US 20150013263A1

(19) United States

(12) Patent Application Publication

Pimentel

(10) Pub. No.: US 2015/0013263 A1

(43) Pub. Date: Jan. 15, 2015

(54) **SLEEVE DEVICE FOR TRANSFERRING BENDING MOMENTS**

(71) Applicant: **Benjamin Joseph Pimentel**, New York, NY (US)

(72) Inventor: **Benjamin Joseph Pimentel**, New York, NY (US)

(21) Appl. No.: **14/330,015**

(22) Filed: **Jul. 14, 2014**

Related U.S. Application Data

(60) Provisional application No. 61/846,079, filed on Jul. 15, 2013.

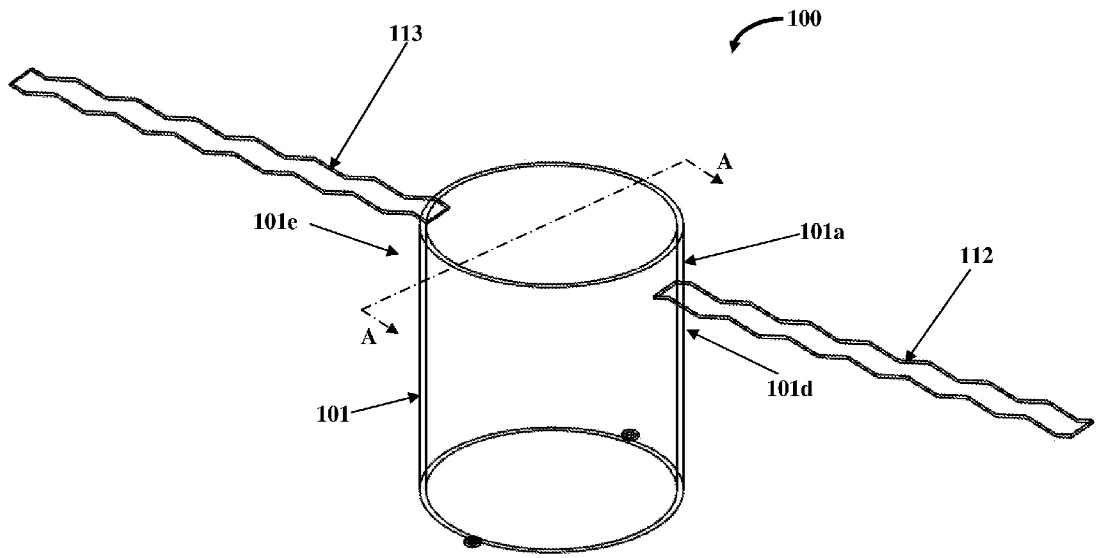
Publication Classification

(51) **Int. Cl.**
E04C 5/20 (2006.01)

(52) **U.S. Cl.**
CPC ***E04C 5/20*** (2013.01)
USPC **52/687**

(57) **ABSTRACT**

A sleeve device for transferring bending moments induced in a reinforced concrete slab includes a generally hollow member and tension rebars. The hollow member is positioned and fastened on a bottom formwork defining the reinforced concrete slab. The tension rebars are connected to opposing sides of an upper portion of the hollow member either directly or using rebar connectors. The hollow member creates a void in the reinforced concrete slab by pouring of concrete around an outer wall of the hollow member. The hollow member transfers compressive stresses across a bottom of the hollow member and tensile stresses through the tension rebars and the upper portion of the hollow member. The affixed tension rebars are spliced with regular reinforced concrete slab rebars to develop tensile stresses that are transferred through the relatively stiffer hollow member to retain a slab moment capacity.



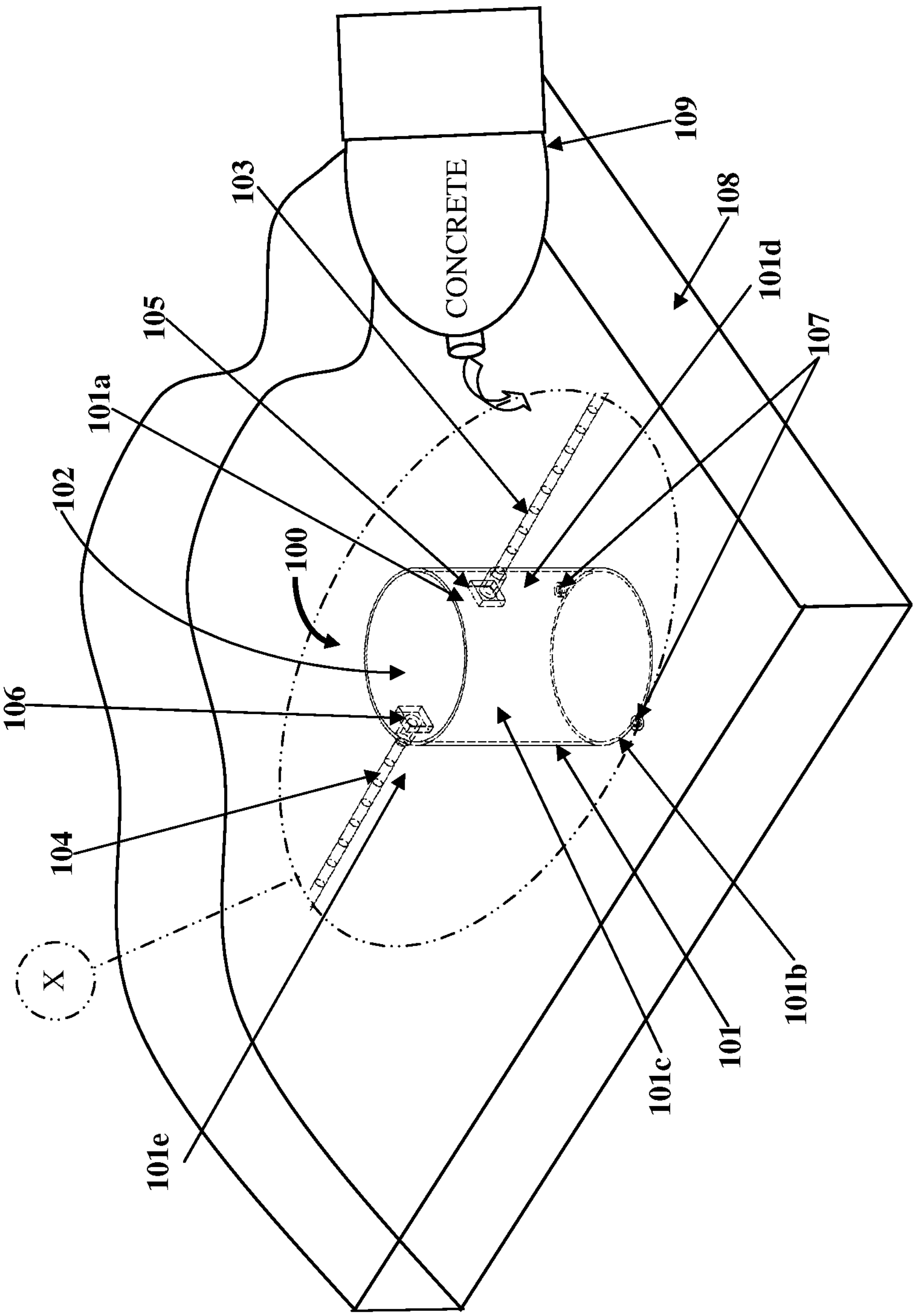

109
CONCRETE
103
108
105
101d
101a
107
102
100
106
104
X
101e
101c
101
101b

FIG. 1A

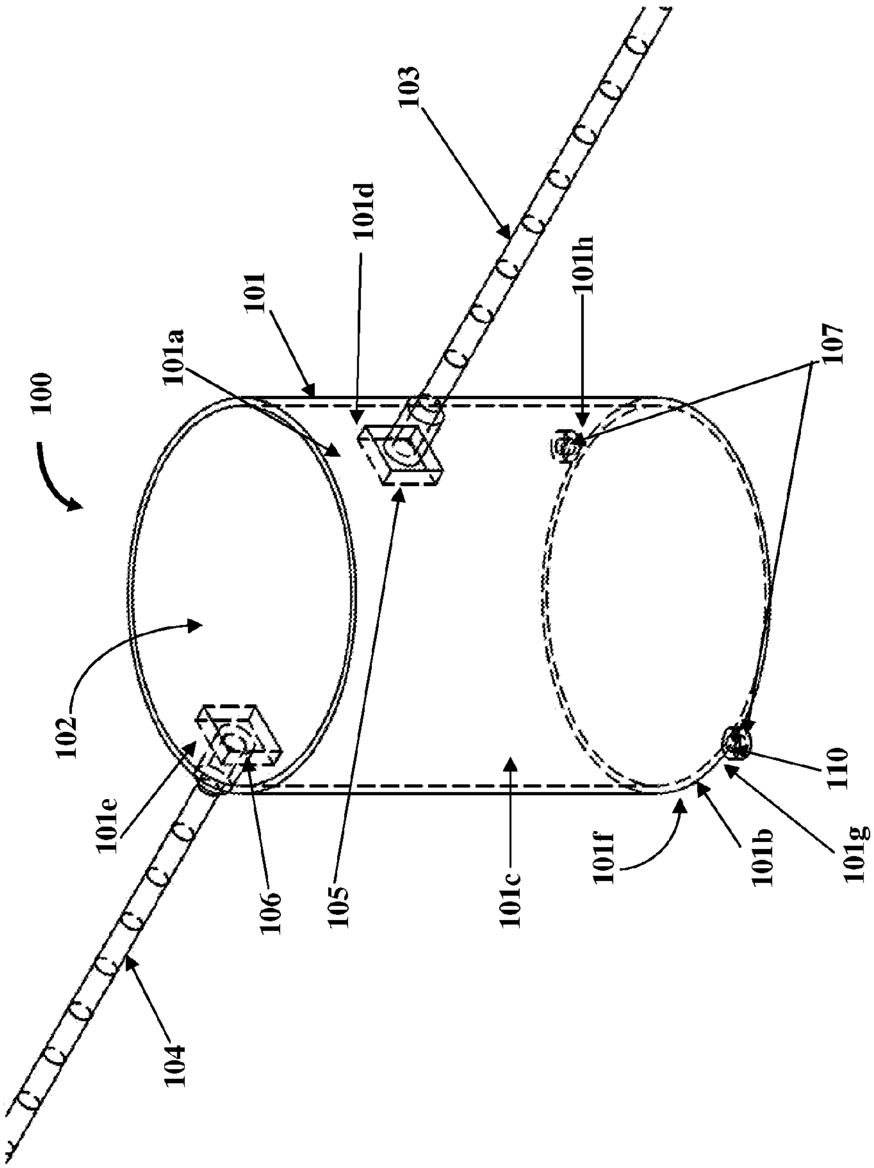

100
101
101a
101d
103
101h
107
102
101e
106
105
101c
101f
101b
101g
110
104

FIG. 1B

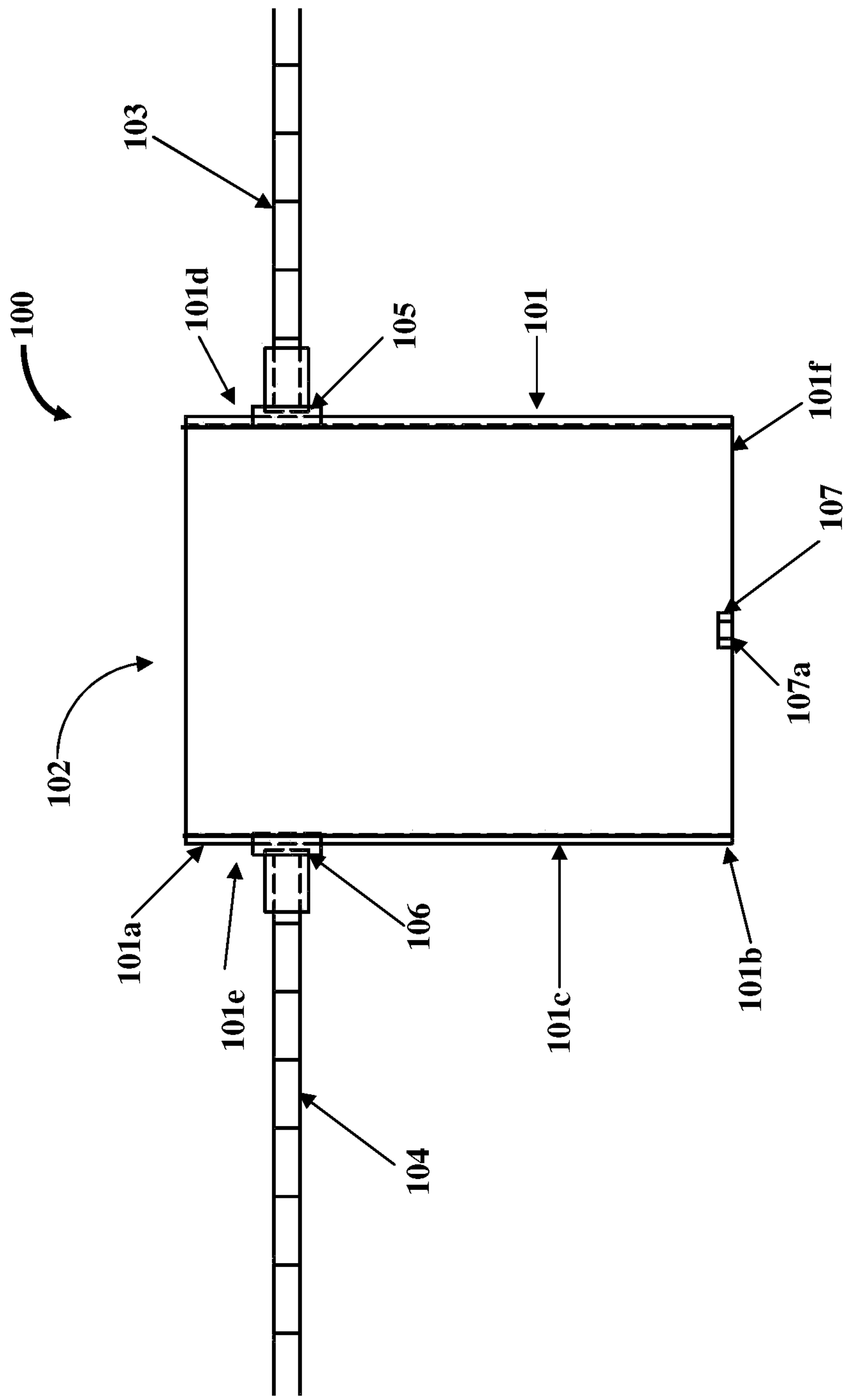

100
103
101d
105
101
101f
107
107a
102
101a
101e
106
101c
101b
104

FIG. 2

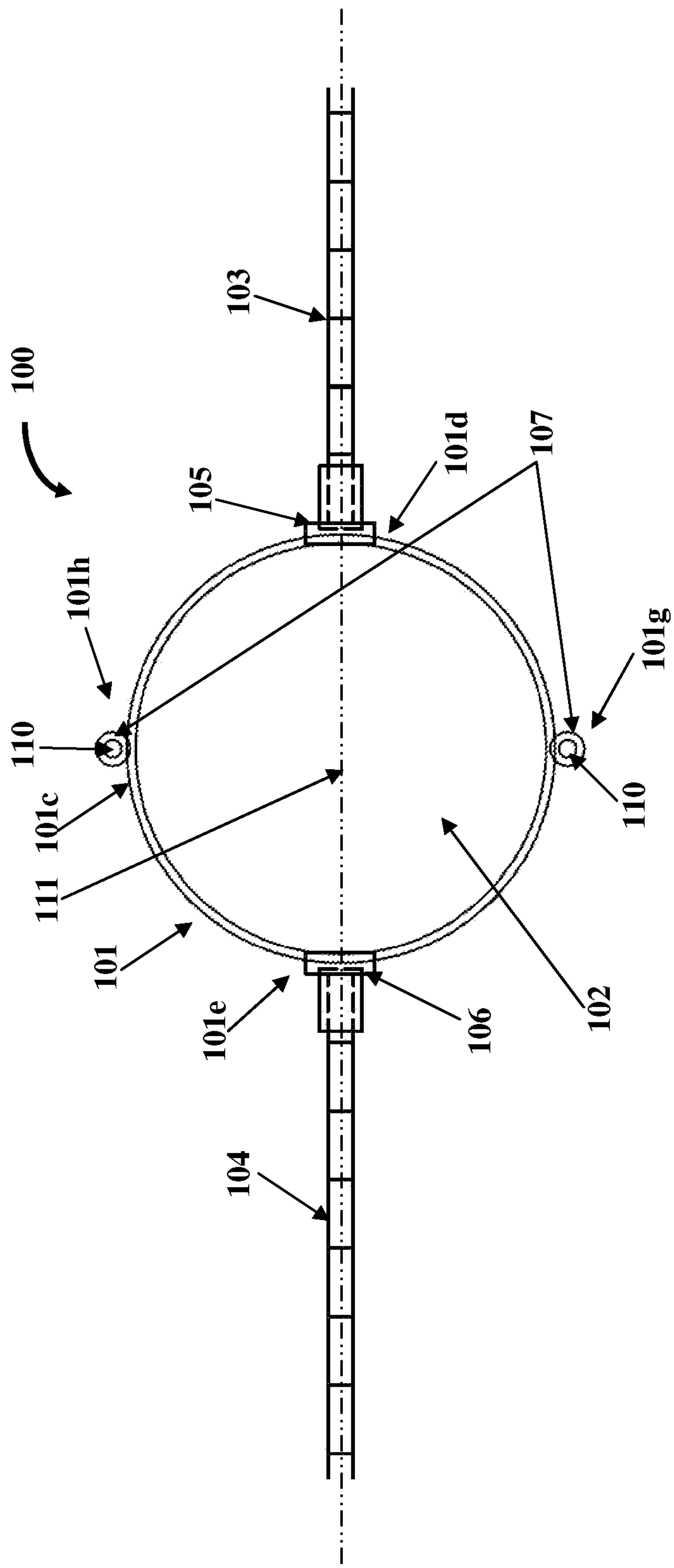

100
103
105
101d
107
101h
110
101c
111
101
101e
106
102
101g
110
104

FIG. 3

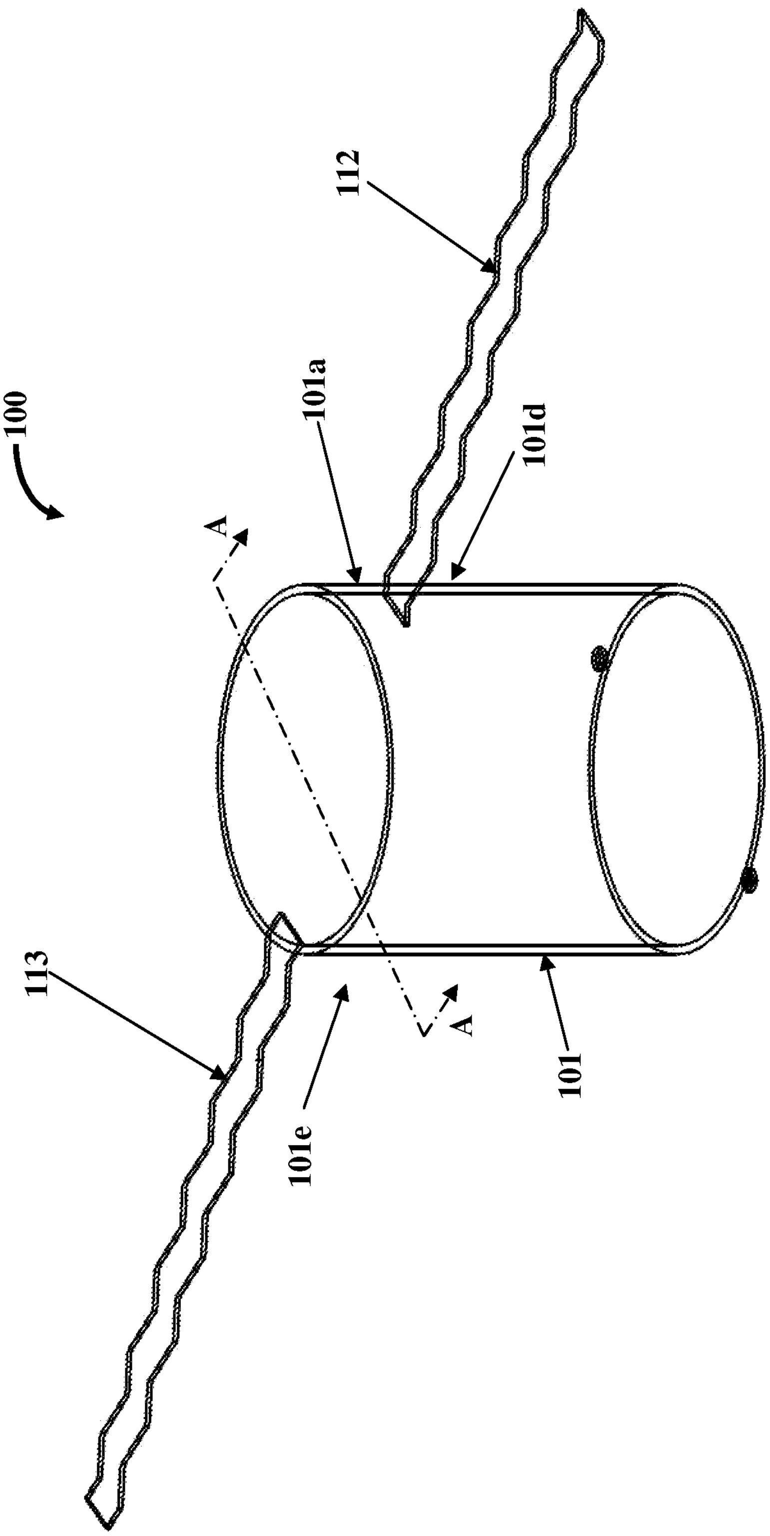


FIG. 4A

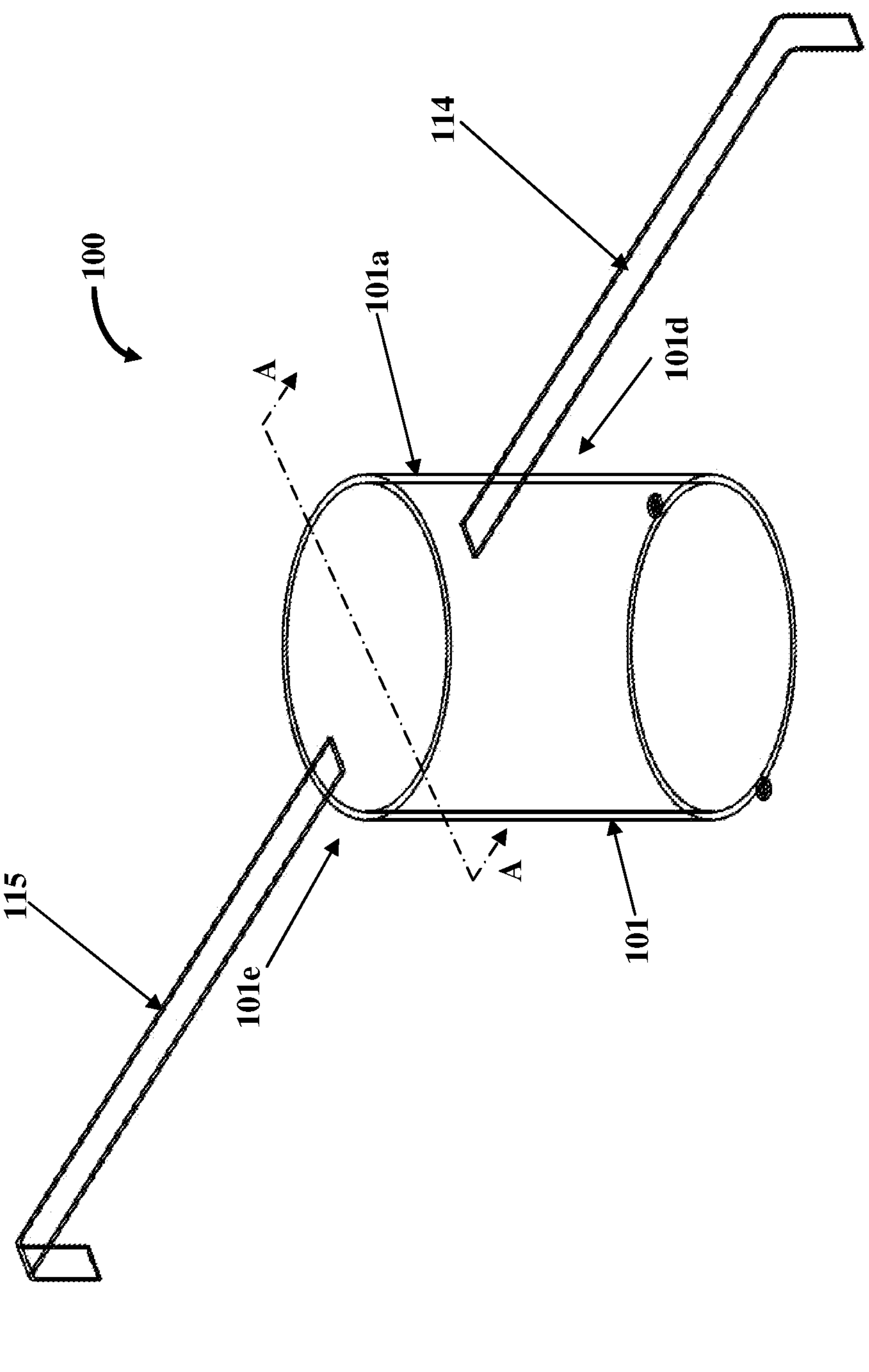


FIG. 4B

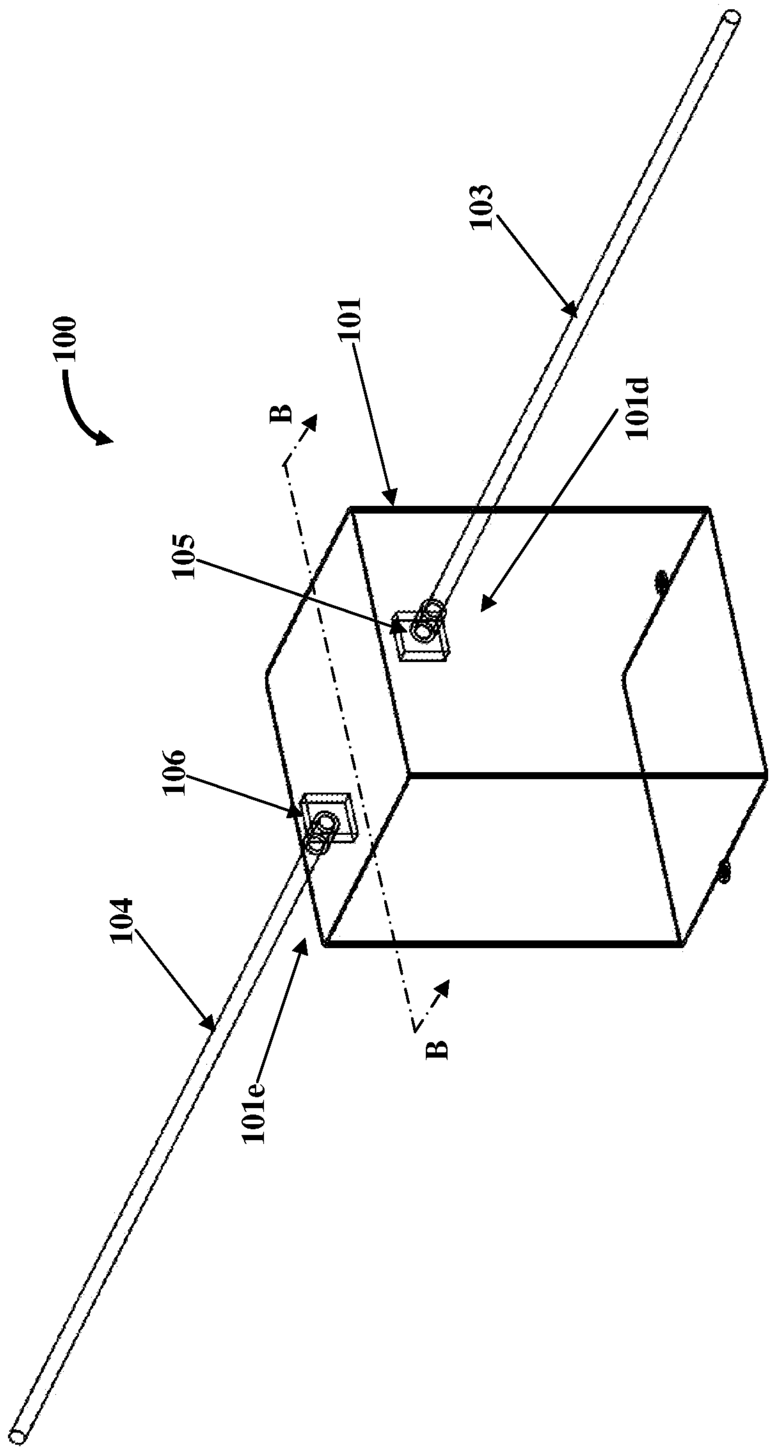


FIG. 5A

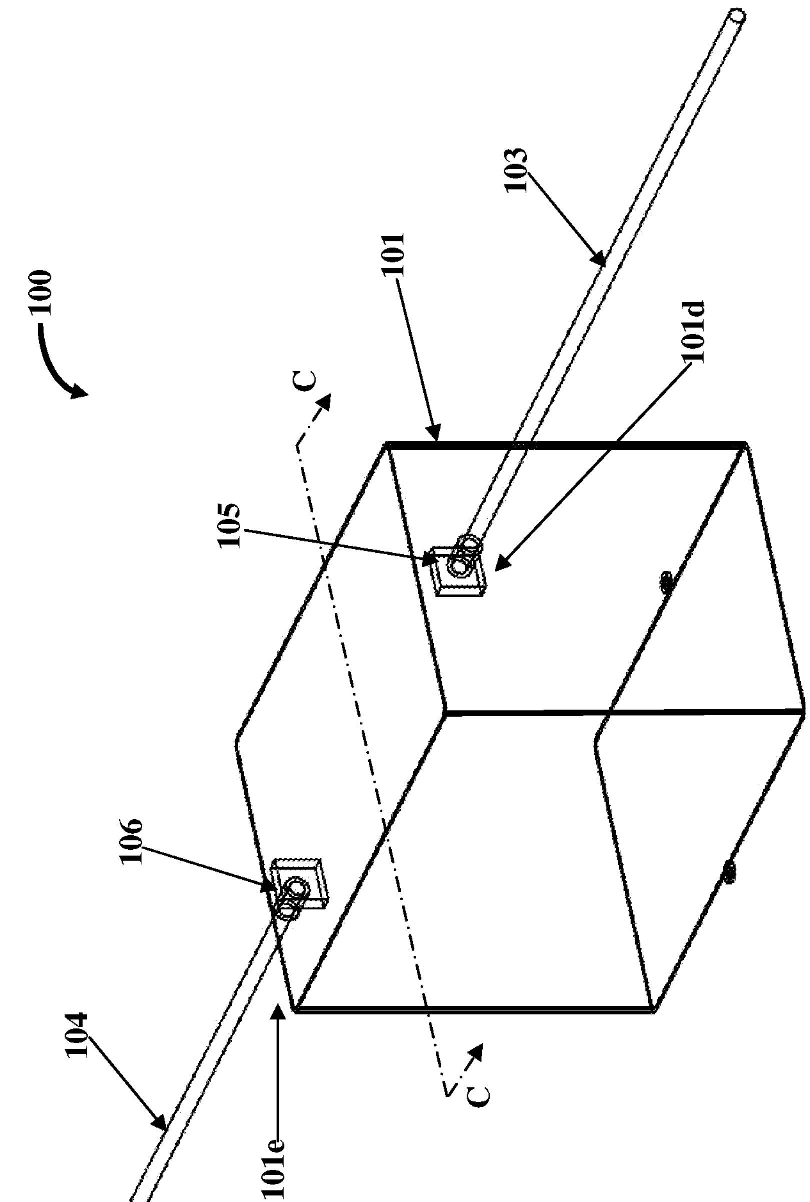


FIG. 5B

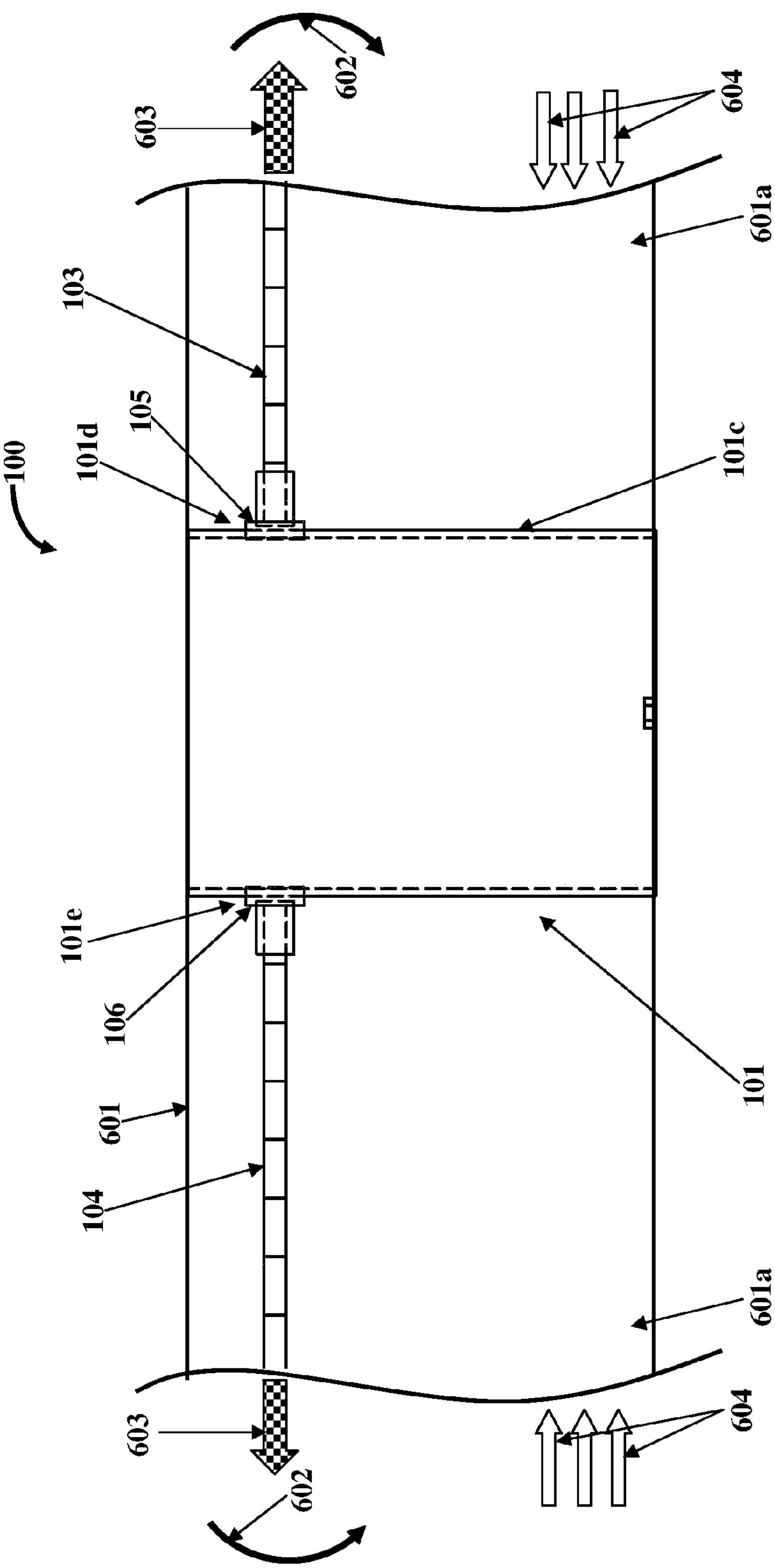

602
603
604
601a
103
105
101d
100
101c
101e
106
101
601
104
601a
603
602
604

FIG. 6

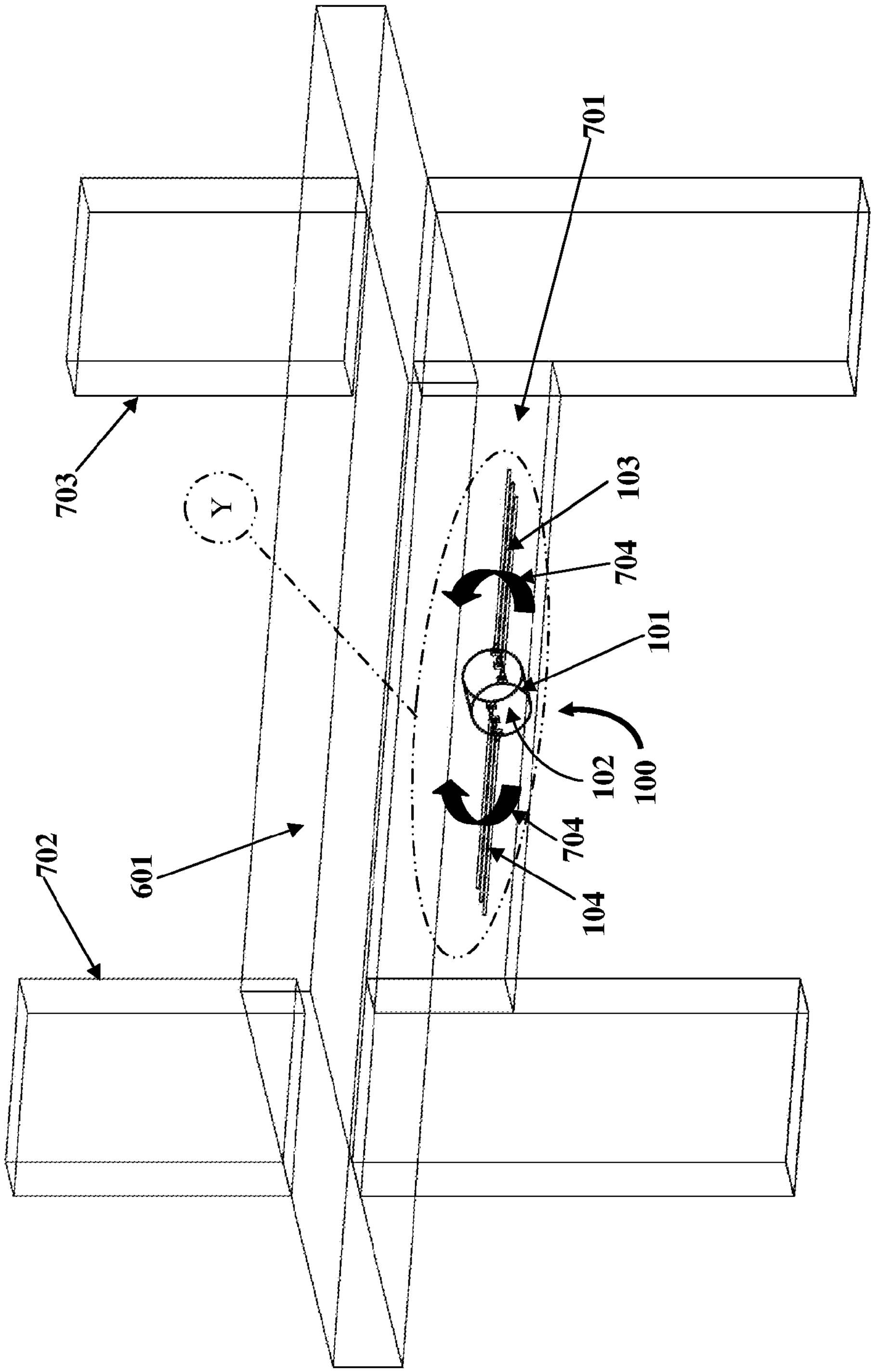


FIG. 7A

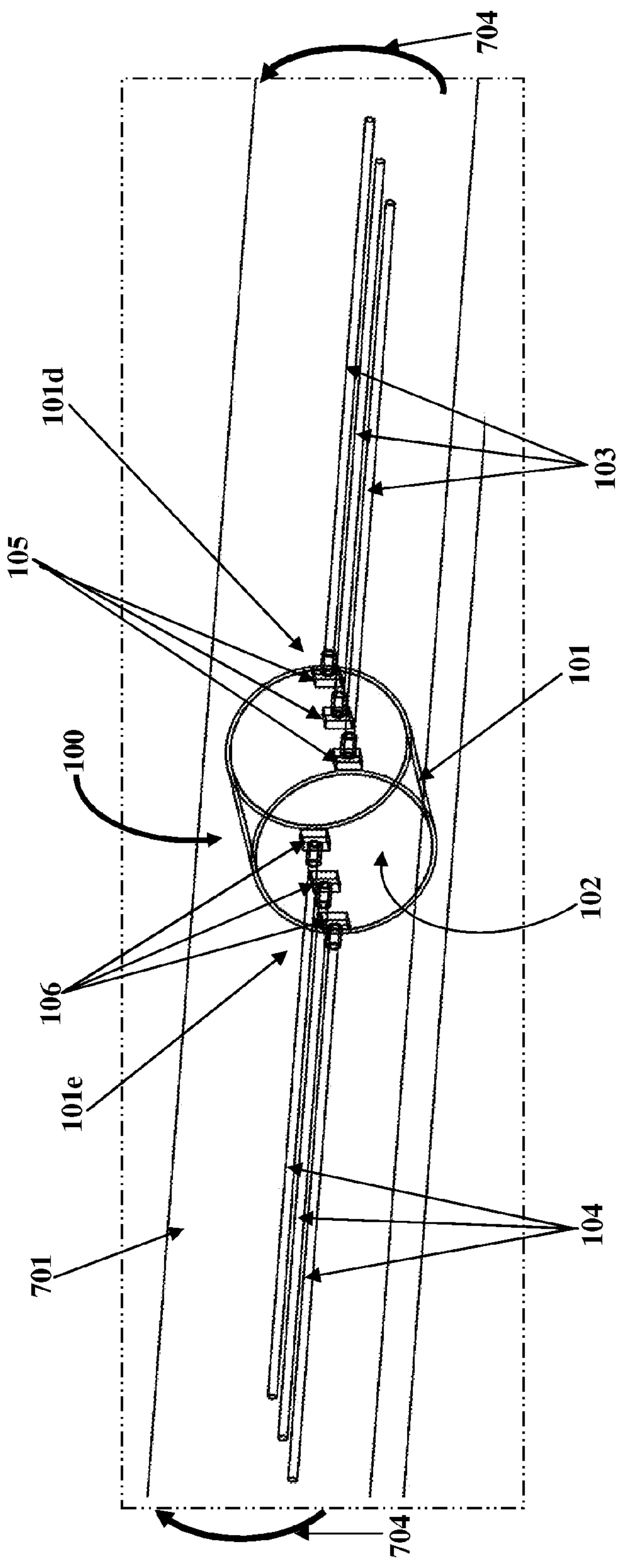


FIG. 7B

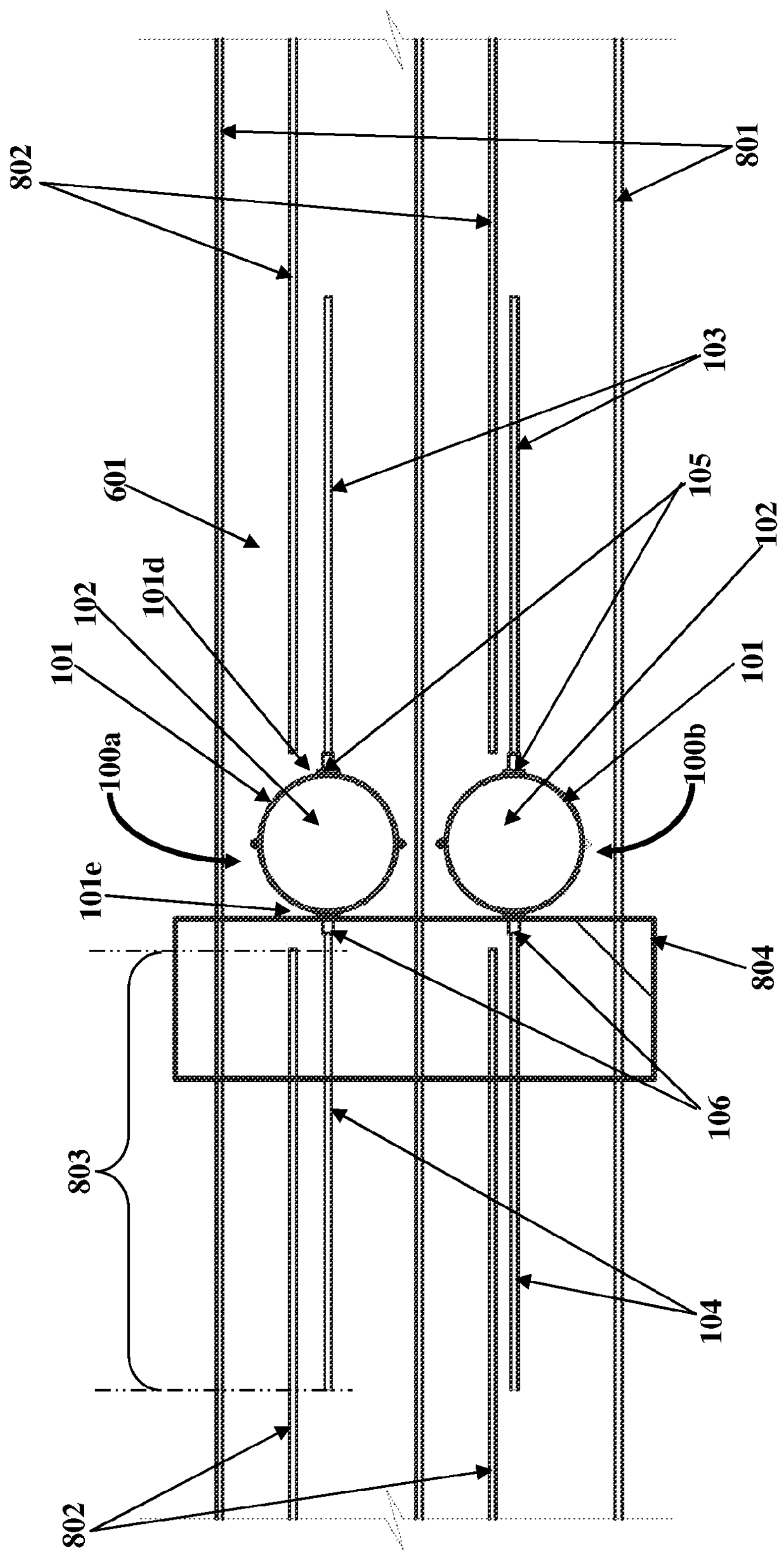

802
801
103
601
105
102
101d
101
100a
100b
101e
804
106
803
104
802

FIG. 8

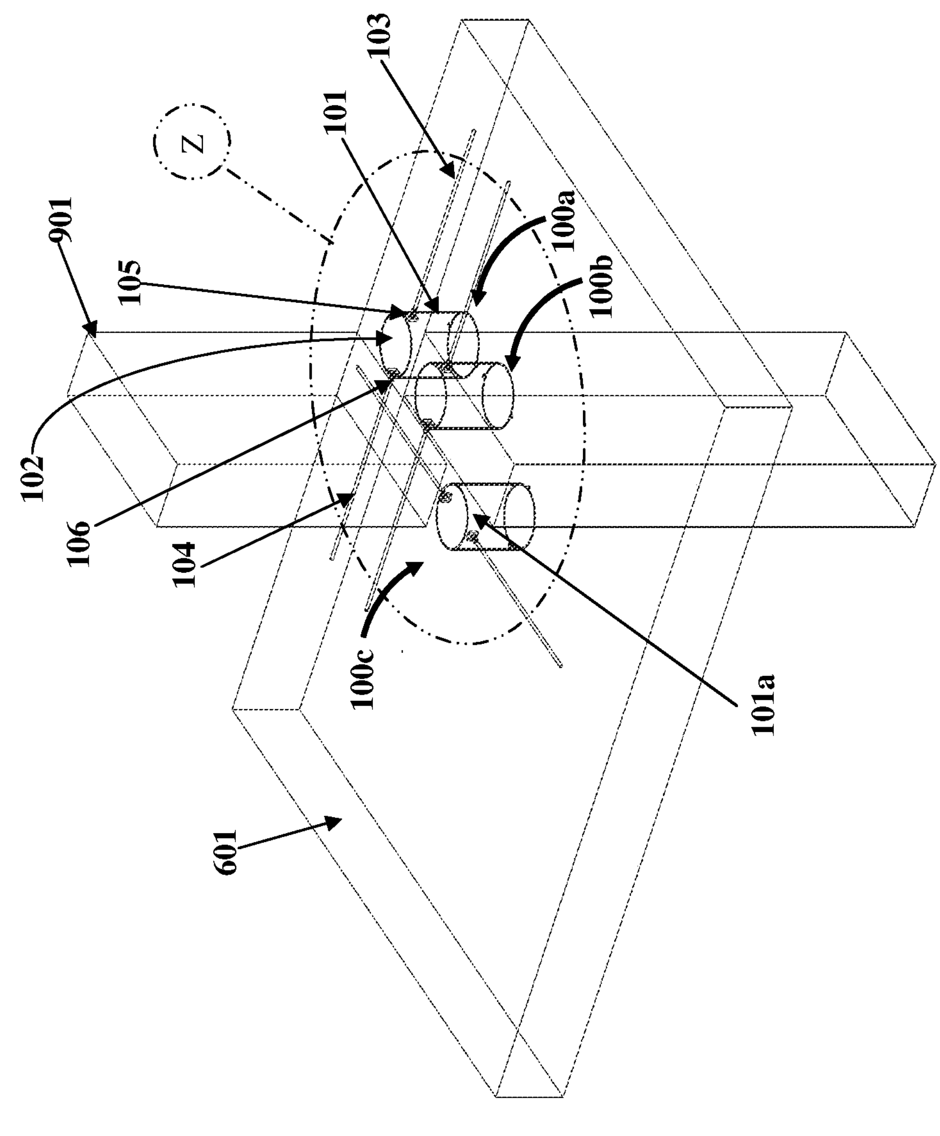


FIG. 9A

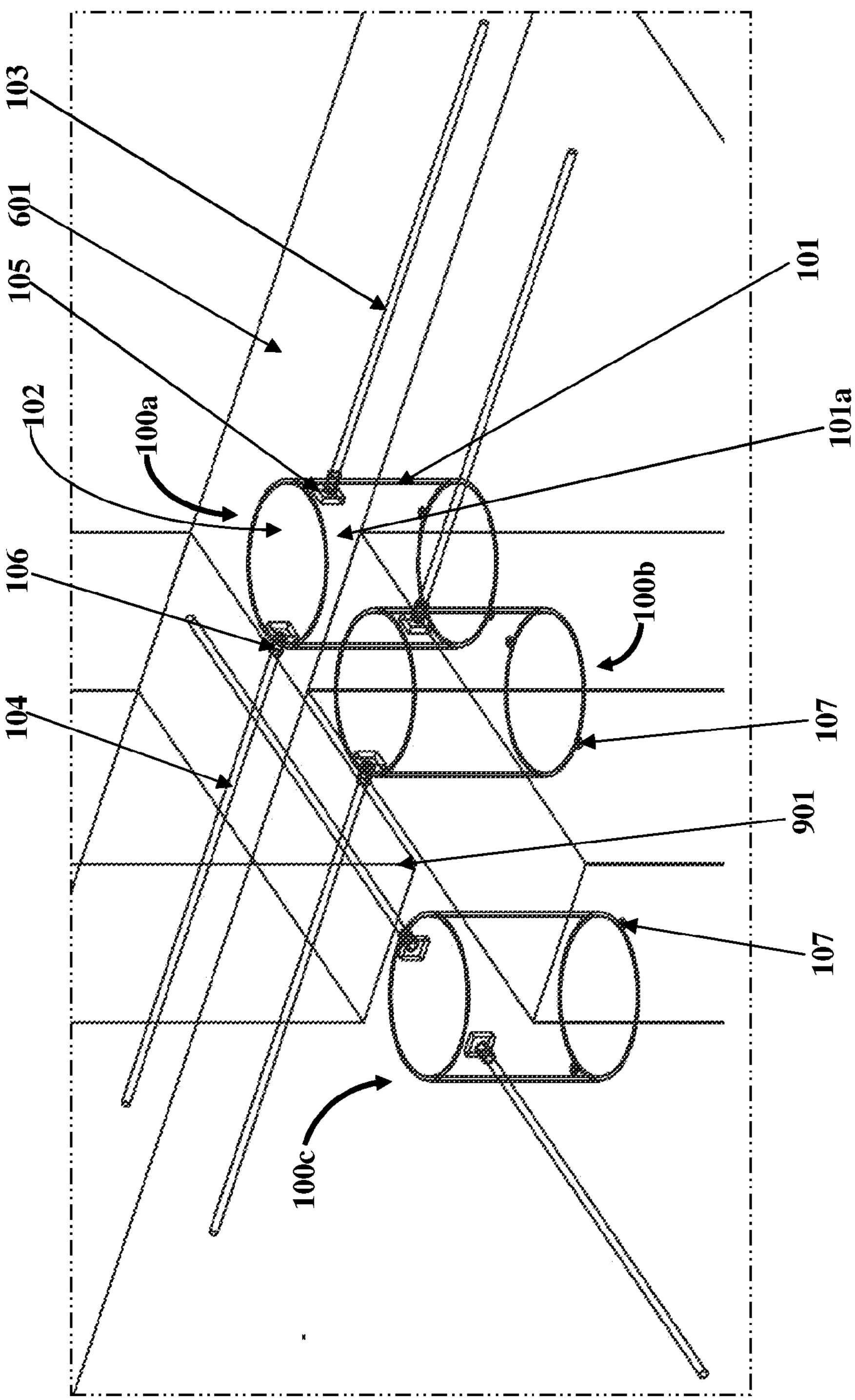


FIG. 9B

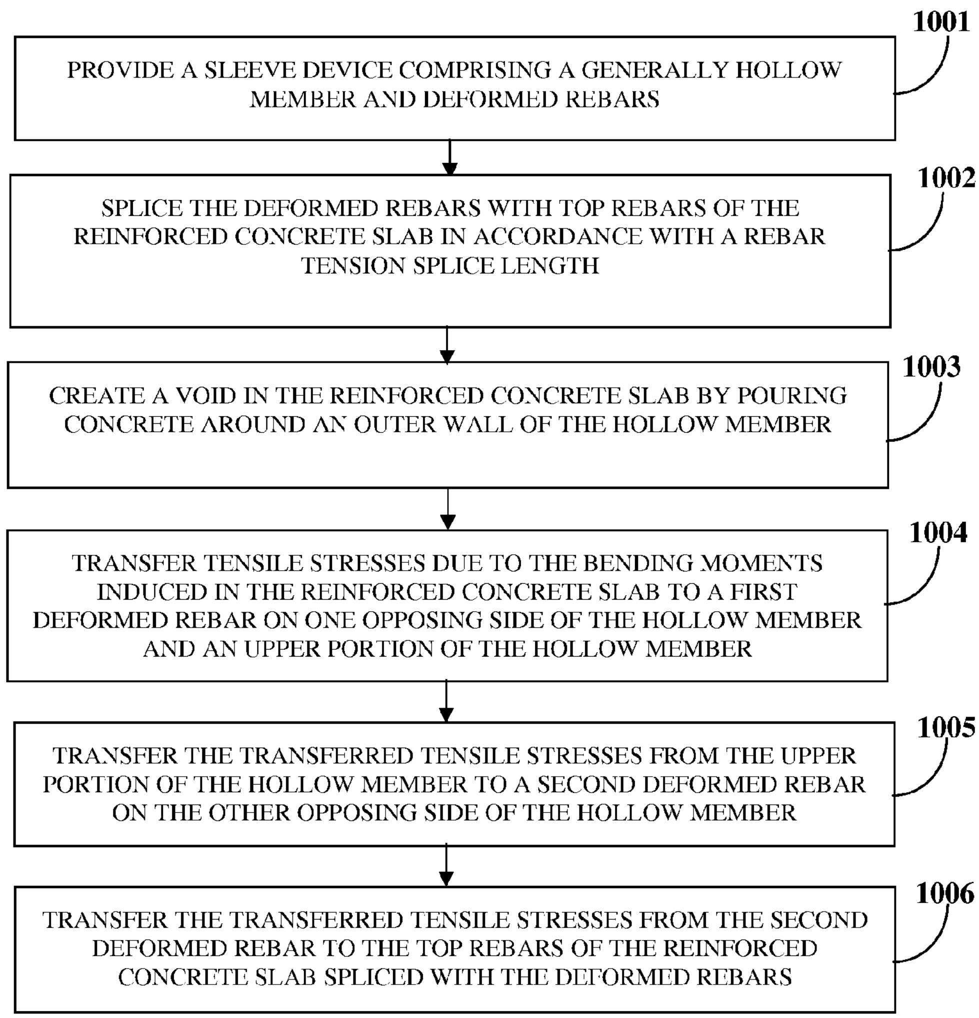

1001
PROVIDE A SLEEVE DEVICE COMPRISING A GENERALLY HOLLOW MEMBER AND DEFORMED REBARS
1002
SPLICE THE DEFORMED REBARS WITH TOP REBARS OF THE REINFORCED CONCRETE SLAB IN ACCORDANCE WITH A REBAR TENSION SPLICE LENGTH
1003
CREATE A VOID IN THE REINFORCED CONCRETE SLAB BY POURING CONCRETE AROUND AN OUTER WALL OF THE HOLLOW MEMBER
1004
TRANSFER TENSILE STRESSES DUE TO THE BENDING MOMENTS INDUCED IN THE REINFORCED CONCRETE SLAB TO A FIRST DEFORMED REBAR ON ONE OPPOSING SIDE OF THE HOLLOW MEMBER AND AN UPPER PORTION OF THE HOLLOW MEMBER
1005
TRANSFER THE TRANSFERRED TENSILE STRESSES FROM THE UPPER PORTION OF THE HOLLOW MEMBER TO A SECOND DEFORMED REBAR ON THE OTHER OPPOSING SIDE OF THE HOLLOW MEMBER
1006
TRANSFER THE TRANSFERRED TENSILE STRESSES FROM THE SECOND DEFORMED REBAR TO THE TOP REBARS OF THE REINFORCED CONCRETE SLAB SPLICED WITH THE DEFORMED REBARS

FIG. 10

SLEEVE DEVICE FOR TRANSFERRING BENDING MOMENTS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of provisional patent application No. 61/846,079 titled "Sleeve Device For Transferring Bending Moments", filed in the United States Patent and Trademark Office on Jul. 15, 2013. The specification of the above referenced patent application is incorporated herein by reference in its entirety.

BACKGROUND

[0002] The apparatus disclosed herein, in general, relates to sleeves for concrete structures. More particularly, the apparatus disclosed herein relates to a sleeve device that transfers bending moments induced in a reinforced concrete slab and compensates for reinforced concrete slab moment capacity loss due to penetrations proximal to concrete columns.

[0003] Reinforced concrete flat slabs are extensively used in concrete construction. During a manufacturing process, utility pipes are typically positioned adjacent to concrete columns due to architectural or mechanical constraints. To position a utility pipe through a reinforced concrete slab, holes are created in the reinforced concrete slab. There are several conventional methods employed to create holes in cast-in-place concrete slabs. One method for creating a hole in a cast-in-place concrete slab is by using a formwork that includes a section defining a hole positioned in a specified location inside the formwork. Concrete is poured inside the formwork around the section that defines the hole to create a reinforced concrete slab with a hole. After the concrete is cured, the formwork is removed.

[0004] Another conventional method to form a void during the concrete pour is to use sleeves. The sleeves are retained in the reinforced concrete slab. Although the voids created using this method allow mechanical piping to run through the reinforced concrete slab, these voids reduce the structural capability of the concrete and the sleeves. The sleeves are generally made of tube shaped steel that offers no structural capacity due to a lack of bond between concrete and steel tubes. Since pipe penetrations tend to cut or displace top rebars and bottom rebars, the moment capacity of reinforced concrete slabs is reduced and in some cases causes flexural failures. In some cases, multiple sleeves are placed in proximity to a column and design engineers cannot accommodate the moment capacity requirements to attain the minimum code prescribed rebar spacing. Therefore, design engineers often have to check moment and shear capacities of the concrete slabs when the sleeves are placed in close proximity to slab supports such as concrete columns. In many cases, structural modifications are required to compensate for the loss of moment capacity caused by pipe penetrations. The structural modifications comprise, for example, increasing slab thickness, positioning extra rebars on both sides of the penetrations, etc.

[0005] Hence, there is a long felt but unresolved need for a sleeve device that reinforces concrete slabs while allowing penetrations in close proximity to slab supports such as concrete columns, adding structural capacity to the concrete slabs, and minimizing the work and effort required from an engineer, thereby allowing architects and mechanical engineers more flexibility in positioning mechanical piping.

SUMMARY OF THE INVENTION

[0006] This summary is provided to introduce a selection of concepts in a simplified form that are further disclosed in the detailed description of the invention. This summary is not intended to identify key or essential inventive concepts of the claimed subject matter, nor is it intended for determining the scope of the claimed subject matter.

[0007] The sleeve device disclosed herein addresses the above stated needs for reinforcing concrete slabs while allowing penetrations in close proximity to slab supports, for example, concrete columns. The sleeve device disclosed herein transfers bending moments induced in a reinforced concrete slab and compensates for reinforced concrete slab moment capacity loss due to penetrations proximal to concrete columns. The sleeve device disclosed herein adds structural capacity to concrete slabs, minimizes the work and effort required from an engineer, and allows architects and mechanical engineers more flexibility in positioning mechanical piping. The sleeve device is a device, for example, made of metal attached to and cast within a concrete structure such as a reinforced concrete slab and is configured to transfer bending moments induced in the reinforced concrete slab. The sleeve device disclosed herein comprises a generally hollow member and tension rebars. The hollow member is positioned on and fastened to a bottom formwork defining a reinforced concrete slab. The tension rebars are connected to opposing sides of an upper portion of the hollow member either directly or using rebar connectors. The hollow member is configured to create a void in the reinforced concrete slab by pouring of concrete around an outer wall of the hollow member. The hollow member is further configured to transfer compressive stresses across a bottom of the hollow member and tensile stresses through the tension rebars and the upper portion or the top of the hollow member. The tensile stresses or forces are transferred through the tension rebars and the relatively stiffer hollow member to the opposing side of the hollow member.

[0008] The tension rebars connected to the opposing sides of the hollow member are configured to be spliced with regular reinforced concrete slab rebars in accordance with a standard rebar tension splice length for transferring the bending moments induced in the reinforced concrete slab. The bending moments in the reinforced concrete slab are resisted by tensile stresses in the tension rebars and the compressive stresses in the concrete. The tensile stresses in the tension rebars on both sides of the hollow member are transferred into the relatively stiffer hollow member, and the tensile stresses acting on the opposing sides of the hollow member are balanced out through the outer wall of the hollow member, thereby bridging the two tensile stresses from the tension rebars.

[0009] After concrete is cast around the sleeve device, the sleeve device is embedded in the reinforced concrete slab and works together with the rest of the reinforced concrete slab. The tensile stresses due to the bending moments are transferred to one of the tension rebars on one opposing side of the hollow member, then through the hollow member, to the other tension rebar on the other opposing side of the hollow member, and then to the regular reinforced concrete slab rebars spliced with the tension rebars.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The foregoing summary, as well as the following detailed description of the invention, is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, exemplary constructions of the invention are shown in the drawings. However, the invention is not limited to the specific methods and structures disclosed herein. The description of a method step or a structure referenced by a numeral in a drawing carries over to the description of that method step or structure shown by that same numeral in any subsequent drawing herein.

[0011] FIG. **1**A exemplarily illustrates a top perspective view of a sleeve device fastened to a bottom formwork for transferring bending moments induced in a reinforced concrete slab.

[0012] FIG. **1**B illustrates an enlarged view of a portion marked X in FIG. **1**A, showing the sleeve device.

[0013] FIG. **2** illustrates a partial sectional view of the sleeve device.

[0014] FIG. **3** illustrates a top plan view of the sleeve device.

[0015] FIG. **4**A exemplarily illustrates an isometric view of an embodiment of the sleeve device, showing tension rebars of the sleeve device configured as corrugated fins fixedly connected to a hollow member of the sleeve device.

[0016] FIG. **4**B exemplarily illustrates an isometric view of an embodiment of the sleeve device, showing the tension rebars of the sleeve device configured as bent plates fixedly connected to the hollow member of the sleeve device.

[0017] FIG. **5**A exemplarily illustrates an isometric view of an embodiment of the sleeve device, showing the hollow member of the sleeve device having a square cross section.

[0018] FIG. **5**B exemplarily illustrates an isometric view of an embodiment of the sleeve device, showing the hollow member of the sleeve device having a rectangular cross section.

[0019] FIG. **6** exemplarily illustrates a side view of the sleeve device positioned within a reinforced concrete slab, showing bending moments, tensile stresses, and compressive stresses acting on the reinforced concrete slab.

[0020] FIG. **7**A exemplarily illustrates an isometric wireframe view, showing deformed rebars of the sleeve device in a different orientation within a concrete beam.

[0021] FIG. **7**B illustrates an enlarged view of a portion marked Y in FIG. **7**A, showing deformed rebars in a different orientation within the concrete beam.

[0022] FIG. **8** exemplarily illustrates a top plan view, showing splicing of deformed rebars of two sleeve devices with top rebars of the reinforced concrete slab.

[0023] FIG. **9**A exemplarily illustrates an isometric view of multiple sleeve devices positioned in a reinforced concrete slab supported by a supporting column.

[0024] FIG. **9**B illustrates an enlarged view of a portion marked Z in FIG. **9**A.

[0025] FIG. **10** illustrates a method for transferring bending moments induced in a reinforced concrete slab.

DETAILED DESCRIPTION OF THE INVENTION

[0026] FIG. **1**A exemplarily illustrates a top perspective view of a sleeve device **100** fastened to a bottom formwork **108** for transferring bending moments induced in a reinforced concrete slab **601** exemplarily illustrated in FIG. **6** and FIG. **7**A. A bending moment is a measure of the average internal stress induced in the reinforced concrete slab **601** when an external force or moment is applied to the reinforced concrete slab **601** causing the reinforced concrete slab **601** to bend. As used herein, "bending moment" in a reinforced concrete slab **601** refers to an algebraic sum of moments of all bending forces acting on the reinforced concrete slab **601** due to the self-load of concrete **109** poured around the sleeve device **100** and an additional load positioned on the reinforced concrete slab **601**. FIG. **1**B illustrates an enlarged view of a portion marked X in FIG. **1**A, showing the sleeve device **100**. The sleeve device **100** disclosed herein is a cast-in-place sleeve device, for example, made of steel and used in a concrete structure, for example, a reinforced concrete slab **601**, to transfer moments due to gravity loads, seismic loads, and wind loads by mechanically attaching a bottom rebar, a top rebar **802** exemplarily illustrated in FIG. **8**, or a combination of the bottom rebar and the top rebar **802** of the reinforced concrete slab **601** to opposing sides **101***d* and **101***e* of the sleeve device **100**.

[0027] The sleeve device **100** disclosed herein comprises a generally hollow member **101** and tension rebars, for example, **103** and **104**. As used herein, "tension rebars" refer to reinforcing steel bars used to transfer tensile stresses in concrete construction. Also, as used herein, "tensile stress" refers to a tensile force acting per unit cross sectional area of a tension rebar, for example, **103** or **104** due to bending moments on sections of the reinforced concrete slab **601**. In an embodiment as exemplarily illustrated in FIGS. **1**A-**3**, the tension rebars are configured as deformed rebars **103** and **104** fixedly connected to the opposing sides **101***d* and **101***e* of an upper portion **101***a* of the hollow member **101** to transfer the tensile stresses to and from the hollow member **101** to the tension rebars.

[0028] In an embodiment as exemplarily illustrated in FIGS. **1**A-**4**B, the hollow member **101** is of a generally cylindrical shape. The hollow member **101** is positioned on and fastened to a bottom formwork **108** defining the reinforced concrete slab **601**. The hollow member **101** is configured to create a void **102** in the reinforced concrete slab **601** by pouring of concrete **109** around an outer wall **101***c* of the hollow member **101**. The void **102** created by the hollow member **101** can be of multiple geometric shapes that allow components, for example, piping, duct work, air passages, fluid passages, etc., to pass through, or for visual purposes, or for other architectural or mechanical needs. The thickness of the hollow member **101** is checked and configured to avoid local yielding of the outer wall **101***c* of the hollow member **101**. The hollow member **101** is further configured to transfer compressive stresses **604** exemplarily illustrated in FIG. **6**, across a bottom or a lower portion **101***b* of the hollow member **101** and tensile stresses **603** exemplarily illustrated in FIG. **6**, through the deformed rebar, for example, **103** and an upper portion **101***a* or the top of the hollow member **101**. As used herein, "compressive stress" refer to a compression force acting per unit cross sectional area at the bottom or a lower portion **101***b* of the hollow member **101** due to bending moments acting on sections of the reinforced concrete slab **601**.

[0029] In an embodiment, the sleeve device **100** further comprises rebar connectors **105** and **106**. The rebar connectors **105** and **106** are operably connected on the opposing sides **101***d* and **101***e* of the upper portion **101***a* of the hollow member **101**. The rebar connectors **105** and **106** fixedly connect the deformed rebars **103** and **104** respectively, to the opposing sides **101***d* and **101***e* of the upper portion **101***a* of the hollow member **101**. The deformed rebars **103** and **104** are, for example, threaded rebars or reinforced bars used in concrete construction and configured to support the load of the concrete **109**. In an example, the deformed rebars **103** and **104** exemplarily illustrated in FIGS. **1A-3**, can be configured as tension rods. The deformed rebars **103** and **104** are spliced with the top rebars **802** of the reinforced concrete slab **601** exemplarily illustrated in FIG. **8**, in accordance with a standard rebar tension splice length **803** exemplarily illustrated in FIG. **8**, for transferring the bending moments induced in the reinforced concrete slab **601**. As used herein, "standard rebar tension splice length" refers to a length by which two rebars, for example, 104 and 802 exemplarily illustrated in FIG. **8**, are overlapped and joined together to create a bond strength equal to a continuous running single rebar. The "standard rebar tension splice length" as defined by the American Concrete Institute (ACI) in Building Code Requirements for Structural Concrete refers to the length required by the ACI 318 to develop the required tensile stress in the rebars, for example, **104** and **802**. After the concrete **109** is cured, the sleeve device **100** is embedded in the reinforced concrete slab **601** and works together with the rest of the reinforced concrete slab **601**.

[0030] The bending moments in the reinforced concrete slab **601** are resisted by the tensile stresses in the deformed rebars **103** and **104** and the compressive stresses in the concrete **109**. The tensile stresses in the deformed rebars **103** and **104** on the opposing sides **101***d* and **101***e* of the hollow member **101** are transferred into the hollow member **101**, and the tensile stresses acting on the opposing sides **101***d* and **101***e* of the hollow member **101** are balanced out through the outer wall **101***c* of the hollow member **101**, thereby bridging the tensile stresses from the deformed rebars **103** and **104**.

[0031] As exemplarily illustrated in FIGS. **1A-1B**, in an embodiment, the sleeve device **100** disclosed herein further comprises mounting rings **107** rigidly connected to and extending outwardly from the opposing sides **101***g* and **101***h* of a lower portion **101***b* of the hollow member **101**. The mounting rings **107** are configured to fasten the hollow member **101** to the bottom formwork **108** defining the reinforced concrete slab **601**. The mounting rings **107** comprise holes **110** concentrically bored on the mounting rings **107** to receive fastening elements, for example, nails. The mounting rings **107** rigidly hold the hollow member **101** in place in the bottom formwork **108** to preclude movement of the hollow member **101** prior to pouring of the concrete **109**. In an embodiment, the mounting rings **107** for fastening or nailing down the sleeve device **100** may be altered or removed.

[0032] In an embodiment, the components of the sleeve device **100** can be of different sizes, for example, can be larger or smaller in size, to accommodate different opening sizes and structural capacities. The rebar connectors **105** and **106** with the deformed rebars **103** and **104** on the opposing sides **101***d* and **101***e* of the hollow member **101** can be replaced with alternative affixations to transfer bending moments. The materials used for manufacturing the sleeve device **100** are, for example, any high or low strength steel, alloy or other metal, carbon fiber, fiber reinforced polymer, or other structural material. The size of the sleeve device **100** can be increased or decreased depending on the requirements. The sleeve device **100** is configured to be installed on site by unskilled labor without using any special tools.

[0033] FIG. **2** illustrates a partial sectional view of the sleeve device **100**. The deformed rebars **103** and **104** of the sleeve device **100** are connected at an upper portion **101***a* of the hollow member **101** and on opposing sides **101***d* and **101***e* of the hollow member **101** via the rebar connectors **105** and **106** respectively. A first deformed rebar **103** is connected to one opposing side **101***d* of the hollow member **101** and extends outward from the outer wall **101***c* of the hollow member **101**. Similarly, a second deformed rebar **104** is connected to the other opposing side **101***e* of the hollow member **101** and extends outward from the outer wall **101***c* of the hollow member **101**. The first deformed rebar **103** is located near the upper portion **101***a* of the hollow member **101**. On the other opposing side **101***e* of the hollow member **101**, the second deformed rebar **104** extends away from the upper portion **101***a* of the hollow member **101**. Concrete **109** exemplarily illustrated in FIG. **1A**, is cast around the hollow member **101** to create the void **102** in the reinforced concrete slab **601** exemplarily illustrated in FIG. **6**.

[0034] FIG. **3** illustrates a top plan view of the sleeve device **100**. The mounting rings **107** of the sleeve device **100** are rigidly connected at the lower portion **101***b* of the hollow member **101** exemplarily illustrated in FIG. **1B**, and on diametrically opposing sides **101***g* and **101***h* of the hollow member **101**. The mounting rings **107** are oriented perpendicular to an axis line **111** that passes through the deformed rebars **103** and **104**. The mounting rings **107** protruding outwardly from the hollow member **101** affix the hollow member **101** to the bottom formwork **108** of the reinforced concrete slab **601** exemplarily illustrated in FIG. **1A**, FIG. **6**, and FIG. **7A**, so that a bottom base plane **107***a* of each of the mounting rings **107** is oriented at the same level as the bottom plane **101***f* of the hollow member **101** exemplarily illustrated in FIG. **2**. The holes **110** defined in the mounting rings **107** are positioned outside the outer wall **101***c*, for example, outside the outer diameter of the hollow member **101**. The deformed rebars **103** and **104** are positioned on the outer wall **101***c* of the hollow member **101** and midway between the mounting rings **107** that are positioned near the bottom plane **101***f* of the hollow member **101**.

[0035] FIGS. **4A-4B** exemplarily illustrate isometric views of different embodiments of the sleeve device **100**, showing different configurations of the tension rebars, for example, **112** and **113**, and **114** and **115**. In an embodiment as exemplarily illustrated in FIG. **4A**, the tension rebars of the sleeve device **100** are configured as corrugated fins **112** and **113** fixedly connected to the hollow member **101** of the sleeve device **100** for transferring tensile stresses to and from the hollow member **101**. In another embodiment as exemplarily illustrated in FIG. **4B**, the tension rebars of the sleeve device **100** are configured as bent plates **114** and **115** fixedly connected to the hollow member **101** of the sleeve device **100** for transferring the tensile stresses to and from the hollow member **101**.

[0036] Although the detailed description refers to the tension rebars of the sleeve device **100** configured as deformed rebars **103** and **104**, corrugated fins **112** and **113**, and bent plates **114** and **115** for transferring the tensile stresses to and from the hollow member **101**, the scope of the sleeve device **100** disclosed herein is not limited to the tension rebars being configured as deformed rebars **103** and **104**, corrugated fins **112** and **113**, and bent plates **114** and **115**, but may be extended to include tension rebars configured as tension rods, corrugated plates, straight bars, angles, pins, wire meshes, synthetic materials, etc., and other tension developing affixations for transferring the tensile stresses to and from the hollow member **101**. Further, the method for transferring tension to and from the hollow member **101** may be performed using multiple other methods comprising, for example, affixing alternative headed stud head members (not shown) as substitutes for the deformed rebars **103** and **104** to the hollow member **101**, affixing a wire mesh (not shown) to the hollow member **101**, affixing a synthetic material (not shown) to the hollow member **101**, configuring ridges (not shown) within the hollow member **101**, etc.

[0037] In an embodiment as exemplarily illustrated in FIGS. **4A-4B**, the tension rebars, for example, the corrugated fins **112** and **113** and the bent plates **114** and **115** are welded directly to the opposing sides **101***d* and **101***e* of the upper portion **101***a* of the hollow member **101** of the sleeve device **100** without the rebar connectors **105** and **106** exemplarily illustrated in FIGS. **1A-3**. In this embodiment, the tensile stresses are directly transferred to and from the hollow member **101** to the tension rebars, for example, **112**, **113** and **114**, **115**. In an embodiment, a cross section A-A of the hollow member **101** is of a circular geometric shape as exemplarily illustrated in FIGS. **4A-4B**.

[0038] FIGS. **5A-5B** exemplarily illustrate isometric views of different embodiments of the sleeve device **100**, showing different cross sections of the hollow member **101**. In an embodiment, a cross section B-B of the hollow member **101** is of a square geometric shape as exemplarily illustrated in FIG. **5A**. In another embodiment, the cross section C-C of the hollow member **101** is of a rectangular geometric shape as exemplarily illustrated in FIG. **5B**.

[0039] FIG. **6** exemplarily illustrates a side view of the sleeve device **100** positioned within a reinforced concrete slab **601**, showing bending moments **602**, tensile stresses **603**, and compressive stresses **604** acting on the reinforced concrete slab **601**. The bending moments **602**, tensile stresses **603**, and compressive stresses **604** are indicated by arrows in FIG. **6**. The bending moments **602** that are induced in the reinforced concrete slab **601** on the opposing sides **101***d* and **101***e* of the hollow member **101** are resisted by the tensile stresses **603** in the deformed rebars **103** and **104** and the compressive stresses **604** in the concrete **109** exemplarily illustrated in FIG. **1A**. The tensile stresses **603** in the deformed rebars **103** and **104** act in opposing directions through the reinforced concrete slab **601** from the opposing sides **101***d* and **101***e* of the hollow member **101**. The compressive stresses **604** in the concrete **109** act inwardly towards the hollow member **101** at the opposing sides **101***d* and **101***e* of the hollow member **101**, proximal to a lower section **601***a* of the reinforced concrete slab **601**. The compressive stresses **604** in the concrete **109** and the tensile stresses **603** acting on the opposing sides **101***d* and **101***e* of the hollow member **101** are balanced out through the outer wall **101***c* of the hollow member **101**.

[0040] FIG. **7A** exemplarily illustrate an isometric wireframe view, showing deformed rebars **103** and **104** of the sleeve device **100** in a different orientation within a concrete beam **701**. As exemplarily illustrated in FIG. **7A**, the concrete beam **701** is positioned below a reinforced concrete slab **601** and is supported by supporting columns **702** and **703** and the reinforced concrete slab **601**. FIG. **7B** illustrates an enlarged view of a portion marked Y in FIG. **7A**. In an embodiment, the deformed rebars **103** and **104** can be rotated and repositioned within the concrete beam **701** to transfer the tensile stresses and moment to and from the deformed rebars **103** and **104** and the hollow member **101** in different ways and in multiple directions, for example, along different axes. The sleeve device **100** can be rotated, for example, at right angles to create a void **102** in a horizontal direction within the concrete beam **701**. The sleeve device **100** counteracts the bending moments **704** generated by the supporting columns **702** and **703** on the concrete beam **701** as exemplarily illustrated in FIGS. **7A-7B**. As exemplarily illustrated in FIG. **7B**, multiple deformed rebars **103** and **104** are connected to the opposing sides **101***d* and **101***e* of the hollow member **101** using multiple rebar connectors **105** and **106** to increase the bending moment transfer capacity of the sleeve device **100**. The sleeve device **100** is used in monolithic poured concrete beams **701** which are positioned proximal to the supporting columns **702** and **703**.

[0041] FIG. **8** exemplarily illustrates a top plan view, showing splicing of the deformed rebars **103** and **104** of two sleeve devices **100***a* and **100***b* with top rebars **802** of the reinforced concrete slab **601**. As exemplarily illustrated in FIG. **8**, two sleeve devices **100***a* and **100***b* are positioned proximal to a supporting column **804**. In an embodiment, the sleeve device **100***a* or **100***b* transfers the bending moments induced in the reinforced concrete slab **601** by coupling the deformed rebars **103** and **104** to the top rebars **802** among the regular reinforced concrete slab rebars **801** by horizontal splicing. The deformed rebars **103** and **104** are configured to be spliced with the top rebars **802** of the reinforced concrete slab **601** in accordance with a standard rebar tension splice length **803** for transferring the bending moments induced in the reinforced concrete slab **601**. With a predefined range of standard rebar tension splice lengths **803** between the deformed rebars **103** and **104** and the top rebars **802**, the tensile stresses are transferred to the top rebars **802** and/or to the regular reinforced concrete slab rebars **801** to compensate the moment capacity loss. As used herein, "moment capacity" refers to the capacity of the reinforced concrete slab **601** to resist bending moment. When loads are applied to the reinforced concrete slab **601**, the reinforced concrete slab **601** tends to deform and induces a tensile strain in the deformed rebars **103** and **104** through a bond between the concrete **109** exemplarily illustrated in FIG. **1A**, and the deformed rebars **103** and **104**. The tensile stresses in the deformed rebars **103** are then transferred through the relatively stiffer hollow member **101** to the opposing side **101***e* of the hollow member **101**. That is, the tensile stresses due to the bending moments are transferred to the first deformed rebar **103** on one opposing side **101***d* of the hollow member **101**, then through the hollow member **101**, to the second deformed rebar **104** on the other opposing side **101***e* of the hollow member **101**, and then to the top rebars **802** among the regular reinforced concrete slab rebars **801**, that are spliced with the deformed rebars **103** and **104**.

[0042] FIG. **9A** exemplarily illustrates an isometric view of multiple sleeve devices **100***a*, **100***b*, and **100***c* positioned in a reinforced concrete slab **601** supported by a supporting column **901**. FIG. **9B** illustrates an enlarged view of a portion marked Z in FIG. **9A**. Each of the sleeve devices **100***a*, **100***b*, and **100***c* comprises the hollow member **101**, the deformed rebars **103** and **104**, and the rebar connectors **105** and **106** as exemplarily illustrated in FIGS. **1A-3**. The sleeve devices **100***a*, **100***b*, and **100***c* are used in concrete construction, for example, in cast-in-place reinforced concrete slabs **601**. A user places each hollow member **101** at a predetermined position in the bottom formwork **108** as exemplarily illustrated in FIG. **1A**. The sleeve devices **100***a*, **100***b*, and **100***c* are positioned adjacent to each other on the bottom formwork **108** with the upper portion **101***a* of each hollow member **101** on the top of the bottom formwork **108** of the reinforced concrete slab **601**. As exemplarily illustrated in FIGS. **9A-9B**, the sleeve device **100***c* is aligned perpendicular to the other two sleeve devices **100***a* and **100***b*. The deformed rebars **103** and **104** are spliced with the top rebars **802** among the regular reinforced concrete slab rebars **801** exemplarily illustrated in FIG. **8**. The mounting rings **107** fasten the sleeve devices **100***a*, **100***b*, and **100***c* to the bottom formwork **108** that defines the reinforced concrete slab **601** and secure the sleeve devices **100***a*, **100***b*, and **100***c* in place. Concrete **109** exemplarily illustrated in FIG. **1**A, is then poured onto the bottom formwork **108** and cast around the hollow member **101** of each of the sleeve devices **100***a*, **100***b*, and **100***c*. Each hollow member **101** defines a void **102** in the reinforced concrete slab **601** formed inside the bottom formwork **108** and the void **102** remains free of concrete **109**.

[0043] After the concrete **109** is cast around the sleeve devices **100***a*, **100***b*, and **100***c*, the sleeve devices **100***a*, **100***b*, and **100***c* are embedded in the reinforced concrete slab **601** and form a component of the reinforced concrete slab **601**. The tensile stresses due to the bending moments in the reinforced concrete slab **601** are transferred to the first deformed rebar **103** on an opposing side **101***d* of the hollow member **101** exemplarily illustrated in FIG. **2**. The tensile stresses are then transferred through the relatively stiffer hollow member **101** to the second deformed rebar **104** on the other opposing side **101***e* of the hollow member **101** exemplarily illustrated in FIG. **2**. The deformed rebars **103** and **104** that are spliced with the top rebars **802** among the regular reinforced concrete slab rebars **801** balance the tensile stresses due to the bending moments induced in the reinforced concrete slab **601**.

[0044] As exemplarily illustrated in FIGS. **9**A-**9**B, when a penetration or a void **102** is made in the reinforced concrete slab **601** located near a supporting column **901**, the reinforced concrete slab **601** undergoes a moment capacity loss and necessitates a moment capacity check of the reinforced concrete slab **601**. The sleeve device **100***a*, or **100***b*, or **100***c* disclosed herein compensates for the moment capacity loss due to the creation of the void **102** by transferring tensile stresses in the mature reinforced concrete slab **601**.

[0045] FIG. **10** illustrates a method for transferring bending moments induced in a reinforced concrete slab **601** exemplarily illustrated in FIG. **6**. A sleeve device **100** comprising a hollow member **101** and tension rebars configured, for example, as deformed rebars **103** and **104** as exemplarily illustrated in FIGS. **1**A-**9**B is provided **1001**. The deformed rebars **103** and **104** of the sleeve device **100** are spliced **1002** with top rebars **802** of the reinforced concrete slab **601** exemplarily illustrated in FIG. **8**, in accordance with a standard rebar tension splice length **803**, for example, by horizontal splicing for transferring the bending moments induced in the reinforced concrete slab **601**. Concrete **109** is poured around an outer wall **101***c* of the hollow member **101** to create **1003** a void **102** in the reinforced concrete slab **601**. The tensile stresses due to the bending moments induced in the reinforced concrete slab **601** are transferred **1004** to a first deformed rebar **103** on one opposing side **101***d* of the hollow member **101** and the upper portion **101***a* of the hollow member **101**. The transferred tensile stresses from the upper portion **101***a* of the hollow member **101** are then transferred **1005** to a second deformed rebar **104** on the other opposing side **101***e* of the hollow member **101**. The transferred tensile stresses from the second deformed rebar **104** are transferred **1006** to the top rebars **802** of the reinforced concrete slab **601** spliced with the deformed rebars **104**. The tensile stresses **603** in the deformed rebars **103** and **104** and the compressive stresses **604** in the concrete **109** exemplarily illustrated in FIG. **6**, resist the bending moments **602** in the reinforced concrete slab **601**. The tensile stresses **603** from the deformed rebars **103** and **104** are bridged by transferring the tensile stresses **603** in the deformed rebars **103** and **104** on the opposing sides **101***d* and **101***e* of the hollow member **101** into the hollow member **101**, and balancing out the tensile stresses **603** acting on the opposing sides **101***d* and **101***e* of the hollow member **101** through the outer wall **101***c* of the hollow member **101**.

[0046] The sleeve device **100** exemplarily illustrated in FIGS. **1**A-**3** is constructed of any suitable material capable of transferring the loads. The components of the sleeve device **100**, for example, the hollow member **101**, the deformed rebars **103** and **104**, and the rebar connectors **105** and **106** are rearranged in multiple orientations to accommodate penetrations in the reinforced concrete slab **601**. The sleeve device **100** can be located anywhere in the reinforced concrete slab **601**, for example, near supports such as the supporting column **901** exemplarily illustrated in FIG. **9**A, and walls. The sleeve device **100** can also be located in a concrete beam **701** as exemplarily illustrated in FIG. **7**A.

[0047] The sleeve device **100** can be made, for example, in a shop. In an example of making the sleeve device **100**, a steel fabricator cuts a steel pipe to an appropriate length to create the hollow member **101**. The steel fabricator then shop welds mechanical couplers or the rebar connectors **105** and **106** to each side **101***d* and **101***e* of the upper portion **101***a* or the top of the hollow member **101**. The deformed rebars **103** and **104** are connected to the rebar connectors **105** and **106** on the opposing sides **101***d* and **101***e* of the hollow member **101** as exemplarily illustrated in FIGS. **1**A-**3**. The rebar connectors **105** and **106** are prefabricated. In an embodiment, the deformed rebars **103** and **104** are welded directly to the opposing sides **101***d* and **101***e* of the hollow member **101** without connecting the rebar connectors **105** and **106** to each side **101***d* and **101***e* of the upper portion **101***a* or the top of the hollow member **101**. The mounting rings **107** or form tabs are welded to the bottom plane **101***f* of the hollow member **101**.

[0048] The sleeve device **100** exemplarily illustrated in FIGS. **1**A-**3** is used, for example, in flat plate cast-in-place concrete construction in two way slabs, one way slabs, slabs with beams, or any other type of slab system. The sleeve device **100** is further used, for example, in beams either vertically or horizontally, on concrete walls or columns, in brackets, capitals, corbels, buttresses, ramps, stairs, or any other portion of building transferring loads. The sleeve device **100** is further used, for example, in concrete on a steel deck, in precast members such as bridge components, marine components, facades, plank, T shaped bridge components, double T bridge components, etc. The sleeve device **100** is further used in combination with pre-stressing or post tensioning.

[0049] The foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention disclosed herein. While the invention has been described with reference to various embodiments, it is understood that the words, which have been used herein, are words of description and illustration, rather than words of limitation. Further, although the invention has been described herein with reference to particular means, materials, and embodiments, the invention is not intended to be limited to the particulars disclosed herein; rather, the invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims. Those skilled in the art, having the benefit of the teachings of this specification, may effect numerous modifications thereto and changes may be made without departing from the scope and spirit of the invention in its aspects.

I claim:

1. A sleeve device for transferring bending moments induced in a reinforced concrete slab, said sleeve device comprising:

a generally hollow member positioned on and fastened to a bottom formwork defining said reinforced concrete slab, said generally hollow member configured to create a void in said reinforced concrete slab by pouring of concrete around an outer wall of said generally hollow member, said generally hollow member further configured to transfer compressive stresses across a bottom of said generally hollow member and tensile stresses through tension rebars and an upper portion of said generally hollow member; and

said tension rebars connected to opposing sides of said upper portion of said generally hollow member, said tension rebars are configured to be spliced with top rebars of said reinforced concrete slab in accordance with a rebar tension splice length for transferring said bending moments induced in said reinforced concrete slab, wherein said bending moments in said reinforced concrete slab are resisted by said tensile stresses in said tension rebars and said compressive stresses in said concrete, and wherein said tensile stresses in said tension rebars on said opposing sides of said generally hollow member are transferred into said generally hollow member, and said tensile stresses acting on said opposing sides of said generally hollow member are balanced out through said outer wall of said generally hollow member, thereby bridging said tensile stresses from said tension rebars.

2. The sleeve device of claim **1**, wherein said tension rebars are welded directly to said opposing sides of said upper portion of said generally hollow member, wherein said tension rebars are configured to directly transfer said tensile stresses to and from said generally hollow member.

3. The sleeve device of claim **1**, further comprising rebar connectors operably connected on said opposing sides of said upper portion of said generally hollow member, wherein said rebar connectors are configured to fixedly connect said tension rebars to said opposing sides of said upper portion of said generally hollow member.

4. The sleeve device of claim **1**, wherein a cross section of said generally hollow member is of a geometric shape comprising at least one of a circular shape, a square shape, and a rectangular shape.

5. The sleeve device of claim **1**, wherein said generally hollow member is of a generally cylindrical shape.

6. The sleeve device of claim **1**, wherein said tension rebars are further configured to be rotated and repositioned to transfer said tensile stresses to and from said tension rebars and said generally hollow member in a plurality of directions.

7. The sleeve device of claim **1**, wherein said tension rebars are configured as deformed rebars to be fixedly connected to said opposing sides of said upper portion of said generally hollow member to transfer said tensile stresses to and from said generally hollow member.

8. The sleeve device of claim **1**, wherein said tension rebars are configured as corrugated fins to be fixedly connected to said opposing sides of said upper portion of said generally hollow member to transfer said tensile stresses to and from said generally hollow member.

9. The sleeve device of claim **1**, wherein said tension rebars are configured as bent plates to be fixedly connected to said opposing sides of said upper portion of said generally hollow member to transfer said tensile stresses to and from said generally hollow member.

10. A method for transferring bending moments induced in a reinforced concrete slab, said method comprising:

providing a sleeve device comprising:

a generally hollow member positioned on and fastened to a bottom formwork defining said reinforced concrete slab; and

tension rebars connected to opposing sides of an upper portion of said generally hollow member;

splicing said tension rebars of said sleeve device with top rebars of said reinforced concrete slab in accordance with a rebar tension splice length for transferring said bending moments induced in said reinforced concrete slab;

creating a void in said reinforced concrete slab by said generally hollow member of said sleeve device by pouring concrete around an outer wall of said generally hollow member;

transferring tensile stresses due to said bending moments induced in said reinforced concrete slab to a first of said tension rebars on one of said opposing sides of said generally hollow member and said upper portion of said generally hollow member;

transferring said transferred tensile stresses from said upper portion of said generally hollow member to a second of said tension rebars on another one of said opposing sides of said generally hollow member; and

transferring said transferred tensile stresses from said second of said tension rebars to said top rebars of said reinforced concrete slab spliced with said tension rebars, wherein said bending moments in said reinforced concrete slab are resisted by said tensile stresses in said tension rebars and compressive stresses in said concrete, and wherein said tensile stresses in said tension rebars on said opposing sides of said generally hollow member being transferred into said generally hollow member, and said tensile stresses acting on said opposing sides of said generally hollow member are balanced out through said outer wall of said generally hollow member, thereby bridging said tensile stresses from said tension rebars.

11. The method of claim **10**, wherein said tension rebars are welded directly to said opposing sides of said upper portion of said generally hollow member to directly transfer said tensile stresses to and from said generally hollow member.

12. The method of claim **10**, wherein said tension rebars are fixedly connected to said opposing sides of said upper portion of said generally hollow member using rebar connectors operably connected on said opposing sides of said upper portion of said generally hollow member.

13. The method of claim **10**, further comprising coupling said tension rebars to said reinforced concrete slab rebars via horizontal splicing for transferring said bending moments induced in said reinforced concrete slab.

14. The method of claim **10**, wherein a cross section of said generally hollow member of said sleeve device is of a geometric shape comprising at least one of a circular shape, a square shape, and a rectangular shape.

15. The method of claim **10**, wherein said generally hollow member is of a generally cylindrical shape.

16. The method of claim **10**, further comprising rotating and repositioning said tension rebars to transfer said tensile stresses to and from said tension rebars and said generally hollow member in a plurality of directions.

17. The method of claim **10**, wherein said tension rebars are configured as one of deformed rebars, corrugated fins, and bent plates to be fixedly connected to said opposing sides of said upper portion of said generally hollow member to transfer said tensile stresses to and from said generally hollow member.

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