examples herein can generally apply to a variety of other concrete sections, in some cases.

**[0035]** When pre-cast columns (for example) are formed from concrete, the concrete can withstand substantial compressive loads exerted to the columns. However, concrete alone sometimes cannot withstand relevant tension loads, and reinforcing bar (rebar) is accordingly embedded within the concrete column. For example, rebar can be assembled to form a rebar cage that includes vertical and horizontal rebars. The vertical rebars can withstand tension loading from a bending moment of the column while the horizontal rebars can provide for lateral and shear strength.

**[0036]** Horizontal rebars of rebar cages are typically wound around rebar couplers. However, horizontal rebars cannot be wrapped around column shoes because this configuration can interfere with access to the interior cavity of the column shoes (e.g., interfere with access through a front opening of the column shoe to block tightening of nuts that secure the column shoes on supporting threaded rods).

**[0037]** Embodiments of the invention can address these and other issues, including by providing improved column shoe assemblies for concrete structures. For example, some configurations can provide improved connections between column shoe bodies via horizontal rebar with corresponding improvements to structural configurations for load distribution within concrete structures without adverse effects on access to the interior of column shoes. In some configurations, column shoe bodies can be securely connected with threaded horizontal rebars within the corresponding pre-cast concrete sections. In some configurations, a rebar tie assembly can be engaged with grooves or vertical members on column shoe bodies.

**[0038]** As also generally noted above, discussion herein applies generally to assembly of column shoe bodies to withstand high load by forming a rebar cage within prefabricated concrete sections. In this regard, the figures presented herein illustrate example column shoes as part of pre-cast columns that are mounted on simple foundations. However, column shoes according to this disclosure (e.g., as shown in the figures) can be used in other types of concrete sections, including as part of a foundation, as part of a pre-cast wall, etc. Correspondingly, discussion herein of foundations is generally applicable to concrete sections of a variety of types, including other columns, walls, etc. that are arranged to support a section that includes a column shoe.

**[0039]** FIG. **1** illustrates an example tie assembly formed as a rebar cage **100** that is disposed within a pre-cast concrete structure **102** (e.g., a column). The rebar cage **100** includes rebar ties formed as horizontal rebars **104** that wrap around vertical rebars **106** extending substantially parallel to each other about a longitudinal axis LA of the concrete structure **102**. As mentioned above, the horizontal rebars **104** provide lateral or shear strength while the vertical rebars **106** provide resistance to tension loading that can come from the bending moment of a concrete structure **102**. In the example shown, the vertical and horizontal rebars **104**, **106** cooperatively provide a tie assembly, with vertical and horizontal ties although other configurations are possible (e.g., as further detailed below).

**[0040]** In the illustrated embodiments, each of the vertical rebars **106** are connected to an adapter **108** that is securely connected to a column shoe **110** (e.g., via a threaded connection). The horizontal rebars **104** can be tied the vertical rebars **106** in various ways. For example, a wire (not shown) can be used to tie the horizontal rebars **104** with the vertical rebars **106**.

**[0041]** In other examples, other types of rods can be used instead of rebars. In some examples, the rods (e.g., rebar) may include threaded ends (e.g., to be received by the adapters **108** or into the column shoes **110**, as further discussed below). In some examples, the rods (e.g., rebars) can be bent to fit the shape of a particular concrete structure that is different from the illustrated configuration of the structure **102**.

**[0042]** In the illustrated embodiment, a plurality of column shoes forms an array, and the plurality of column shoes may include substantially identical same components and features. For the sake of discussion, a single column shoe will be discussed in detail to describe different components and features of the column shoe. In some examples, however, differently configured column shoes can be used together in an array (e.g., to accommodate extended flat sections of concrete walls or other geometry).

**[0043]** Generally, a column shoe discussed below can be formed as an integral casting (or otherwise) using a variety of suitably strong materials (e.g., ductile iron, tempered ductile iron, etc.). A shoe body of a column shoe can also take a variety of forms, including those with improved material distribution as further discussed below. As further discussed below, in the example shown, the column shoe **110** includes a shoe body **112** that is connected to the adapter **108** at an upper end **114** (or an upper wall). Further, a lower end **116** (or the lower wall) of the shoe body **112** includes a lower protrusion **140** to secure a rebar tie assembly **118** (e.g., a single overlapped length of rebar) to the shoe body **112**.

**[0044]** Referring now to FIG. **2**, an example configuration of the column shoe **110** of FIG. **1** includes an upper opening **122** (or an upper rod opening) defined at the upper end **114**, a lower opening **124** (or a lower rod opening) defined at the lower end **116**, and an access opening **126** (or an opening) defined between the upper end **114** and the lower end **116** of the shoe body **112**. The access opening **126** may extend to meet the lower opening **124** or the upper opening **122** (or both). An internal cavity **136** is closed continuously around a rear side **137** and at opposite lateral sides **138**, **139** (see FIG. **1**) by a rear wall **128**, a first side wall **130**, and a second side wall **132**. The internal cavity **136** is accessible from at least the access opening **126** of the upper and lower openings **122**, **124**.

**[0045]** The upper opening **122** and the lower opening **124** are aligned coaxial to each other about a connection axis CA. In some examples, referring back to FIG. **1**, the upper opening **122** is securely coupled to the adapter **108** that receives the vertical rebar **106**. More specifically, the adapter **108** may receive a threaded end (not shown) of the vertical rebar **106**. Alternatively, in some examples, the threaded of the vertical rebar **106** can be inserted directly through the upper opening **122**. For example, the upper opening **122** may be a tapered and threaded opening to directly receive the threaded end of the vertical rebar **106**.

**[0046]** The lower opening **124** of the illustrated embodiment extends through the lower protrusion **140**, which can be formed integrally with the column shoe **110**. In particular, the lower protrusion **140** includes a shaft body **142** that extends away from the lower end **116** of the shoe body **112**. The shaft body **142** includes a lip **144** that protrudes radially from the axially extending shaft body **142** to define a groove **146** that extends circumferentially about the connection axis CA. The lip **144** includes a flattened lower surface **148** that can be configured to sit on a fastening mechanism (e.g., nut, washers) on a threaded rebar end when the threaded rebar end is received into the shoe body **112** along the connection axis CA to support the column shoe **110** (and the concrete structure **102**).

**[0047]** In the example shown, the lower protrusion **140** is radially asymmetrical relative to the connection axis CA. More specifically, the lip **144** of the lower protrusion **140** may extend radially only partially about the connection axis CA. For example, the lip **144** of the lower protrusion **140** can form a sector of a circular disk. With the lower protrusion being radially asymmetrical, the groove **146** defined between the lip **144** and the lower end **116** of the shoe body **112** can also be asymmetrical relative to the connection axis CA. Alternatively, in some examples, the lip **144** may be a disc-like shape and the lower protrusion **140** or the groove **146** may be otherwise radially symmetrical relative to the connection axis CA.

**[0048]** Referring back to FIG. **1**, the rebar cage **100** includes a plurality of column shoes **110** arranged in a spaced array **150** (i.e., in a spatial arrangement in which each of the column shoes is spaced apart from the adjacent column shoes of the array). For example, the column shoes **110** can be disposed in each lower corner as shown (e.g., with four of the column shoes **110** in total), or the column shoes **110** can be otherwise arranged (e.g., along side faces and at the corners of a column). The grooves **146** of the lower protrusions **140** of the column shoes **110** can thus be aligned to receive a rebar tie or a stirrup that is wrapped around the grooves **146** to form the rebar tie assembly **118**. The grooves **146** can accordingly help to locate the rebar tie so that the rebar tie assembly **118** does not get dislodged from column shoes **110** when the concrete is poured to form the concrete structure **102**. In particular, the integrally formed lower protrusions **140** can also provide fewer components for the assembly of the rebar cage **100** and provide easier access for assembly since the rebar tie assembly **118** wraps around the exterior of the shaft bodies **142**.

**[0049]** FIGS. **3** and **4** illustrate a rebar assembly formed as a rebar cage **200** including alternative column shoe **210**. Referring to FIG. **3**, the rebar cage **200** includes rebar ties formed as horizontal rebars **204** that wrap around vertical rebars **206** extending vertically from the column shoes **210**.

**[0050]** Other column shoes described hereinafter may include similar features. For example, referring to FIG. **4**, a shoe body **212** of the column shoe **210** may include an upper end **214** (or an upper wall), a lower end **216** (or a lower wall), a rear wall **228**, a first side wall **230**, and a second side wall **232**. A front side **234** is defined opposite of the rear wall **228**, and the front side **234** includes an access opening **226** that opens into an internal cavity **236** (Sec FIG. **3**) at the front side **234** of the shoe body **212**. The internal cavity **236** is closed continuously around a rear side **237** and at opposite lateral sides **238**, **239** by the rear wall **228**, the first side wall **230**, and the second side wall **232**. The upper end **214** and the lower end **216** include an upper opening **222** and a lower opening **224** (See FIG. **3**), respectively, that is in communication with the internal cavity **236**. In some examples, the lower opening **224** and the upper opening **222** defines a connection axis CA. In some examples, the lower opening **224** may receive a threaded end of a first length of a first rod or a first rebar into the internal cavity **236** along the connection axis CA and the upper opening **222** is configured to receive a second length of a second rod or a second rebar into the internal cavity **236** and opposite of the lower opening **224** (not shown). The first and second rods can be accessed through the access opening **226** such that the threaded ends of the first and second length of the first and second rods can be secured within the internal cavity **236**.

**[0051]** Still referring now to FIG. **4**, an example configuration of the column shoe **210** of FIG. **3** includes ports **240**A, **240**B including threaded openings **242**A, **242**B that are disposed on respective lateral side walls of the shoe body **212** (e.g., formed integrally with the column shoe **210**). In the illustrated example, the first threaded opening **242**A defines a first thread direction (e.g., for clockwise threaded insertion) and the second threaded opening **242**B defines a second thread direction (e.g., for counterclockwise threaded insertion). The first and second threaded openings **242**A, **242**B thus define a first axis FA and a second axis SA to receive a first threaded rebar **246**A and a second threaded rebar **246**B, respectively.

**[0052]** In the illustrated example, the first axis FA and the second axis SA are substantially perpendicular to each other. As used herein, unless otherwise limited or defined, "substantially perpendicular" indicates a direction that is within ±12 degrees of perpendicular a reference direction (e.g., within ±6 degrees or ±3 degrees), inclusive. Alternatively, the first axis FA and the second axis SA can be substantially parallel to each other, or otherwise oriented. As used herein, unless otherwise limited or defined, "substantially parallel" indicates a direction that is within ±12 degrees of a reference direction (e.g., within ±6 degrees or ±3 degrees), inclusive.

**[0053]** Referring back to FIG. **3**, the rebar cage **200** includes a plurality of the column shoes **210** arranged in a spaced array **250**. More specifically, the column shoes **210** are arranged so that the first and second threaded openings **242**A, **242**B (see FIG. **4**) are oriented at about 45 degrees from a front face of the respective column shoe **210** and the first axis FA and second axis SA of adjacent column shoes (see FIG. **4**) are aligned with each other. Thus, a rebar tie assembly **218** (e.g., a single overlapped length of rebar) can extend between the column shoes **210**, as secured at the first and second threaded openings **242**A, **242**B.

**[0054]** In particular, in the illustrated example, the first and second threaded rebars **246**A, **246**B extending from the column shoes **210** are connected by a turnbuckle **254** that is disposed between two adjacent column shoes **210** to provide an adjustable coaxial connection between the rebars **246**A, **246**B. Due to the opposed thread directions discussed above, the turnbuckle **254** can thus be rotated in a single direction to tighten the connection with the first and second threaded rebars **246**A, **246**B to a desired length. The securement of the threaded rebar via turnbuckle **254** can thus allow easy adjustment of the rebar length between the column shoes **210**.

**[0055]** As mentioned above, in the illustrated example, the first axis FA of the first threaded opening **242**A and the second axis SA of the second threaded opening **242**B are perpendicular to each other, corresponding to the location of the column shoes **210** at the four corners of the column **202**. Additionally and alternatively, additional ports **240**A, **240**B including corresponding threaded openings can be oriented at various other angles to provide otherwise configured arrays. For example, as discussed above, ports on column shoes can be substantially parallel to each other (e.g., parallel with the front face of the column shoe).

**[0056]** FIGS. **5** and **6** illustrate a rebar assembly formed as a rebar cage **300** that is disposed within a concrete structure **302** including an alternative column shoe **310**. The column shoe **310** includes similar structural components as illustrated in FIG. **4**. To that end, features of the rebar cage **300** described below include reference numbers that are generally similar to those used in FIGS. **3** and **4** (unless otherwise specified), but in the "**300**" series, and discussion of similarly numbered components above similarly applies below. For example, referring to FIG. **5**, the rebar cage **300** includes rebar ties formed as horizontal rebars **304** that wrap around vertical rebars **306** extending vertically from the column shoes **310**. Furthermore, the column shoe **310** includes a shoe body **312** including an upper end **314**, a lower end **316**, a rear wall **328**, a first side wall **330**, and a second side wall **332**.

**[0057]** Referring now to FIG. **6**, an example configuration of the column shoe **310** of FIG. **5** includes a vertical member **340** that extends at a rear side **337** of the shoe body **312**.

More specifically, first and second lugs **344**A, **344**B extend integrally from the rear side **337** of the shoe body **312**, with apertures **346** that receive the vertical member **340**. The vertical member **340** (e.g., threaded rebar, vertical rod, pin) extends between the first and second lugs **344**A, **344**B. In the illustrated example, the vertical member **340** extends only sufficiently past (i.e., above and below) the first and second lugs **344**A, **344**B to be secured with nuts. Alternatively, the vertical member **340** may extend farther beyond either of the first or second lugs **344**A, **344**B (or both). In some examples, it can be beneficial to include a portion of the vertical member **340** extending above or below the first and second lugs **344**A, **344**B to receive additional rebar ties or horizontal rebars to provide additional lateral or shear strength.

**[0058]** Referring back to FIG. **5**, the rebar cage **300** includes a plurality of column shoes **310** arranged in a spaced array **350**. A rebar tie assembly **318** (e.g., a single overlapped length of rebar) can be formed by bending the horizontal rebar **304** into a predetermined shape prior to installment. The rebar tie assembly **318** can then be placed in position, (e.g., inboard of the apertures **346** (see FIG. **6**)) and the vertical member **340** can be engaged with the lugs **344**A, **344**B to secure the rebar tie assembly **318** in position. In other examples, as also noted above, the vertical member **340** can extend farther vertically and the rebar tie assembly **318** can thus in some cases be similarly engaged above or below the lugs **344**A, **344**B.

**[0059]** FIGS. **7** and **8** illustrate a rebar assembly formed as a rebar cage **400** disposed within a concrete structure **402** including an alternative column shoe **410**. The column shoe **410** includes similar structural components as illustrated in FIG. **4**. To that end, features of the rebar cage **400** described below include reference numbers that are generally similar to those used in FIGS. **3** and **4**, but in the "**400**" series, and discussion of similarly numbered components above similarly applies below. For example, referring to FIG. **7**, the rebar cage **400** includes rebar ties formed as horizontal rebars **404** that wrap around vertical rebars **406** extending vertically from the column shoes **410**. Furthermore, the column shoe **410** includes a shoe body **412** including an upper end **414**, a lower end **416**, a rear wall **428**, a first side wall **430**, and a second side wall **432**.

**[0060]** Referring now to FIG. **8**, an example configuration of the column shoe **410** of FIG. **7** includes a vertical member **440** that protrudes from a rear side **437** of the shoe body **412** and is formed integrally with the column shoe **410**. More specifically, the vertical member **440** extends from a first end **444** to a second end **446** of the shoe body **412** forming a closed loop **448**.

**[0061]** Referring back to FIG. **7**, the rebar cage **400** includes a plurality of the column shoes **410** arranged in a spaced array **450**. A rebar tie assembly **418** (e.g., a single overlapped length of rebar) is formed by inserting a length of rebar through the closed loop **448** and bending the rebar to accommodate the shape of the spaced array **450**.

**[0062]** FIGS. **9** and **10** illustrate a rebar assembly formed as a rebar cage **500** disposed within a concrete structure **502** including an alternative column shoe **510**. The column shoe **510** includes similar structural components as illustrated in FIG. **4**. To that end, features of the rebar cage **500** described below include reference numbers that are generally similar to those used in FIGS. **3** and **4**, but in the "**500**" series, and discussion of similarly numbered components above similarly applies below. For example, referring to FIG. **9**, the rebar cage **500** includes rebar ties formed as horizontal rebars **504** that wrap around vertical rebars **506** extending vertically from the column shoes **510**. Furthermore, the column shoe **510** includes a shoe body **512** including an upper end **514**, a lower end **516**, a rear wall **528**, a first side wall **530**, and a second side wall **532**.

**[0063]** Referring now to FIG. **10**, an example configuration of the column shoe **510** of FIG. **9** includes a vertical member **540** that protrudes from a rear side **537** of the shoe body **512** and is formed integrally with the column shoe **510**. More specifically, the vertical member **540** is formed as part of a hook **560** that extends from the rear side **537** of the shoe body **512** to define a gap **548** between the shoe body **512** and the hook **560**.

**[0064]** Referring back to FIG. **9**, the rebar cage **500** includes a plurality of the column shoes **510** arranged in a spaced array **550**. A rebar tie assembly **518** (e.g., a single overlapped length of rebar) is formed by bending the horizontal rebar **504** and arranging the bent rebar form within the gap **548** of each of the column shoes **510**.

**[0065]** FIGS. **11** and **12** illustrate a rebar assembly formed as a rebar cage **600** disposed within a concrete structure **602** including an alternative column shoe **610**. The column shoe **610** includes similar structural components as illustrated in FIG. **4**. To that end, features of the rebar cage **600** described below include reference numbers that are generally similar to those used in FIGS. **3** and **4**, but in the "**600**" series, and discussion of similarly numbered components above similarly applies below. For example, referring to FIG. **11**, the rebar cage **600** includes rebar ties formed as horizontal rebars **604** that wrap around vertical rebars **606** extending vertically from the column shoes **610**. Furthermore, the column shoe **610** includes a shoe body **612** including an upper end **614**, a lower end **616**, a rear wall **628**, a first side wall **630** and a second side wall **632**.

**[0066]** Referring now to FIG. **12**, an example configuration of the column shoe **610** of FIG. **11** includes a port **640** that is disposed at a rear side **637** of the shoe body **612** (e.g., formed integrally with the column shoe **610**). The port **640** includes a threaded opening **644** that receives a threaded rebar tail (e.g., bent rebar) **648** that is threadedly secured to the shoe body **612** via the threaded opening **644**. The threaded opening **644** can be tapered or straight. In some examples, additional fastening mechanisms (e.g., a lock nut, not shown) can be used to couple the bent rebar **648** to the threaded opening **644**. The bent rebar **648** includes a free end that extends vertically and parallel with the vertical rebars **606** extending from the column shoe **610** (see FIG. **11**).

**[0067]** Referring back to FIG. **11**, the rebar cage **600** includes a plurality of the column shoes **610** arranged in a spaced array **650**. A rebar tie assembly (not shown) can be formed by coupling a horizontal rebar **604** with the bent rebars **648** extending from the column shoes **610**.

**[0068]** FIGS. **13** and **14** illustrate a rebar assembly formed as a rebar cage **700** disposed within a concrete structure **702** including an alternative column shoe **710**. The column shoe **710** includes similar structural components as illustrated in FIG. **4**. To that end, features of the rebar cage and the column shoe **710** described below include reference numbers that are generally similar to those used in FIGS. **3** and **4**, but in the "**700**" series, and discussion of similarly numbered components above similarly applies below. For example, the column shoe **710** includes a shoe body **712** including an upper end **714**, a lower end **716**, a rear wall **728**, a first side

wall **730** and a second side wall **732**. Although only vertical rebars **706** are shown above the column shoes **710**, tie rods (e.g., rebars) extending horizontally between the vertical rebars **706** can be included in some cases. Similarly, although an adapter **708** including a receiving end and threaded inserting end can be used (as shown) to connect the vertical rod with the column shoe **710**, a threaded (or other) rod end can directly engage with the upper end **714** of the shoe body **712** in some examples.

**[0069]** Referring now to FIG. **14**, an example configuration of the column shoe **710** of FIG. **13** includes a first lug **740** that protrudes from a junction between the first side wall **730** and the rear wall **728**, and a second lug **742** that protrudes from a junction between the second side wall **732** and the rear wall **728**, at angular offsets relative to each other. In the illustrated example, the location of the lugs **740**, **742** can optimize material usage and load alignment for particular installations, but other configurations are possible (e.g., with either of the lugs **740**, **742** extending from one or more of the first side wall **730**, second side wall **732**, or the rear wall **728**).

**[0070]** In the illustrated example, the first lug **740** of the shoe body **712** is integrally formed with the one or more of the first side wall **730** or the rear wall **728** of the shoe body. Similarly, the second lug **742** of the shoe body **712** is integrally formed with the one or more of the second side wall **732** or the rear wall **728** of the shoe body **712**. In some examples, the first and second lugs **740**, **742** extends from a medial region **743** that is disposed between the upper end **714** and the lower end **716** of the column shoe **710**.

**[0071]** In the illustrated example, the first lug **740** of the shoe body **712** is a first flattened car **744** that includes a first bore **746** defining a first connection axis FA through the first bore **746**. Similarly, the second lug **742** of the shoe body **712** is a second flattened ear **748** that includes a second bore **751** defining a second connection axis SA through the second bore **751**. In some examples, the first connection axis FA, the second connection axis SA and the connection axis CA of the column shoe **710** that extends through the upper opening **722** and the lower opening **724** can be parallel (or substantially parallel) with respect to each other. The first flattened ear **744** extends from the first side wall **730** or the rear wall **728** at a first direction FD and the second flattened ear **748** extends from the second side wall **732** or the rear wall **728** at a second direction SD. In some examples, the first direction FD is angularly offset from the second direction by about 90 degrees. Thus, as also discussed below, the first bore **746** allows a tie assembly to be secured to the shoe body **712**, spaced apart from the connection axis CA of the shoe body **712** in the first direction FD, the second bore **751** allows a tie assembly to be secured to the shoe body **712**, spaced apart from the connection axis CA of the shoe body **712** in the second direction SD (e.g., angularly offset from the first direction FD by about 90 degrees).

**[0072]** As shown in the front elevation view of FIG. **15** (e.g., as projected onto a vertical plane P of FIG. **14**, defined by the access opening **726** into the internal cavity **736** of the shoe body **712**), the first flattened ear **744** of the shoe body **712** extends laterally to the outside of the first side wall **730** of the shoe body **712**. Similarly, the second flattened ear **748** of the shoe body **712** extends laterally to the outside of the second side wall **732** of the shoe body **712**. Correspondingly, in the illustrated example, the first and second flattened ear **744**, **748** extends laterally wider than the lower end **716** and the internal cavity **736** along the lateral direction. This arrangement can improve accessibility for installation of tie assemblies, as well as the distribution of stresses associated with the tie assemblies and overall operational loading of the shoe body **712** (e.g., relative to coaxial securement of the associated vertical rods, embedded in adjacent concrete sections).

**[0073]** Referring back to FIG. **13**, a first column shoe **710**A, a second column shoe **710**B, a third column shoe **710**C, and a fourth column shoe **710**D are shown in an installed array, although other arrangements are possible. In particular, the first, second, third, and fourth column shoes **710**A, **710**B, **710**C, **710**D are embedded within respective corners of the concrete structure **702**. For example, the concrete installation forms a first corner **711**A and the first column shoe **710**A are embedded within concrete of the first corner **711**A.

**[0074]** The vertical rebar **706** is secured (e.g., by the adapters **708**, as shown) at an upper opening **722** of each of the column shoes **710**A, **710**B, **710**C, **710**D (see, e.g., FIG. **14**) that can in some cases extend coaxially to the associated upper opening **722** and associated lower opening **724** of the column shoes **710**A, **710**B, **710**C, **710**D.

**[0075]** Each of the column shoes **710**A, **710**B, **710**C, **710**D is connected to another (e.g., adjacent) column shoe by a tie **752** (e.g., a rebar tie). For example, a first lug **740**A of the first column shoe **710**A is coupled to a second lug **742**B of the second column shoe **710**B by a first tie **752**A, a second lug (not shown) of the first column shoe **710**A is coupled to a first lug **740**D of the fourth column shoe **710**D by a second tie **752**B, a second lug **742**D of the fourth column shoe **710**D is coupled to a first lug **740**C of the third column shoe **710**C by a third tie **752**C, and the second lug **742**C of the third column shoe **710**C is coupled to the first lug **740**B of the second column shoe **710**B by a fourth tie **752**D.

**[0076]** In particular, the ties **752**A, **752**B, **752**C, **752**D include a first bent end **754** and a second bent end **756** that are received by the first and second bores **746**, **751** of the first and second flattened ear **744**, **748** of adjacent shoe bodies **712**. For example, the first bent end **754** of the first tie **752**A can be received by the first bore **746** of the first column shoe **710**A and the second bent end **756** of the first tie **752**A can be received by the second bore **751** of the second column shoe **710**B. Furthermore, the first bent end **754** of a second tie **752**B can be received by the second bore **751** of the first column shoes **710**A and the second bent end **756** of the second tie **752**B can be received by the first bore **746** of the fourth column shoes **710**D. Accordingly, multiple column shoes **710**A, **710**B, **710**D can be linked together by rebar ties **752** in series (or in a chain configuration).

**[0077]** As described above, the laterally extending first flattened cars **744** of the first, second, third, and fourth column shoes **710**A, **710**B, **710**C, **710**D extends laterally to the outside of the respective first side wall **730** and the laterally extending second flattened cars **748** extend laterally to the outside of the respective second side wall **732**. In some examples, the cars **744**, **748** can extend to have top or bottom surfaces substantially parallel with the flattened cars **744**, **748** of an adjacent column shoe. For example, the first flattened ear **744** of the first shoe body **710**A can extend substantially parallel to a second flattened ear **748** of the second shoe body **710**B.

**[0078]** Generally, adjacent cars can be spaced apart from each other by a gap. For example, the first flattened ear **744** of the first shoe body **710**A and a second flattened ear **748** of the second shoe body **710**B be spaced apart by a lateral gap, which can be bridge by a tie assembly.

**[0079]** As described above, the column shoe **710** includes multiple openings and bores that are configured to receive a rod (e.g., a rebar). The upper opening **722** and the lower opening **724** of the column shoe **710** are configured to receive vertical rod and can be substantially coaxial to each other. The upper opening and the lower opening being substantially coaxial relative to reach other can provide structural rigidity to distribute the stress more evenly throughout the structure, and may in some cases correspond to thickened material around a front opening of a shoe body, rearward placement of lugs, or other adjustments. The first and second lugs **740**, **742** (e.g., flattened cars, as shown) are configured to receive the rebar ties **752** to connect the column shoes **710** together. In other words, the first and second lugs **740**, **742** are specifically configured to establish linking connections between the column shoes **710** through the rebar ties **752** to provide lateral and shear strength to the assembly, whereas engagement of the rods at the openings **722**, **724** subject specifically implicates tension loading.

**[0080]** In particular, the first and second lugs **740**, **742** extend from the medial region **743** of the column shoe **710**, which can be beneficial to redistribute tension load that can be exerted by the rebar ties **752** when connecting to adjacent column shoes **710**. For example, since the upper end **714** and the lower end **716** includes upper opening **722** and lower opening **724** respectively, inclusion of first and second lugs **740**, **742** along the closer to the upper end **714** and the lower end **716** could result in unfavorable stress concentrations around the upper and lower opening **722**, **724**. Thus, the positioning of the first and second lugs **740**, **742** being disposed along the medial region **743** allows the load to be redistributed while forming the tie assembly **718** and may also allow the tie assembly to be easily and reliably connected during and after pouring of concrete to form the concrete structure **702**.

**[0081]** In some examples, a thickness T of the first and second lugs **740**, **742** can be changed to withstand different loading conditions.

**[0082]** Additionally and alternatively, the first and second lugs of the column shoe **710** can configured to provide lateral and shear strength of the rebar cage **700**. For instance, the horizontal rebars surrounding the vertical rebars require wires to connect the horizontal rebars to the vertical rebars. This may be a cumbersome task for a user. However, inclusion of the first and second lugs **740**, **742** enables the rebar tie **752** to directly engage the neighboring column shoes **710**, allowing easy installation.

**[0083]** The column shoes described above can be used to form a concrete column or a concrete structure **702**. For instance, still referring to FIG. **13**, a first shoe body **712**A and a second shoe body **712**B can be arranged in a spaced array **750**. Once the shoe bodies **712**A, **712**B are positioned within the concrete column, a tie assembly **718** can be engaged between the shoe bodies **712**A, **712**B. For example, a first tie can be used to tie the first lug **740** of the first shoe body **712**A and the second lug **742** of the second shoe body **712**B to extend between, and secure together the first and second shoe body **712**A, **712**B. The first end (or the first bent end) **754** of the first tie **752**A can extend through a first bore **746** of the first lug **740** and the second end (or the second bent end) **756** of the first tie **752**A can extend through a second bore **751** of the second lug **742**. Furthermore, as described above, the first end **754** and the second end **756** of the ties can be a bent end such that the bent ends are received by the first and second bore while a medial region of the tie extends between the first and second shoe bodies **712**A, **712**B transverse to the first and second connection axis FA, SA of the first and second shoe bodies **712**A, **712**B. Once the shoe bodies are secured together, concrete is poured over the first and second shoe bodies and the tie assembly. In particular, the lower opening of the first and second shoe bodies remain exposed to the exterior of the concrete, as does a front opening to allow access to secure a rod received through the lower opening (e.g., with a nut, as shown in FIG. **13**). In some cases, a removable block (not shown) can be used to cover a front opening of a shoe body, then removed after the poured concrete has set, to allow access to an internal cavity via a front opening.

**[0084]** Generally, the various concrete structures **102** through **702** (or other columns) can be formed by pouring concrete to cover the components of the rebar cages **100** through **700** described above. For instance, once any of the rebar cages **100** through **700** with the column shoes **110** through **710** are arranged to form the arrays **150** through **750** and rebar tie assemblies **118** through **718** are coupled to the relevant structures of the column shoes **110** through **710**, the concrete can be poured and cured to form the relevant pre-cast concrete structures.

**[0085]** In some implementations, devices or systems disclosed herein can be utilized, manufactured, installed, etc. using methods embodying aspects of the disclosed technology. Correspondingly, any description herein of particular features, capabilities, or intended purposes of a device or system should be considered to disclose, as examples of the disclosed technology a method of using such devices for the intended purposes, a method of otherwise implementing such capabilities, a method of manufacturing relevant components of such a device or system (or the device or system as a whole), and a method of installing disclosed (or otherwise known) components to support such purposes or capabilities. Similarly, unless otherwise indicated or limited, discussion herein of any method of manufacturing or using for a particular device or system, including installing the device or system, should be understood to disclose, as examples of the disclosed technology, the utilized features and implemented capabilities of such device or system.

**[0086]** In this regard, for example, some embodiments of the disclosed invention can include prefabricating concrete structures using the column shoe assemblies as disclosed herein (or components thereof), or securing concrete structures together using the column shoe assemblies disclosed herein (or components thereof). Similarly, some examples can include manufacturing or using sets of substantially identical column shoes or column shoe assemblies (e.g., of one or more sizes) for prefabrication or for on-site operations.

**[0087]** It is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms "mounted," "connected," "sup-

ported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings.

**[0088]** With respect to methods presented herein, unless otherwise specified, operations can be optionally included, excluded, or performed in different sequences (e.g., with different orders, in parallel, etc.). Thus, for example, relative to the methods discussed herein, rebar or other rods or associated adaptors can be secured to top walls of column shoes (e.g., the upper end **714**, etc.) before or after the column shoes are arrayed and secured together with a tie assembly (and vice versa).

**[0089]** Unless otherwise specifically indicated, ordinal numbers are used herein for convenience of reference, based generally on the order in which particular components are presented in the relevant part of the disclosure. In this regard, for example, designations such as "first," "second," etc., generally indicate only the order in which a thus-labeled component is introduced for discussion and generally do not indicate or require a particular spatial, functional, temporal, or structural primacy or order.

**[0090]** As used herein, unless otherwise limited or specified, "substantially identical" refers to two or more components or systems that are manufactured or used according to the same process and specification, with variation between the components or systems that are within the limitations of acceptable tolerances for the relevant process and specification. For example, two components can be considered to be substantially identical if the components are manufactured according to the same standardized manufacturing steps, with the same materials, and within the same acceptable dimensional tolerances (e.g., as specified for a particular process or product).

**[0091]** As used herein, unless otherwise limited or defined, "or" indicates a non-exclusive list of components or operations that can be present in any variety of combinations, rather than an exclusive list of components that can be present only as alternatives to each other. For example, a list of "A, B, or C" indicates options of: A; B; C; A and B; A and C; B and C; and A, B, and C. Correspondingly, the term "or" as used herein is intended to indicate exclusive alternatives only when preceded by terms of exclusivity, such as "either," "one of," "only one of," or "exactly one of." For example, a list of "one of A, B, or C" indicates options of: A, but not B and C; B, but not A and C; and C, but not A and B. A list preceded by "one or more" (and variations thereon) and including "or" to separate listed elements indicates options of one or more of any or all of the listed elements. For example, the phrases "one or more of A, B, or C" and "at least one of A, B, or C" indicate options of: one or more A; one or more B; one or more C; one or more A and one or more B; one or more B and one or more C; one or more A and one or more C; and one or more of A, one or more of B, and one or more of C. Similarly, a list preceded by "a plurality of" (and variations thereon) and including "or" to separate listed elements indicates options of multiple instances of any or all of the listed elements. For example, the phrases "a plurality of A, B, or C" and "two or more of A, B, or C" indicate options of: A and B; B and C; A and C; and A, B, and C.

**[0092]** Also as used herein, unless otherwise limited or defined, "integral" and derivatives thereof (e.g., "integrally") describe elements that are manufactured as a single piece without fasteners, adhesive, or the like to secure separate components together. For example, an element stamped or cast as a single-piece component from a single piece of sheet metal or a single mold (etc.), without rivets, screws, or adhesive to hold separately formed pieces together, is an integral (and integrally formed) element. In contrast, an element formed from multiple pieces that are separately formed initially, then later connected together, is not an integral (or integrally formed) element.

**[0093]** Also as used herein, unless otherwise limited or specified, "substantially identical" refers to two or more components or systems that are manufactured or used according to the same process and specification, with variation between the components or systems that are within the limitations of acceptable tolerances for the relevant process and specification. For example, two components can be considered to be substantially identical if the components are manufactured according to the same standardized manufacturing steps, with the same materials, and within the same acceptable dimensional tolerances (e.g., as specified for a particular process or product).

**[0094]** Unless otherwise specified or limited, the terms "about" and "approximately", as used herein with respect to a reference value, refer to variations from the reference value of +5% or less, inclusive of the endpoints of the range. Similarly, as used herein with respect to a reference value, the term "substantially equal" (and the like) refers to variations from the reference value of less than ±5% (e.g., ±2%, ±1%, ±0.5%) inclusive. Where specified in particular, "substantially" can indicate a variation in one numerical direction relative to a reference value. For example, the term "substantially less" than a reference value (and the like) indicates a value that is reduced from the reference value by 30% or more (e.g., 35%), and the term "substantially more" than a reference value (and the like) indicates a value that is increased from the reference value by 30% or more (e.g., 35%).

**[0095]** Additionally, unless otherwise specified or limited, "substantially coaxial" indicates that the described elements have axes that are substantially parallel with each other and are aligned so that extension of the axis one of the elements intersects an axial end of another of the elements (e.g., at or within a diameter thereof, within 50% of a diameter thereof, within 25% of a diameter thereof, or within 5%—or less—of a diameter thereof). Thus, for example, substantially coaxial sections of rebar on opposing sides of a column shoe can extend substantially in parallel with each other, along a substantially identical axis, to provide single-axis load transmission across the column shoe as further detailed above.

**[0096]** The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

**1**. An assembly for a concrete column, the assembly comprising:

a first shoe body and a second shoe body, each of the first shoe body and second shoe body defining, respectively:

an internal cavity that is closed continuously around a rear side and at opposite lateral sides by a rear wall, a first side wall, and a second side wall of the first or second shoe body;

a lower wall with a lower rod opening that defines a connection axis and receives a threaded end of a first length of rod into the internal cavity along the connection axis;

an upper wall that secures a second length of rod opposite the lower rod opening;

an opening that opens into the internal cavity at a front side of the shoe body to provide access to secure the threaded end of the first length of rod within the internal cavity;

a first lug protruding from one or more of the first side wall or the rear wall; and

a second lug protruding from one or more of the second side wall or the rear wall; and

a tie assembly that includes a first tie secured to, and extending between, the first lug of the first shoe body and the second lug of the second shoe body to secure the first and second shoe bodies together.

**2**. The assembly of claim **1**, further comprising:

a third shoe body that defines:

an internal cavity that is closed continuously around a rear side and at opposite lateral sides by a rear wall, a first side wall, and a second wall of the third shoe body;

a lower wall with a lower rod opening that defines a connection axis and receives a threaded end of a third length of rod into the internal cavity along the connection axis;

an upper wall that secures a fourth length of rod opposite the lower rod opening;

an opening that opens into the internal cavity at a front side of the shoe body to provide access to secure the threaded end of the third length of rod within the internal cavity;

a first lug protruding from one or more of the first side wall or the rear wall; and

a second lug protruding from one or more of the second side wall or the rear wall;

wherein the tie assembly further includes a second tie secured to, and extending between, the second lug of the first shoe body and the first lug of the third shoe body to tie the first and third shoe bodies together.

**3**. The assembly of claim **1**, wherein for each of the first shoe body and the second shoe body:

the first lug is integrally formed with the one or more of the first side wall or the rear wall of the first shoe body; and

the second lug of the first shoe body is integrally formed with the one or more of the second side wall or the rear wall of the first shoe body.

**4**. The assembly of claim **1**, wherein the first lug of the first shoe body is a first flattened ear, including a first bore that receives a first bent end of the first tie; and

wherein the second lug of the second shoe body is a second flattened ear, including a second bore that receives a second bent end of the first tie.

**5**. The assembly of claim **1**, wherein the first lug of the first shoe body includes a first bore spaced apart from the connection axis in a first direction to engage the tie assembly;

wherein the second lug of the first shoe body includes a second bore spaced from the connection axis in a second direction to engage the tie assembly; and

wherein the first direction is angularly offset from the second direction by about 90 degrees.

**6**. The assembly of claim **1**, wherein, as projected onto a plane defined by the opening into the internal cavity of the first shoe body, the first lug of the first shoe body extends laterally to the outside of the first side wall of the first shoe body and the second lug of the first shoe body extends laterally to the outside of the second side wall of the first shoe body.

**7**. The assembly of claim **1**, wherein the upper wall of the first shoe body secures the second length of rod with a threaded connection.

**8**. The assembly of claim **7**, wherein the upper wall of the first shoe body includes a threaded bore that receives one of:

a threaded end of the second length of rod; or

a threaded adapter that is secured to the second length of rod.

**9**. An assembly for a concrete installation, the assembly comprising:

a first shoe body, a second shoe body, and a third shoe body;

each of the first shoe body, the second shoe body, and the third shoe body including, respectively:

an enclosed internal cavity;

a lower rod opening that receives a threaded end of a corresponding first length of rod into the internal cavity along a connection axis to be secured within the internal cavity;

an upper wall that secures a corresponding second length of rod on an opposite side of the enclosed internal cavity from the lower rod opening;

a first lug protruding in a first direction away from the connection axis; and

a second lug protruding in a second direction away from the connection axis; and

a tie assembly that includes:

a first tie that extends between the first lug of the first shoe body and the second lug of the second shoe body to secure the first and second shoe bodies together; and

a second tie that extends between the second lug of the first shoe body and the first lug of the third shoe body to secure the first and third shoe bodies together.

**10**. The assembly of claim **9**, wherein the concrete installation forms a first corner and the first shoe body is embedded within concrete of the first corner.

**11**. The assembly of claim **9**, further comprising:

a fourth shoe body that includes:

an internal cavity;

a lower rod opening that receives a threaded end of a corresponding first length of rod into the internal cavity along a connection axis to be secured within the internal cavity;

an upper wall that secures a corresponding second length of rod on an opposite side of the enclosed internal cavity from the lower rod opening;

a first lug protruding in a first direction away from the connection axis; and

a second lug protruding in a second direction away from the connection axis;

wherein the tie assembly further includes:

a third tie that extends between the first lug of the second shoe body and the second lug of the fourth shoe body to secure the second and fourth shoe bodies together; and

a fourth tie that extends between the second lug of the third shoe body and the first lug of the fourth shoe body to secure the third and fourth shoe bodies together.

**12**. The assembly of claim **9**, wherein the first tie includes a tie rod with a first bent end received into the first lug of the first shoe body and a second bent end received into the second lug of the second shoe body.

**13**. The assembly of claim **12**, wherein the first lug of the first shoe body is a first flattened ear, including a first bore that extends in parallel with the connection axis to receive the first bent end; and

wherein the second lug of the second shoe body is a second flattened ear, including a second bore that extends in parallel with the connection axis to receive the second bent end.

**14**. The assembly of claim **9**, wherein the first lug of the first shoe body is a first ear, integrally formed with the first shoe body and including a first bore spaced apart from the connection axis in a first direction to receive the first tie; and

wherein the second lug of the first shoe body is a second ear, integrally formed with the first shoe body and including a second bore spaced from the connection axis in a second direction to receive the second tie.

**15**. The assembly of claim **14**, wherein the first direction is angularly offset from the second direction by about 90 degrees.

**16**. The assembly of claim **9**, wherein the lower rod opening is formed in a lower wall at a lower end of the first shoe body; and

wherein, as projected onto a plain perpendicular to the connection axis, the first and second lugs extend wider than the lower wall and the internal cavity along a lateral direction.

**17**. A method of forming a concrete column, the method comprising:

arranging a first shoe body and a second shoe body in a spaced array with:

internal cavities of the first and second shoe bodies closed continuously around a rear side and at opposite lateral sides by a rear wall, a first side wall, and a second side wall of the respective first or second shoe body;

lower rod openings defining connection axes to receive ends of first lengths of rod into the internal cavities; and

openings into the internal cavity at front sides of the shoe bodies providing access to the ends of the first lengths of rod within the internal cavities; and

first and second lugs extending away from the corresponding connection axis;

securing second lengths of rod to upper ends of the first and second shoe bodies;

engaging a tie assembly with the first and second shoe bodies, including:

securing a first tie to the first lug of the first shoe body and to the second lug of the second shoe body to extend between, and secure together, the first and second shoe bodies; and

pouring concrete to cover the first and second shoe bodies and the tie assembly, with the lower rod openings and the openings at the front sides of the first and second shoe bodies remaining exposed to an exterior of the concrete.

**18**. The method of claim **17**, wherein securing the first tie to the first lug of the first shoe body includes bending a first end of the first tie to extend through the first lug; and

securing the first tie to the second lug of the second shoe body includes bending a second end of the first tie to extend through the second lug.

**19**. The method of claim **18**, wherein the first end of the first tie extends through a first bore of the first lug of the first shoe body in parallel with the connection axis of the first shoe body;

wherein the second end of the first tie extends through a second bore of the second lug of the second shoe body in parallel with the connection axis of the second shoe body; and

wherein the first tie extends between the first and second shoe bodies transverse to the connection axes of the first and second shoe bodies.

**20**. The method of claim **17**, wherein the first tie is secured to the first lug of the first shoe body, spaced apart from the connection axis of the first shoe body in a first direction; and

wherein the method further includes, before pouring the concrete, securing a second tie to the second lug of the first shoe body, spaced apart from the connection axis of the first shoe body in a second direction that is angularly offset from the first direction by about 90 degrees, to secure the first shoe body to a third shoe body.

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