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MECHANICAL CONNECTION FOR CONCRETE STRUCTURES

George Morcous

Raed Tawadrous

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Morcous et al.

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(54) **MECHANICAL CONNECTION FOR CONCRETE STRUCTURES**

(71) Applicant: **NUtech Ventures, Inc.**, Lincoln, NE (US)

(72) Inventors: **George Morcous**, Omaha, NE (US); **Raed Tawadrous**, Winter Springs, FL (US)

(73) Assignee: **NUtech Ventures**, Lincoln, NE (US)

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(51) **Int. Cl.**
E04B 1/04 (2006.01)
E04B 1/41 (2006.01)

(52) **U.S. Cl.**
CPC ***E04B 1/4128*** (2013.01); ***E04B 1/043*** (2013.01); ***E04B 1/415*** (2013.01)

(58) **Field of Classification Search**
CPC E04B 1/043; E04B 5/023; E04B 1/215; E04B 5/43; E04B 1/04; E04B 1/41; E01D 19/125; E01D 2101/268; E01C 11/14
See application file for complete search history.

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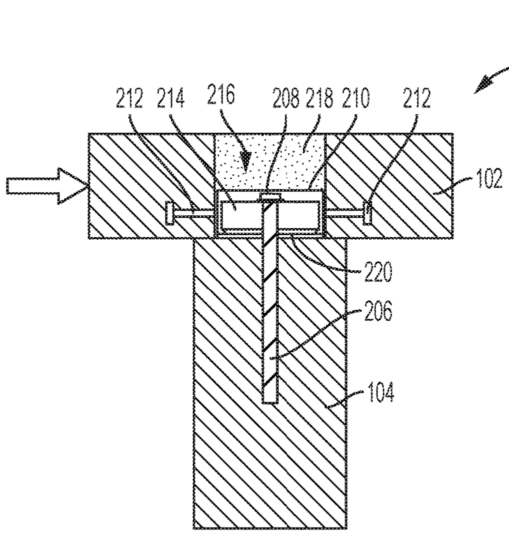
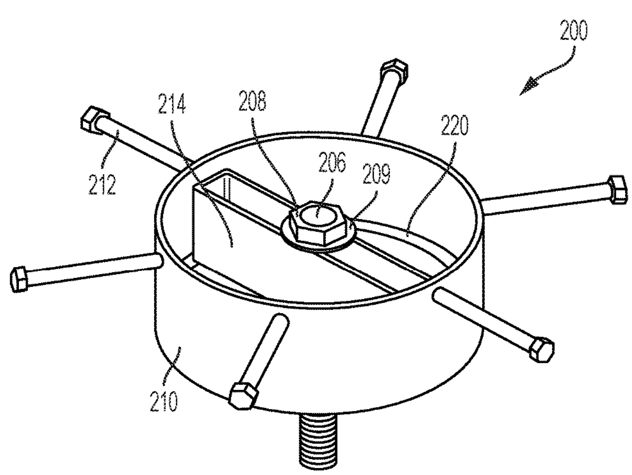
Primary Examiner — Brian D Mattei
Assistant Examiner — Daniel J Kenny
(74) *Attorney, Agent, or Firm* — Leydig, Voit & Mayer, Ltd.

(57) **ABSTRACT**

A system and method for connecting precast concrete structures includes anchoring a sleeve within a pocket formed in one of the concrete structures, and placing the concrete structures in contact with one another such that the pocket is diposed around a protruding end of a shear connector embedded in the other concrete structure. A bridge is inserted around the protruding end of the shear connector and a fastener is installed onto the protruding end of the shear connector to engage the bridge and urge the bridge in abutting relation with a lip of the sleeve. The pocket is then filled with a grout.

20 Claims, 4 Drawing Sheets





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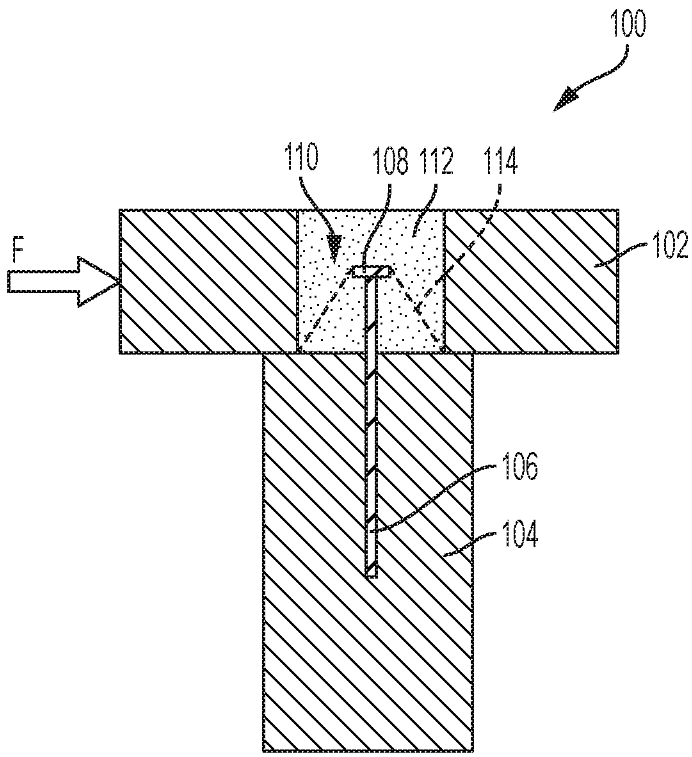
100
110
108
112
114
F
102
106
104

FIG. 1

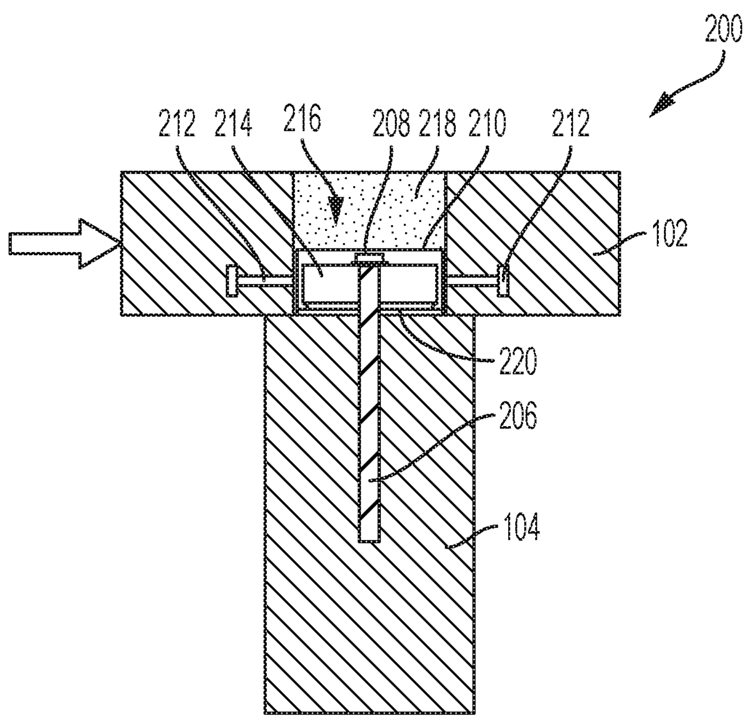
200
212
214
216
208
218
210
212
102
220
206
104

FIG. 2

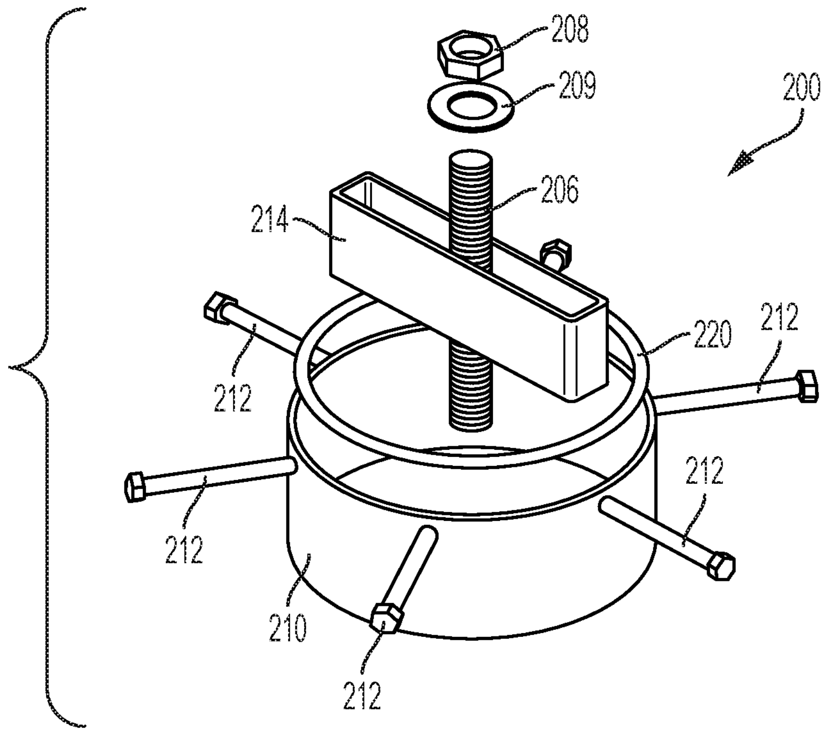
208
209
200
206
214
220
212
212
212
212
212
210
212

FIG. 3

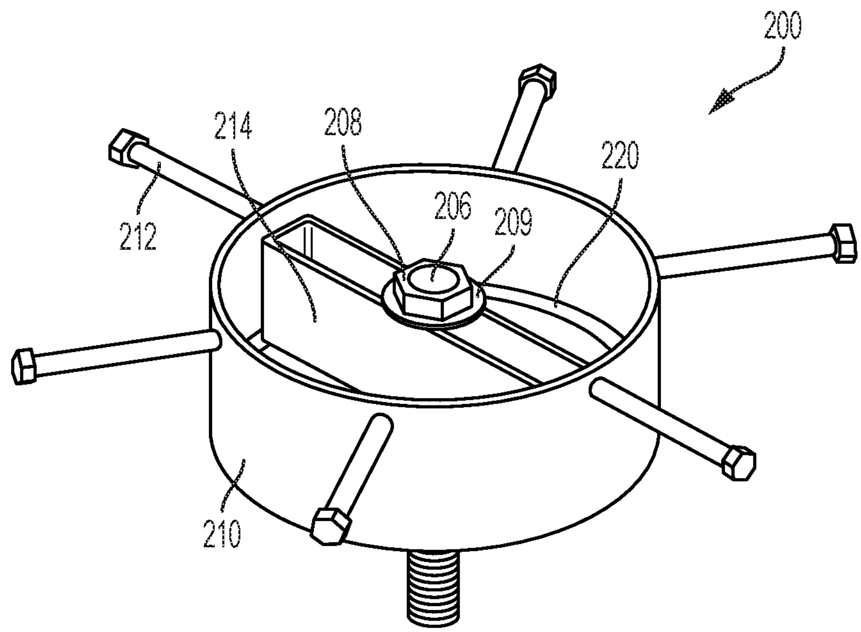
200
214
208
220
212
206
209
210

FIG. 4

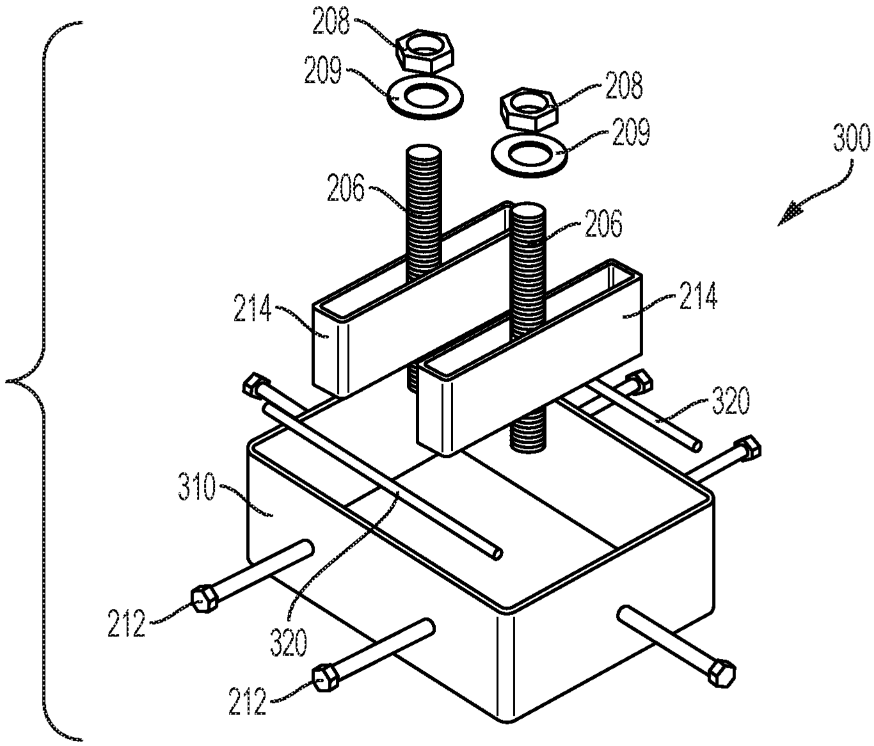
208
209
208
209
300
206
206
214
214
320
310
212
320
212

FIG. 5

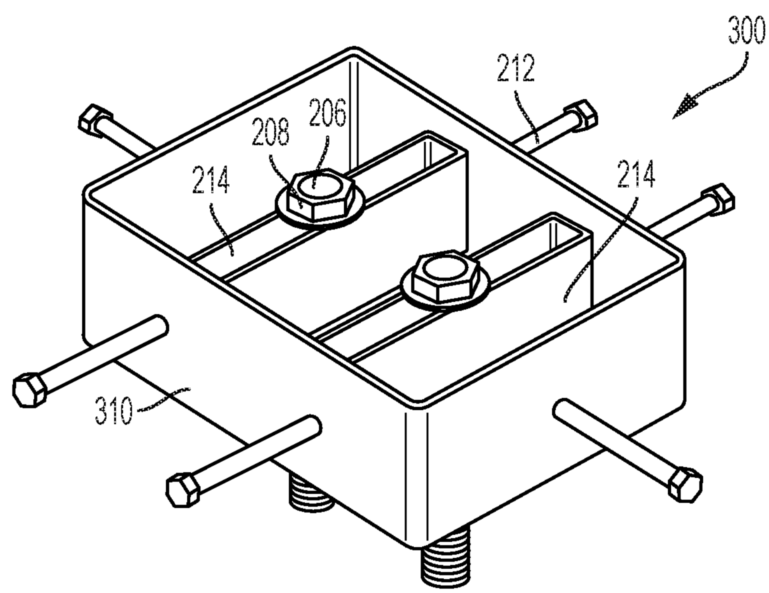
300
212
208
206
214
214
310

FIG. 6

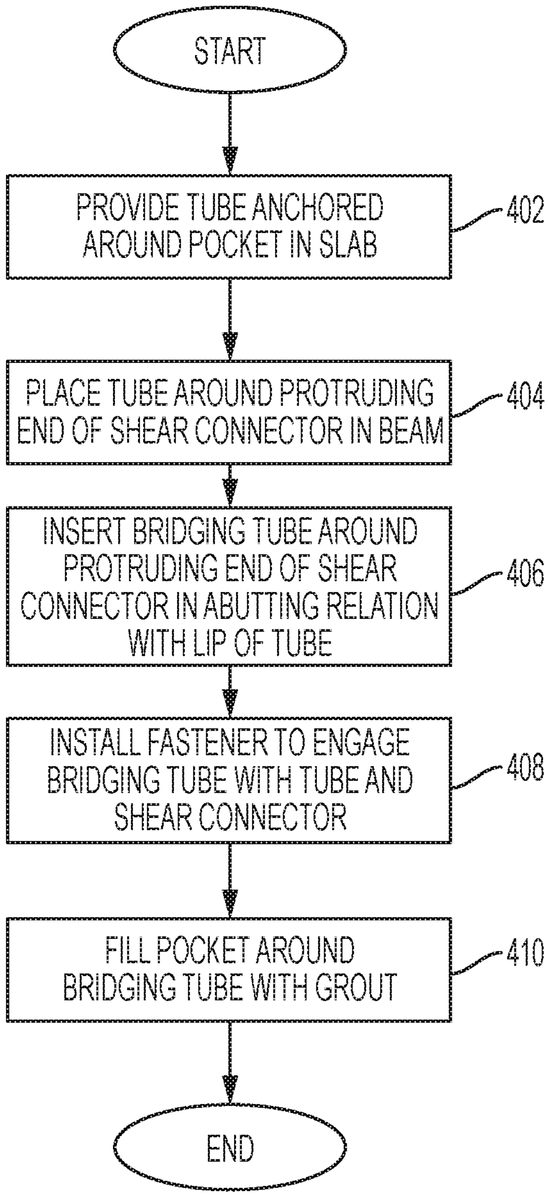
START
PROVIDE TUBE ANCHORED AROUND POCKET IN SLAB
402
PLACE TUBE AROUND PROTRUDING END OF SHEAR CONNECTOR IN BEAM
404
INSERT BRIDGING TUBE AROUND PROTRUDING END OF SHEAR CONNECTOR IN ABUTTING RELATION WITH LIP OF TUBE
406
INSTALL FASTENER TO ENGAGE BRIDGING TUBE WITH TUBE AND SHEAR CONNECTOR
408
FILL POCKET AROUND BRIDGING TUBE WITH GROUT
410
END

FIG. 7

MECHANICAL CONNECTION FOR CONCRETE STRUCTURES

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application claims the benefit of U.S. Provisional Patent Application No. 62/550,317, filed Aug. 25, 2017, which is incorporated herein by reference in its entirety.

FIELD OF THE DISCLOSURE

The present disclosure relates to connections for precast concrete structures and, more particularly, to a shear connection using a shear pocket formed in a precast concrete slab and a support girder or beam.

BACKGROUND OF THE DISCLOSURE

In precast concrete construction of bridges and buildings, it is highly desirable to connect deck/slab panels to the supporting girders/beams to create composite sections for economical design and reduced structural depth. Existing connections are field cast/grouted channels or pockets in the precast concrete panels that enclose shear connectors projecting from the precast concrete girders/beams. The performance of these connections is highly dependent on the quality of grouting material. Also, none of the these connections mechanically connects the components due to their imperfect alignment and relatively high construction tolerance.

BRIEF SUMMARY OF THE DISCLOSURE

In one aspect, the present disclosure is directed to a connection assembly for fastening a first precast concrete member to a second precast concrete member, which are in physical contact with one another. The connection assembly includes a threaded rod protruding from a first face of the first precast concrete member, which first face of the first concrete member contacts the second precast concrete member. A sleeve has a lateral wall surrounding an opening formed in the second precast concrete member. The sleeve is integrated into the second precast concrete member such that the opening extends through a thickness of the second precast concrete member. The second precast concrete member is disposed in contact with the first precast concrete member such that the threaded rod extends at least partially through the sleeve. A lip is connected along an inner side of the lateral wall, and a bridge is disposed within the opening. The bridge has a body that forms a bore disposed around at least a portion of the threaded rod and ends that abut against the lip. A fastener is engaged with the threaded rod and positioned to retain the bridge in contact with the lip.

In another aspect, the disclosure describes a method for connecting a first precast concrete member with a second precast concrete member. The method includes placing the first precast concrete member in contact with the second precast concrete member; providing a threaded protruding from a first face of the first precast concrete member, the first face of the first concrete member contacting the second precast concrete member; providing a sleeve having a lateral wall surrounding an opening, the sleeve being integrated into the second precast concrete member such that the opening extends through a thickness of the second precast concrete member. The method further includes placing the

second precast concrete in contact with the first precast concrete member such that the threaded rod extends through the sleeve; placing a bridge within the opening, the bridge having a body that forms a bore disposed around at least a portion of the threaded rod, and ends that abut against a a lip connected along an inner side of the lateral wall; and engaging the threaded rod with a fastener such that the bridge is retained in contact with the lip.

In yet another aspect, the disclosure describes a method for connecting a concrete slab to a support. The method includes anchoring a tube around a pocket in the concrete slab; placing the pocket around a protruding end of a shear connector embedded in an end of the support; inserting a bridge around the protruding end of the shear connector; installing a fastener onto the protruding end of the shear connector to engage the bridge and urge the bridge in abutting relation with a lip of the tube; and filling the pocket in the concrete slab with a grout or flowable concrete material around the bridge.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

FIG. **1** is a schematic view in cross section of a known connection configuration between a slab and a support beam.

FIG. **2** is a schematic view in cross section of a mechanical connection configuration in accordance with the disclosure.

FIG. **3** is an exploded perspective view of a mechanical connection assembly in accordance with the disclosure.

FIG. **4** is an assembled perspective view of the mechanical connection assembly of FIG. **3**.

FIG. **5** is an exploded perspective view of an alternative embodiment for a mechanical connection assembly in accordance with the disclosure.

FIG. **6** is an assembled view of the mechanical connection assembly of FIG. **5**.

FIG. **7** is a flowchart for a method in accordance with the disclosure.

DETAILED DESCRIPTION

The present disclosure describes a system and method to mechanically connect precast concrete components while accommodating production and construction tolerances. The illustrated embodiments significantly enhance the structural performance of the connection and eliminate dependence on the strength of grouting materials.

To illustrate at least some disadvantages of the currently used connection arrangements, a cross section schematic of a typical connection **100** is shown in FIG. **1**. The connection **100** is made to resist shear loading resulting from a force, F, applied on a slab **102** in a horizontal direction. The slab **102** is supported on and connected to a beam **104**, which is embodied as a concrete pillar but which may be embodied in any suitable fashion such as a metal girder and the like. For connecting the slab **102** to the beam **104**, a pocket **110** is formed in the slab **102**, which accommodates a protruding portion **108** of a shear connector **106**. The shear connector **106** is embedded or otherwise connected at one end in the beam **104**, and includes a free end protruding into the pocket **110**. To complete the connection, a grout **112** or other material such as flowable concrete fills the pocket **110** and solidifies around the protruding portion **108**. One disadvantage of the connection **100** is that the strength or rigidity of the connection depends on the rigidity and strength of the grout **112**, since failures of such connections are often attributed to a crack or separation failure along a line, such as line **114**, that appears within the grout **112**.

In contrast to the typical connection **100**, a connection **200** in accordance with the disclosure is shown in cross section in FIG. **2**. The connection is also shown from various perspectives in FIGS. **3**, **4** and **5**. In reference to these figures, the connection **200** includes a tube **210** having anchors **212** extending radially therefrom. The tube **210**, which in the illustrated embodiment is basically a hollow structural section (HSS) that is cast into the slab **102** such that the anchors **212** are embedded in the concrete of the slab **102** and an interior of the tube **210** forms a bottom portion of a pocket **216** of the slab **102**. Adjacent a lower end of the tube **210** or, stated differently, an end of the tube **210** that faces the beam **104** to which the slab **102** is connected, the tube **210** includes a lip **220**, which is illustrated as a ring or thin bar that is connected to the tube **210**.

During assembly, the tube **210** is provided already cast into the slab **102**. The slab **102** is hoisted into place and set onto the beam **104** such that the pocket **216** and tube **210** are placed around a protruding end of a shear connector **206**, which is illustrated as a threaded rod. A bridging tube **214** is inserted around the shear connector **206** and within the tube **210** until seated against the lip **220**. A fastener such as a nut **208**, with an optional washer **209**, engages an end of the shear connector **206** that protrudes past the bridging tube **214** and is tightened against the bridging tube **214**. In this fashion, the bridging tube **214** restrained along the shear connector **206** between the lip **220** and the nut **208** and, therefore, the slab **102** by its connection to the tube **210** is mechanically connected to the beam **104** via the connection **200**. More specifically, a torque applied to the nut **208** to tighten the same against the bridging tube **214** creates a clamping force in the body of the shear connector **206** tending to pull in an upward direction in the orientation shown in FIG. **2**, and a reactionary clamping force is transferred between the slab **102** and beam **104** from the bridging tube **214**, to the lip **220**, to the tube **210** and to the slab **102** via the anchors **212** connected to the tube **210**. Following assembly, the pocket **216** may be filled with grout **218** to produce a finished slab surface.

An alternative embodiment for a connection **300** is shown in FIGS. **5** and **6**. In reference to these figures, where structures that are the same or similar to structures of connection **200** are denoted by the same reference numerals for simplicity, the connection **300** includes a tube **310**. In this embodiment, the tube **310** has a rectangular shape rather than the circular shape of tube **210**. The tube **310** includes anchors **212** extending laterally outwardly therefrom in all directions. The tube **310**, which in the illustrated embodiment is basically a hollow structural section (HSS) that is cast into the slab **102** such that the anchors **212** are embedded in the concrete of the slab **102** and an interior of the tube **310** forms a bottom portion of a pocket **316** of the slab **102**. Adjacent a lower end of the tube **310** or, stated differently, an end of the tube **310** that faces the beam **104** to which the slab **102** is connected, the tube **310** includes a lip **320**, which is illustrated as a pair of rods that are connected in parallel on one side of opposite faces of the tube **310**.

During assembly, the tube **310** is provided already cast into the slab **102**. The slab **102** is hoisted into place and set onto the beam **104** such that the pocket **316** and tube **310** are placed around a protruding end of a pair of shear connectors **206**, which are illustrated as threaded rods. A bridging tube **214** is inserted around each of the shear connectors **206** and within the tube **310** until seated against the lips **320**. A fastener such as a nut **208**, with an optional washer **209**, engages an end of each tie **206** that protrudes past each bridging tube **214** and is tightened against the bridging tube **214**. In this fashion, the connection between a slab **102** and beam **104** can be accomplished as described above.

The connections **200** and **300** present numerous advantages over the known connections **100**. For example, failure in a connection **100** will typically be a brittle failure of the grout used to fill the pocket. In the connections **200** and **300**, failure will be a ductile failure of the mechanical parts participating in the connection between the tube (slab) and the shear connector (beam). Additionally, the improved connections allow for increased tolerance in the alignment of the slab to the beam, faster construction, easy implementation and are more durable owing to the ductile fractures that are required to fail the joint. The connections **200** or **300**, or other similar arrangements, can be used for pre-cast applications such as bridge construction, and can also be used in other types of applications requiring connections, such as in structural building, precast residential and commercial housing, flooring, roofing and other applications.

To realize the advantages of connections in accordance with the disclosure, experiments were carried out. Based on the results of the experimental and analytical investigations conducted in this research, the researchers developed the new connection detail that eliminates the brittle failure mechanism of concrete breakout, which is commonly experienced in large-sized shear pockets. One difference between the new connection and ones previously proposed or currently in use is the load path between the slab and beam. In the new connection, load is transferred from the HSS-formed tube in the shear pocket to the shear connector mechanically using a bridging tube placed around the shear connector and on a loop bar welded to the tube of the shear pocket, as shown in FIG. **2**. The loop bar or lip is welded to the bottom of the tube by fillet welding at discrete locations to support the bridging tube after the threaded rod nut is tightened. This locking mechanism allows the shear connector and precast concrete slab to be connected without fringing on the specified tolerance. Shear studs are also welded to the exterior surface of the tube to provide the necessary anchorage into the slab concrete.

For assembling the connection, first, the precast concrete slab is erected on top of the supporting beam; second, the bridging tube is placed inside the shear pocket and around the shear connector to be supported on the lip; and third, the washer and nut are placed and tightened.

Two specimens corresponding to connection **100** (FIG. **1**) and connection **200** (FIG. **2**) were tested to evaluate the performance of the new connection. One 1.5 in. diameter A193 B7 threaded rod was used as shear connector. Round HSS 12.75×0.25 with #4 loop bar was used for the tube and lip, respectively, and rectangular HSS 12×2×0.25 was used for bridging tube. Self-consolidating concrete (SCC) was used to fill the shear pocket with an average slump flow of 24 in. The two specimens were tested 40 days after casting the shear pocket and the average measured concrete compressive strength at the testing time was 6.5 ksi. Same test setup and testing procedures were used in testing the two specimens. The load was applied incrementally at an average of 3 kips/sec. The specimen corresponding to connection **200** failed by shearing off the threaded rod without any damage to the concrete inside the shear pocket. The relative displacement was measured between the precast concrete slab and beam in the horizontal direction. The specimens corresponding to connection **200** of the present disclosure started to experience significant horizontal displacement under a constant load when the load reached 150 kips and the corresponding horizontal displacement was 0.09 in. The specimens failed at an average maximum load of 192.4 kips and a corresponding horizontal displacement of 1.66 in.

In contrast, the specimen corresponding to connection **100** (FIG. **1**) failed in a brittle mode of failure (concrete breakout failure) and the post yielding resistance was not achieved. The new connection was determined to have increased the connection resistance by an average of 24% when it was compared to the conventional shear pocket connection. In addition, the new connection concept provided ductile mode of failure compared to the brittle mode of failure observed in the conventional shear pocket connection.

A flowchart for a method of connecting a concrete structure to a support is shown in FIG. **7**. In accordance with the method, a tube is provided and anchored around a pocket in a concrete slab at **402**. The pocket is placed around a protruding end of a shear connector embedded in the beam at **404**. A bridging tube is inserted around the protruding end of the shear connector and in abutting relation to a lip of the tube at **406**. A fastener is installed to engage the bridging tube between the tube and the shear connector at **408**, and the pocket is filled with a grout/flowable concrete around the bridging tube at **410**.

The use of the terms "a" and "an" and "the" and "at least one" and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The use of the term "at least one" followed by a list of one or more items (for example, "at least one of A and B") is to be construed to mean one item selected from the listed items (A or B) or any combination of two or more of the listed items (A and B), unless otherwise indicated herein or clearly contradicted by context. The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

The invention claimed is:

1. A connection assembly for fastening a first precast concrete member to a second precast concrete member, the first and second precast concrete members being in physical contact with one another, the connection assembly comprising:

a threaded rod protruding from a first face of the first precast concrete member, the first face of the first concrete member contacting the second precast concrete member;

a sleeve having a lateral wall surrounding an opening, the sleeve being integrated into the second precast concrete member such that the opening extends through a thickness of the second precast concrete member, the second precast concrete member being disposed in contact with the first precast concrete member such that the threaded rod extends at least partially through the sleeve;

a lip connected along an inner side of the lateral wall;

a bridge disposed within the opening, the bridge having a body that forms a bore disposed around at least a portion of the threaded rod and ends that abut against the lip; and

a fastener engaged with the threaded rod and positioned to retain the bridge in contact with the lip.

2. The connection assembly of claim **1**, further comprising one or more concrete anchors connected with the lateral wall of the sleeve along an outer side thereof, the one or more concrete anchors being embedded into the second precast concrete member.

3. The connection assembly of claim **2**, wherein each of the one or more concrete anchors has an elongate shape and is connected at one end on the outer side of the lateral wall.

4. The connection assembly of claim **3**, wherein each of the one or more concrete anchors has a head connected an an opposite end thereof.

5. The connection assembly of claim **1**, further comprising a grout material occupying an internal space of the opening.

6. The connection assembly of claim **1**, wherein the lip is connected to the lateral wall and extends around a perimeter of the opening.

7. The connection assembly of claim **6**, wherein the lip is disposed adjacent the first precast concrete member.

8. The connection assembly of claim **1**, wherein the threaded rod is embedded and anchored at one end in the first precast concrete member.

9. The connection assembly of claim **1**, wherein the sleeve has a tubular shape.

10. The connection assembly of claim **1**, wherein the sleeve has a round cross section.

11. The connection assembly of claim **1**, wherein the sleeve has a rectangular cross section.

12. The connection assembly of claim **1**, wherein the body of the bar has an elongate shape that abuts the lip at two locations.

13. The connection assembly of claim **1**, wherein the sleeve, the lip, and the bridge are made of steel.

14. A method for connecting a first precast concrete member with a second precast concrete member, comprising:

placing the first precast concrete member in contact with the second precast concrete member;

providing a threaded protruding from a first face of the first precast concrete member, the first face of the first concrete member contacting the second precast concrete member;

providing a sleeve having a lateral wall surrounding an opening, the sleeve being integrated into the second precast concrete member such that the opening extends through a thickness of the second precast concrete member;

placing the second precast concrete in contact with the first precast concrete member such that the threaded rod extends through the sleeve;

placing a bridge within the opening, the bridge having a body that forms a bore disposed around at least a portion of the threaded rod, and ends that abut against a a lip connected along an inner side of the lateral wall;

engaging the threaded rod with a fastener such that the bridge is retained in contact with the lip.

15. The method of claim **14**, further comprising connecting one or more concrete anchors to an outer side of the lateral wall of the sleeve, and embedding the one or more concrete anchors into the second precast concrete member.

16. The method of claim **14**, further comprising filling an internal space of the opening with a grout material.

17. A method for connecting a concrete slab to a support, comprising:

anchoring a tube around a pocket in the concrete slab;

placing the pocket around a protruding end of a shear connector embedded in an end of the support;

inserting a bridge around the protruding end of the shear connector;

installing a fastener onto the protruding end of the shear connector to engage the bridge and urge the bridge in abutting relation with a lip of the tube; and

filling the pocket in the concrete slab with a grout or flowable concrete material around the bridge.

18. The method of claim **17**, wherein anchoring the tube around the pocket includes connecting anchors on an outer side of the tube, and casting the concrete slab around the tube and anchors to embed the anchors in the concrete slap and allow an interior of the tube to form the pocket.

19. The method of claim **17**, wherein the shear connector is a threaded rod that is embedded in the support, and wherein the fastener is a nut that threadably engages the shear connector.

20. The method of claim **17**, further comprising inserting a second bridge around a protruding end of a second shear connector disposed in the pocket, and fastening the second bridge in abutting relation with the lip.

* * * * *