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(54) **METHOD AND APPARATUS FOR MAKING AN EXPANDED BASE PIER**

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PROCÉDÉ ET APPAREIL DE FABRICATION DE PILIER À BASE ÉLARGIE

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Description

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is related to and claims the priority of U.S. Utility Patent Application Serial No. 12/875,986, filed September 3, 2010.

FIELD OF THE INVENTION

[0002] The present invention relates to construction of a structural support column. More specifically, the present invention relates to a method and apparatus for building an expanded base pier to bypass weak soils and transfer structural loads to underlying strong soils.

BACKGROUND OF INVENTION

[0003] Heavy or settlement-sensitive facilities that are located in areas containing soft or weak soils are often supported on deep foundations, consisting of driven piles or drilled concrete columns. The deep foundations are designed to transfer the structure loads through the soft soils to more competent soil strata.

[0004] In recent years, aggregate columns have been increasingly used to support structures located in areas containing soft soils. The columns are designed to reinforce and strengthen the soft layer and minimize resulting settlements. The columns are constructed using a variety of methods including the drilling and tamping method described in U.S. Patent Nos. 5,249,892 and 6,354,766; the driven mandrel method described in U.S. Patent No. 6,425,713; the tamper head driven mandrel method described in U.S. Patent No. 7,226,246; and the driven tapered mandrel method described in U.S. Patent No. 7,326,004.

[0005] The short aggregate column method (U.S. Patent Nos. 5,249,892 and 6,354,766), which includes drilling or excavating a cavity, is an effective foundation solution when installed in cohesive soils where the sidewall stability of the hole is easily maintained. The method generally consists of: a) drilling a generally cylindrical cavity or hole in the foundation soil (typically around 30 inches); b) compacting the soil at the bottom of the cavity; c) installing a relatively thin lift of aggregate into the cavity (typically around 12-18 inches); d) tamping the aggregate lift with a specially designed beveled tamper head; and e) repeating the process to form an aggregate column generally extending to the ground surface. Fundamental to the process is the application of sufficient energy to the beveled tamper head such that the process builds up lateral stresses within the matrix soil up along the sides of the cavity during the sequential tamping. This lateral stress build up is important because it decreases the compressibility of the matrix soils and allows applied loads to be efficiently transferred to the matrix soils during column loading.

[0006] The tamper head driven mandrel method (U.S. Patent No. 7,226,246) is a displacement form of the short aggregate column method. This method generally consists of driving a hollow pipe (mandrel) into the ground without the need for drilling. The pipe is fitted with a tamper head at the bottom which has a greater diameter than the pipe and which has a flat bottom and beveled sides. The mandrel is driven to the design bottom of column elevation, filled with aggregate and then lifted, allowing the aggregate to flow out of the pipe and into the cavity created by withdrawing the mandrel. The tamper head is then driven back down into the aggregate to compact the aggregate. The flat bottom shape of the tamper head compacts the aggregate; the beveled sides force the aggregate into the sidewalls of the hole thereby increasing the lateral stresses in the surrounding ground.

[0007] The driven tapered mandrel method (U.S. Patent No. 7,326,004) is another means of creating an aggregate column with a displacement mandrel. In this case, the shape of the mandrel is a truncated cone, larger at the top than at the bottom, with a taper angle of about 1 to about 5 degrees from vertical. The mandrel is driven into the ground, causing the matrix soil to displace downwardly and laterally during driving. After reaching the design bottom of the column elevation, the mandrel is withdrawn, leaving a cone shaped cavity in the ground. The conical shape of the mandrel allows for temporarily stabilizing of the sidewalls of the hole such that aggregate may be introduced into the cavity from the ground surface. After placing a lift of aggregate, the mandrel is redriven downward into the aggregate to compact the aggregate and force it sideways into the sidewalls of the hole. Sometimes, a larger mandrel is used to compact the aggregate near the top of the column.

[0008] U.S. Patent No. 7,604,437 is related to a mandrel for making aggregate support columns wherein flow restrictors are provided to prevent upward movement of aggregate through the mandrel during driving of the mandrel. The mandrel contemplated in this art relates to formation of an aggregate support column such as described in U.S. Patent Nos. 6,425,713 and 7,226,246 discussed above.

[0009] U.S. Patent Nos. 4,992,002 and 6,773,208 relate to methods for casting a partially reinforced concrete pier in the ground. One method involves the use of an elongate mandrel with a cupped foot having a larger cross-sectional area than the mandrel, wherein flowable grout that is placed in the mandrel flows through openings located near the bottom of the mandrel into the space between the mandrel and the foot. The other method involves the installation of an elongate hollow tubular casing that is then filled with fluid concrete that is allowed to set while the casing remains in the ground. Each of these references is merely to concrete hardened inclusions and does not allow for the additional stability and strength provided by a pier that has an expanded base.

[0010] U.S. Patent No. 3,568,452 relates to a method and apparatus for forming bulbular base piles.

[0011] In the area of soil improvement, it is often desirable to install a stiff inclusion into the ground to transfer loads through a soft or weak soil layer. Although these soil layers may also be treated by non-cementitious aggregate columns, non-cementitious columns are typically confining-stress dependent (i.e., they rely on the strength of the sidewall soils to prevent bulging). Occasionally, it is desirable to utilize cementitious inclusions to bypass weak soils and transfer loads to underlying strong soils. The object of the present invention is to efficiently form a strong and stiff expanded base (either cementitious or non-cementitious) at the bottom of the column and to provide an efficient means for the introduction of grout, concrete, post-grouted aggregate, or other cementitious material through the upper portions of the column to form a cementitious inclusion.

BRIEF DESCRIPTION OF INVENTION

[0012] The present invention relates to a system for constructing a support column. A mandrel has an upper portion and a tamper head. A feed tube extends through the mandrel for feeding aggregate, concrete, grout, or other flowable materials to the tamper head. The tamper head includes a lower enlarged chamber with a reducing surface at an upper portion thereof for compacting aggregate or concrete and restricting upward flow of aggregate or concrete during compaction. The tamper head is of a size providing an enclosed region for allowing cementitious materials to be placed therein. A closure cap is on an end of the feed tube opposite the tamper head. A concrete supply tube is connected to the feed tube, and an air pressure source is connected to the feed tube for evacuating concrete from the feed tube through air pressure supplied thereto.

[0013] The invention may comprise a valve mechanism movable between an open position and a closed position for closing off the feed tube from communication with the tamper head during tamping operations and may comprising stiffening members secured between the reducing surface and the mandrel for providing load support during tamping operations. The invention may further comprise chains attached or notches within the interior of the tamper head for restricting upward flow of material into the feed tube during downward movement of the mandrel. A second tube may extend through the mandrel on the side of the feed tube for allowing cementitious material to flow upward through the second tube for inspection of the cementitious material during pumping. A hopper may be located at the top of the mandrel for feeding aggregate into the feed tube of the mandrel.

[0014] A second aspect of the invention relates to a method of constructing a support column comprising use of a mandrel assembly having a feed tube connected to a tamper head at an opening thereof for allowing aggregate, concrete, grout, or other flowable material to flow into the tamper head. The method comprises providing the tamper head of a shape with a defined lower enlarged chamber having a reducing surface at an upper portion thereof for compaction and for restricting upward flow of material into the feed tube during tamping, the tamper head further sized to provide an enclosed region for allowing cementitious material to be placed therein; providing a closure cap on an end of the feed tube opposite the tamper head and a concrete supply tube connected to the feed tube, and an air pressure source connected to the feed tube for evacuating concrete from the feed tube through air pressure supplied thereto; driving the mandrel assembly into a ground surface to a given depth thereby forming a cavity; lifting the mandrel assembly to release an initial charge of aggregate or concrete from the tamper head into a bottom of the cavity; re-driving the mandrel assembly to compact the aggregate or concrete at a bottom of the cavity and to form an expanded base, the expanded base having a width greater than the tamper head; and withdrawing the mandrel assembly while continuously feeding cementitious material or aggregate to be subsequently fully or partially treated with grout through the feed tube, thereby forming a cementitious inclusion at least partially within the cavity, the cementitious inclusion having a width of the cavity and being formed on top of the expanded base.

[0015] The method may further comprise introducing a pipe through the feed tube and tamper head after formation of the expanded base, placing aggregate during the withdrawing step to partially surround the pipe, and introducing cementitious material into the pipe following aggregate placement to treat the aggregate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The invention will be better understood from the following detailed description made with reference to the drawings, wherein:

Figure 1 is a side cross-section view of a first embodiment of a mandrel;

Figure 2 is a side cross-section view of a second embodiment of the mandrel with a valve;

Figure 3 is a side cross-section view of a third embodiment of the mandrel with internal upward flow restrictors;

Figure 4 is a side cross-section view of a fourth embodiment of the mandrel with a grout return pipe;

Figures 5A-5E illustrate a method of constructing a pier with the mandrel of Figure 1;

Figures 6A-6F illustrate an alternate method of constructing a pier with one embodiment of the mandrel of the invention;

Figure 7 is a side cross-section view of an alternative embodiment of the mandrel using a closed top system to allow air pressure to build;

Figure 8 is a more detailed view of the operation of a closed top system including use of an external air source;

Figure 9 is a graph showing results of load tests performed on columns made according to Example I as compared to reference piers; and

Figures 10 and 11 are graphs showing results of load tests performed on columns made according to Example III.

DETAILED DESCRIPTION OF THE INVENTION

[0017] With reference to the attached figures, various embodiments of a new and novel mandrel for forming an expanded base pier, as part of a hardened inclusion, is provided.

[0018] Figure 1 illustrates an embodiment of a base mandrel assembly (1) contemplated herein. In this embodiment, a tamper head (2) is formed as a unitary structure attached to one end of a feed tube or pipe (4) to form the mandrel assembly (1). The feed pipe (4) can typically be 4" to 12" in diameter and has an upper end (not shown) opposite the tamper head (2) in which aggregate, concrete, grout, and other flowable material can be fed. The tamper head (2) typically comprises an enlarged lower chamber (3), typically 10" to 24" in diameter. The reducing surface (5) from the lower chamber walls to the feed pipe walls serves the function as a compaction plate for compacting aggregate or concrete as described hereinbelow, as well as serving as an upward flow restrictor while the initial aggregate is being driven such that the aggregate or concrete forms a "plug" within the chamber (3) and does not flow back up into the feed pipe (4). The reducing surface (5) may be angled as shown in Figure 2. The lower chamber (3) at the bottom of the head allows for formation of a densified bottom expanded base and provides an enclosed area for the placement of grout or concrete. Stiffeners (6) can also be placed between the feed pipe (4) and lower chamber (3) to assist in load transfer during driving.

[0019] Figure 2 illustrates an embodiment of a base mandrel similar to Figure 1, but includes a special valve mechanism (7) that may be used to further block the flow of aggregate or concrete from the lower chamber (3) into the feed pipe (4). The valve mechanism (7) seats against the reducing surface (5) of the feed pipe (4) and physically restricts the flow of aggregate, or concrete, back up into the feed pipe during downward driving (as opposed to the "plug" formed as described above with reference to Figure 1). When the feed pipe (4) is lifted, the valve mechanism (7) opens to allow the downward flow of grout, concrete, or other flowable material through the feed pipe (4) and into the lower chamber (3). The valve mechanism (7) may be manipulated by a pipe extending to the top of the mandrel or by a mechanism that pins the valve mechanism (7) to the sidewalls of the feed pipe (4).

[0020] The purpose of the valve mechanism (7) envisioned with reference to Figure 2 is to allow subsequent compaction of the bottom aggregate or concrete expanded base initially placed and formed. For instance, the mandrel would first be driven in the ground with the lower chamber (3) charged with aggregate or concrete. The feed pipe (4) would then be lifted, and the valve mechanism (7) would open. Grout or concrete would then be added through the feed pipe (4). The mandrel assembly (1) would then be driven back down, thereby allowing for further compaction of the aggregate or concrete at the bottom to form an expanded base.

[0021] Figure 3 illustrates another variation of the embodiment of Figure 1. More specifically, chain links (8) are attached within the tamper head (2) so that upon tamping, the chain links (8) move inward to constrict the aggregate or concrete in the lower chamber (3) and restrict aggregate or concrete from flowing upward into the feed tube (4). It is also envisioned that internal notches may be provided in lieu of chains in order to provide non-mechanical (or passive) upward flow restriction.

[0022] Figure 4 illustrates a further embodiment of a mandrel similar to that shown in Figure 1 but which includes a special provision for ensuring grout placement. Instead of having only a single chute feed pipe or tube (4) as shown in Figure 1, the embodiment contemplated with reference to Figure 4 has a feed pipe including a primary feed pipe (4) and a grout return pipe (9) that is used to ensure that a continuous column of grout is installed. Positive flow of grout from the top of the grout return pipe (9) demonstrates that the mandrel is full of grout before or during mandrel extraction (lifting) operations.

[0023] A method of use is shown with reference to Figures 5A-5E, which shows an installation sequence with the base mandrel depicted in Figure 1. Step A (Figure 5A) shows placing a mound (10) of the aggregate on the ground surface. Step B (Figure 5B) shows driving the mandrel assembly (1) through the mound (10) of aggregate (to form an initial charge of aggregate) and to the final driving elevation. During the driving process, the aggregate in the lower chamber (3) forms a plug (11) in the neck of the feed pipe (4) at the bottom of the tamper head (2). The valve mechanism (7) shown in Figure 2 or the chain links (8) shown in Figure 3 may be used within the tamper head (2) to facilitate plugging. Step C (Figure 5C) shows lifting of the mandrel assembly (1) wherein the aggregate plug (11) or initial charge remains in place at the bottom of the hole (it is understood that the initial charge may also be added after driving of a closed tamper head, such as with a sacrificial cap covering the bottom opening of the tamper head). Step D (Figure 5D) shows re-driving the mandrel assembly (1) one or more times to compact the aggregate at the bottom of the hole and to form an expanded base (12). Grout or concrete (13) may then be pumped through the feed pipe as shown. Step E (Figure 5E) shows placing grout or concrete (13) from the element up from the bottom while removing the mandrel. When the grout return pipe (9) as shown in Figure 4 is used in conjunction with Step E of the construction process, grout continuity within the mandrel shaft is determined if grout continues to flow out of the grout return pipe (9) during extraction. The finished support column comprises an expanded base with a cementitious inclusion located thereon.

[0024] An alternative method of use can also be used with reference to Figures 5A-5E. Step A consists of filling the lower chamber (3) of the tamper head (2) with concrete. This may be achieved by driving the tamper head (2) through a mound (10) of concrete as shown in Figure 5A or by pumping concrete through the feed tube (4) while the tamper head (2) is resting on the ground surface. In this case, the ground surface seals the concrete from flowing out of the bottom of the lower chamber (3). As shown in Figure 5B, the tamper head (2) is then driven to design elevation with the concrete at the bottom of the tamper head (2) forming a plug (11) at the bottom of the assembly mandrel (1). The valve mechanism (7) shown in Figure 2 or the chain links (8) shown in Figure 3 may be used within the tamper head (2) to facilitate plugging. Step C shows the retraction (lifting) of the assembly (2) to allow the concrete to flow out of the bottom of the tamper head (2). Step D shows the placement of additional concrete (13) through the feed pipe (4) and the subsequent or simultaneous lowering of the mandrel assembly (1) onto the previously placed concrete to force the concrete outward thus forming an expanded base (12). Step E shows the simultaneous placement of grout or concrete (13) through the feed tube (4) while extracting the mandrel assembly (1) to the ground surface. This technique forms an expanded base pier comprised of concrete at the expanded base (12) and concrete within the pier shaft (or inclusion) on top of the expanded base (12).

[0025] The benefits of the system contemplated herein are the efficient formation of an expanded base (12) that allows load to be transferred to the bottom of the pier and the very quick and efficient formation of the grouted inclusion by rapidly raising the mandrel while placing grout or concrete (13). While the method sequence of Figures 5A-5E depicts the use of the base mandrel shown in Figure 1, it is envisioned that the method could principally be used with any of the mandrels shown in Figures 1 - 4.

[0026] Figures 6A-6F shows an alternative construction sequence where Steps A through C (Figures 6A-6C) are generally as described above with reference to the initial charge of aggregate being in the lower chamber (see Figures 5A-5C). In Step D (Figure 6D) of this sequence, the mandrel assembly (1) is lowered to compact the aggregate and a secondary disposable pipe (14) is inserted into the mandrel assembly (1) to rest on the expanded base (12). In Step E (Figure 6E) the mandrel assembly (1) is raised and additional aggregate (15) is allowed to fill the annular space between the disposable pipe (14) and the sidewall of the cavity (16). A hopper (17) can be used to place the aggregate (15) within the feed pipe (4). The aggregate (15) placed in this step is not compacted. In Step F (Figure 6F) the disposable pipe (14) is then used as a conduit to place grout into the inclusion by filling the voids in the loose aggregate (15) around the disposable pipe (14). Typically, the disposable pipe (14) is not removed but can be cut at ground level or just below ground level and made part of the permanent inclusion. Additionally, while Figures 6D-6F depict representative grout ports at the bottom end of disposable pipe (14), it is understood that such ports or other openings can be located partially or fully along the length of disposable pipe (14).

[0027] Figure 7 illustrates a further embodiment of a mandrel similar to that shown in Figure 1 but which includes a closed system for the placement of concrete, grout, or other flow able materials. The mandrel of this embodiment includes an external feed tube (18) that enters the mandrel feed tube (4) near the top of the mandrel to allow for the passage of a flowable material (19). The external feed tube (18) is used to pump concrete, grout, or other flowable materials into the primary feed tube (4). The top of the mandrel is sealed with a top plate (21) making this a closed system. An air pressure gage (20) may optionally be installed to measure the internal air pressure within the mandrel and allow for the use of a pressure release valve (22) to facilitate removal of excess internal pressure during pumping. The mandrel system of Figure 7 may be used in conjunction with the construction sequences shown in Figures 5A-5E.

[0028] Figure 8 illustrates yet another embodiment of the mandrel similar to that shown in Figure 7. In this embodiment, an air source, such as compressor (24), may optionally be used to apply elevated air pressure to trapped air (23) within the mandrel feed pipe (4) to evacuate concrete (13) from the mandrel.

[0029] The following examples illustrate further aspects of the invention.

Example I

[0030] As an example, an embodiment of the system of the present invention was used to install a support column, also described herein as an expanded base pier ("EBP"), at a test site in Iowa. The test site was characterized by 4 feet of sandy lean clay underlain by sand. This testing program was designed to compare the load versus deflection characteristics of this embodiment of the EBP to reference piers constructed in successive lifts, such as a pier constructed by the tamper head driven mandrel method. The reference piers of this example had a nominal diameter of 20 inches and an installed length of 23 feet. One reference pier was constructed of aggregate only to a diameter of 20 inches. Another reference pier was constructed with a grout additive, commonly referred to as grouted pier, to a diameter of 14 inches.

[0031] In this embodiment of the invention, the EBP was formed by filling the extractable mandrel (Figure 1) with a combination of open graded aggregate and fluid grout. The mandrel had a lower chamber (3) outside diameter of 14 inches and a feed pipe (4) outside diameter of 12 inches. The mandrel of this embodiment was connected at its open end (opposite the tamper head) to an open hopper for filling and was attached to a high frequency hammer which is often associated with driving sheet piles. The hammer is capable of providing both downward force and vibratory energy. The full mandrel was advanced to a depth of 23 feet below the ground surface. The mandrel assembly was then raised 3 feet and lowered 3 feet a total of 3 times to form a bottom expanded base. Each raising and lowering of the mandrel is referred to as a "stroke." The mandrel was then raised 3 feet, lowered 2 feet, and then slowly extracted to the ground surface allowing a column of grout and aggregate to be placed in the cavity created during mandrel installation. The EBP was constructed with a base diameter of 20 inches, and a shaft diameter of 14 inches. Once the mandrel was fully extracted, a 1 inch diameter reinforcing steel rod was inserted the full length of the EBP. A concrete cap was then poured above the EBP to facilitate load testing.

[0032] The reference piers and the EBP were load tested using a hydraulic jack pushing against a test frame. Figure 9 shows the results of the load test of the EBP compared with the reference piers. At a top of pier deflection of 0.5 inches, the reference pier with aggregate supported a load of about 23,300 pounds, the reference pier with grout supported a load of about 50,000 pounds, and the EBP supported a load of about 70,300 pounds. At a top of pier deflection of 1 inch, the reference pier with aggregate supported a load of about 38,800 pounds, the reference pier with grout supported a load of about 62,700 pounds, and the EBP supported a load of about 97,000 pounds. The load carrying capacity of the pier constructed in accordance with this embodiment of the present invention showed a 2.5 to 3 fold improvement when compared to a reference pier with aggregate, and a 1.4 to 1.5 fold improvement when compared to a reference pier with grout. The difference in the behavior relative to the grouted pier is caused by the formation of the bottom expanded base during the construction of the EBP according to the invention.

<u>Example II</u>

[0033] As another example, the system of another embodiment of the present invention was used to install five EBP elements at a test site in Virginia. The test site was characterized by hard clay. Prior to installation of the EBP, 30 inch diameter drill holes were excavated to a depth of 8 feet below the ground surface. The voids were then loosely backfilled with sand. The EBP elements of this example were formed within the backfilled holes.

[0034] In this embodiment of the invention, the EBP was formed by filling the mandrel described in Figure 7 with concrete. The mandrel of this embodiment featured a "closed top" as opposed to the "open hopper" configuration as described with reference to Example I. The mandrel in this embodiment was attached to a similar hammer as in the embodiment of Example I. The full mandrel was advanced to a depth of 8 feet below the ground surface. The mandrel was then raised 3 feet, and then lowered 2 feet for three repetitions to create the expanded base. A process of raising the mandrel 3 feet, and then lowering 1 foot was then used to complete the full length of the pier. Once the concrete had cured, each of the piers was excavated and the pier base and shaft diameters were measured.

[0035] The lower chamber in this embodiment had a nominal 12 inch diameter outer dimension. The excavated and measured piers had an average nominal diameter of 18 inches. Expanded bases at the bottoms of the piers exceeded 24 inches demonstrating the effectiveness of this construction technique.

<u>Example III</u>

[0036] As yet another example, the embodiment of the present invention from Example II was used on a site in Washington, D.C. The site was characterized by 20 to 30 feet of soft clay and clayey sand underlain by dense sand or hard clay. The embodiment of the present invention at the site was used to support mechanically stabilized earth (MSE) walls and embankments. The mandrel used for this project was similar to that used in Example II. The lower chamber in this embodiment had a nominal 18 inch diameter outer dimension. In this example, two fully concrete EBP were constructed and subsequently load tested. In this example of the embodiment, the EBP were constructed with a 24 inch diameter expanded base, and an 18 inch diameter shaft.

[0037] In this embodiment of the invention, the EBP was formed by filling the mandrel (such as in Figures 7 or 8) with concrete. The full mandrel was then advanced to a depth of 26 feet below the ground surface for Test Pier 1 and to a depth of 36.5 feet below the ground surface for Test Pier 2. The mandrel was then raised 4 feet, and then lowered 3 feet. The process of raising the mandrel 4 feet, and then lowering 3 feet was completed for a total of 4 cycles at the test piers to create an expanded base. After the expanded base was created, the mandrel was extracted at a constant rate while pumping concrete into the mandrel. Once the concrete had cured, each of the piers was load tested.

[0038] The load tests were performed using Statnamic load test methods. Figure 10 shows the results of the load test on Test Pier 1 (26 feet below ground surface) and Figure 11 shows the results of the load test on Test Pier 2 (36.5 feet below the ground surface - two test load cycles on this test pier). Both Test Pier 1 and Test Pier 2 supported a test load of approximately 425 kips at 1 inch of top of pier deflection, with a maximum supported load of approximately 575 kips.

[0039] The foregoing detailed description of embodiments refers to the accompanying drawings, which illustrate specific embodiments of the invention. The term "the invention" or the like is used with reference to certain specific examples of the many alternative aspects or embodiments of the applicant's invention set forth in this specification, and neither its use nor its absence is intended to limit the scope of the applicant's invention or the scope of the claims. This specification is divided into sections for the convenience of the reader only. Headings should not be construed as limiting of the scope of the invention. The definitions are intended as a part of the description of the invention. It will be understood that various details of the invention may be changed without departing from the scope of the claims.

Claims

1. A system for constructing a support column, comprising:

    (a) a mandrel (1) having an upper portion and a tamper head (2), and a feed tube (4) extending therethrough for feeding aggregate, concrete, grout, or other flowable materials through the mandrel to the tamper head;
    (b) the tamper head defining a lower enlarged chamber (3) having a reducing surface (5) at an upper portion thereof for compacting aggregate or concrete and for restricting upward flow of aggregate or concrete into the mandrel during compacting and the tamper head being of sufficient size for providing an enclosed region for allowing cementitious material to be placed therein; the system being **characterized in that** it comprises
    (c) a closure cap (21) on an end of the feed tube opposite the tamper head, a concrete supply tube (18) connected to the feed tube, and an air pressure source (24) connected to the feed tube for evacuating concrete from the feed tube through air pressure supplied thereto.

2. The system of claim 1, further comprising a valve mechanism (7) movable between an open position and a closed position for closing off the feed tube from communication with the tamper head during tamping operations.

3. The system of claim 1, further comprising stiffening members (6) secured between the reducing surface and the mandrel for providing load support during tamping operations.

4. The system of claim 1, further comprising chains (8) attached within the interior of the tamper head for restricting upward flow of material into the feed tube during downward movement of the mandrel.

5. The system of claim 1, further comprising notches within the interior of the tamper head, for restricting upward flow of material into the feed tube during downward movement of the mandrel.

6. The system of claim 1, further comprising a second tube (9) extending through the mandrel on the side of the feed tube for allowing cementitious material to flow upward through the second tube for inspection of the cementitious material during pumping or further comprising a hopper located at the top of the mandrel for feeding aggregate into the feed tube of the mandrel.

7. A method of constructing a support column comprising use of a mandrel assembly (1) having a feed tube (4) connected to a tamper head (2) at an opening thereof for allowing aggregate, concrete, grout, or other flowable material to flow into the tamper head, the method comprising:

    (a) providing the tamper head of a shape with a defined lower enlarged chamber (3) having a reducing surface (5) at an upper portion thereof for compaction and for restricting upward flow of material into the feed tube during tamping, the tamper head further sized to provide an enclosed region for allowing cementitious material to be placed therein;
    (b) providing a closure cap (21) on an end of the feed tube opposite the tamper head and a concrete supply tube connected to the feed tube, and an air pressure source (24) connected to the feed tube for evacuating concrete from the feed tube through air pressure supplied thereto;
    (c) driving the mandrel assembly into a ground surface to a given depth thereby forming a cavity;
    (d) lifting the mandrel assembly to release an initial charge of aggregate or concrete from the tamper head into a bottom of the cavity;
    (e) re-driving the mandrel assembly to compact the aggregate or concrete at a bottom of the cavity and to form an expanded base, the expanded base having a width greater than the tamper head; and
    (f) withdrawing the mandrel assembly while continuously feeding cementitious material or aggregate to be subsequently fully or partially treated with grout through the feed tube, thereby forming a cementitious inclusion at least partially within the cavity, the cementitious inclusion having a width of the cavity and being formed on top of the expanded base.

8. The method of claim 7, wherein the tamper head is filled with the initial charge of aggregate or concrete before driving.

9. The method of claim 7, wherein the cementitious material is one selected from the group consisting of concrete, grout, or aggregate that is subsequently fully or partially treated with grout.

10. The method of claim 7, further comprising providing

a valve mechanism (7) movable between an open position and a closed position at the opening between the feed tube and the tamper head, for restricting the passage from flow into the tamper head, and moving the closure member to an open position for introducing cementitious material into the tamper head, and into a closed position during downward compaction.

11. The method of claim 7, further comprising introducing cementitious material into the enclosed region.

12. The method of claim 7, further comprising introducing a pipe (14) through the feed tube and tamper head after formation of the expanded base, placing aggregate during the withdrawing step to partially surround the pipe, and introducing cementitious material into the pipe following aggregate placement to treat the aggregate.

13. The method of claim 7, further comprising chains (8) attached within the interior of the tamper head for restricting upward flow of material into the feed tube during downward movement of the mandrel.

14. The method of claim 7, further comprising notches within the interior of the tamper head for restricting upward flow of material into the feed tube during downward movement of the mandrel.

15. The method of claim 7, further comprising providing the mandrel with a second tube (9) adjacent the feed tube to allow for the inspection of cementitious material during pumping or further comprising a hopper located at the top of the mandrel for feeding aggregate into the feed tube of the mandrel.

Patentansprüche

1. System zum Bau einer Stützsäule, umfassend:

(a) einen Dorn (1), der einen oberen Abschnitt und einen Stampferkopf (2) aufweist, und ein Zuführrohr (4), das sich dort hindurch erstreckt, um Schotter, Beton, Mörtel oder andere fließfähige Materialien durch den Dorn zu dem Stampferkopf zuzuführen;
(b) den Stampferkopf, der eine untere vergrößerte Kammer (3) definiert, die eine reduzierende Fläche (5) an einem oberen Abschnitt davon aufweist, um Schotter oder Beton zu komprimieren und um aufwärtigen Fluss von Schotter oder Beton in den Dorn während des Komprimierens einzuschränken und wobei der Stampferkopf von ausreichender Größe ist, um einen eingeschlossenen Bereich bereitzustellen, um zu ermöglichen, dass darin zementartiges Material platziert wird; wobei das System **dadurch gekennzeichnet ist, dass** es Folgendes umfasst:
(c) eine Verschlusskappe (21) an einem Ende des Zuführrohres gegenüber dem Stampferkopf, ein Betonzulaufrohr (18), das mit dem Zuführrohr verbunden ist, und eine Luftdruckquelle (24), die mit dem Zuführrohr verbunden ist, um Beton durch dorthin zugeführten Luftdruck aus dem Zuführrohr zu entnehmen.

2. System nach Anspruch 1, ferner umfassend einen Ventilmechanismus (7), der zwischen einer offenen Position und einer geschlossenen Position bewegbar ist, um das Zuführrohr während Stampfvorgängen gegenüber Kommunikation mit dem Stampferkopf zu verriegeln.

3. System nach Anspruch 1, ferner umfassend Versteifungselemente (6), die zwischen der reduzierenden Fläche und dem Dorn befestigt sind, um während Stopfvorgängen eine Laststütze bereitzustellen.

4. System nach Anspruch 1, ferner umfassend Ketten (8), die innerhalb des Inneren des Stampferkopfes angebracht sind, um aufwärtigen Fluss von Material in das Zuführrohr während der abwärtigen Bewegung des Dorns einzuschränken.

5. System nach Anspruch 1, ferner umfassend Kerben innerhalb des Inneren des Stampferkopfes, um aufwärtigen Fluss von Material in das Zuführrohr während der abwärtigen Bewegung des Dorns einzuschränken.

6. System nach Anspruch 1, ferner umfassend ein zweites Rohr (9), das sich durch den Dorn auf der Seite des Zuführrohres erstreckt, um zu ermöglichen, dass zementartiges Material nach oben durch das zweite Rohr zur Inspektion des zementartigen Materials während des Pumpens fließt oder ferner umfassend einen Trichter, der sich an der Oberseite des Dorns befindet, um Schotter in das Zuführrohr des Dorns zuzuführen.

7. Verfahren zum Bau einer Stützsäule, umfassend die Verwendung einer Dornbaugruppe (1), die ein Zuführrohr (4) aufweist, das an einer Öffnung davon mit einem Stampferkopf (2) verbunden ist, um zu ermöglichen, dass Schotter, Beton, Mörtel oder anderes fließfähiges Material in den Stampferkopf fließt, wobei das Verfahren Folgendes umfasst:

(a) Bereitstellen des Stampferkopfes in einer Form mit einer definierten unteren vergrößerten Kammer (3), die eine reduzierende Fläche (5) an einem oberen Abschnitt davon aufweist, um zu komprimieren und um aufwärtigen Fluss von Material in das Zuführrohr während des Stampfens einzuschränken, wobei der Stampferkopf ferner größenbemessen ist, um einen eingeschlossenen Bereich bereitzustellen, um zu ermöglichen, dass zementartiges Material darin platziert wird;

(b) Bereitstellen einer Verschlusskappe (21) an einem Ende des Zuführrohres gegenüber dem Stampferkopf und eines Betonzulaufrohres, das mit dem Zuführrohr verbunden ist, und einer Luftdruckquelle (24), die mit dem Zuführrohr verbunden ist, um Beton durch dorthin zugeführten Luftdruck aus dem Zuführrohr zu entnehmen;

(c) Treiben der Dornbaugruppe in eine Bodenfläche zu einer gegebenen Tiefe, wodurch ein Hohlraum gebildet wird;

(d) Anheben der Dornbaugruppe, um eine anfängliche Ladung an Schotter oder Beton aus dem Stampferkopf in einen Boden des Hohlraums abzugeben;

(e) erneutes Treiben der Dornbaugruppe, um den Schotter oder Beton an einem Boden des Hohlraums zu komprimieren und um eine erweiterte Basis zu bilden, wobei die erweiterte Basis eine Breite aufweist, die größer als der Stampferkopf ist; und

(f) Zurückziehen der Dornbaugruppe, während durchgehend zementartiges Material oder Schotter zugeführt wird, um anschließend vollständig oder teilweise mit Mörtel durch das Zuführrohr behandelt zu werden, wodurch ein zementartiger Einschluss zumindest teilweise innerhalb des Hohlraums gebildet wird, wobei der zementartige Einschluss eine Breite des Hohlraums aufweist und an der Oberseite der erweiterten Basis gebildet wird.

8. Verfahren nach Anspruch 7, wobei der Stampferkopf vor dem Treiben mit der anfänglichen Ladung an Schotter oder Beton gefüllt wird.

9. Verfahren nach Anspruch 7, wobei das zementartige Material eines ist, das aus der Gruppe ausgewählt ist, die aus Beton, Mörtel oder Schotter besteht, der anschließend vollständig oder teilweise mit Mörtel behandelt wird.

10. Verfahren nach Anspruch 7, ferner umfassend das Bereitstellen eines Ventilmechanismus (7), der zwischen einer offenen Position und einer geschlossenen Position bewegbar ist, an der Öffnung zwischen dem Zuführrohr und dem Stampferkopf, um den Durchlass von Fluss in den Stampferkopf einzuschränken und das Verschlusselement in eine offene Position zu bewegen, um zementartiges Material in den Stampferkopf einzuführen, und in eine geschlossene Position während des abwärtigen Komprimierens.

11. Verfahren nach Anspruch 7, ferner umfassend das Einführen von zementartigem Material in den eingeschlossenen Bereich.

12. Verfahren nach Anspruch 7, ferner umfassend das Einführen einer Leitung (14) durch das Zuführrohr und den Stampferkopf nach dem Bilden der erweiterten Basis, das Platzieren des Schotters während des Schrittes des Zurückziehens, sodass die Leitung teilweise umgeben ist, und das Einführen von zementartigem Material in die Leitung nach dem Platzieren des Schotters, um den Schotter zu behandeln.

13. Verfahren nach Anspruch 7, ferner umfassend Ketten (8), die innerhalb des Inneren des Stampferkopfes angebracht sind, um aufwärtigen Fluss von Material in das Zuführrohr während der abwärtigen Bewegung des Dorns einzuschränken.

14. Verfahren nach Anspruch 7, ferner umfassend Kerben innerhalb des Inneren des Stampferkopfes, um aufwärtigen Fluss von Material in das Zuführrohr während der abwärtigen Bewegung des Dorns einzuschränken.

15. Verfahren nach Anspruch 7, ferner umfassend das Bereitstellen eines zweiten Rohres (9) für den Dorn neben dem Zuführrohr, um die Inspektion von zementartigem Material während des Pumpens zu ermöglichen oder ferner umfassend einen Trichter, der sich an der Oberseite des Dorns befindet, um Schotter in das Zuführrohr des Dorns zuzuführen.

Revendications

1. Système destiné à la construction d'une colonne de support, comprenant :

(a) un mandrin (1) comportant une partie supérieure et une tête de dameuse (2) et un tube d'alimentation (4) s'étendant à travers celui-ci permettant de distribuer un agrégat, du béton, du mortier liquide ou tout autre matériau pouvant être fluidifié à travers le mandrin jusqu'à la tête de dameuse ; et

(b) la tête de dameuse définissant une chambre basse élargie (3) possédant une surface de réduction (5) au niveau d'une partie supérieure de celle-ci destinée au compactage d'agrégat ou de béton et destinée à limiter l'écoulement d'agrégat ou de béton vers le haut dans le mandrin durant le compactage et la tête de dameuse étant de taille suffisante pour fournir une zone confinée permettant à un matériau cimentaire d'être placé dans celle-ci, ledit système étant **caractérisé en ce qu'**il comprend

(c) un bouchon de fermeture (21) sur une extrémité du tube d'alimentation opposée à la tête de dameuse, un tube d'approvisionnement en béton (18) raccordé au tube d'alimentation et une source de pression d'air (24) raccordée au tube d'alimentation pour l'évacuation du béton du tube d'alimentation par la pression d'air fournie à celui-ci.

2. Système selon la revendication 1, comprenant en outre un mécanisme de soupape (7) mobile entre une position ouverte et une position fermée permettant la fermeture du tube d'alimentation à une communication avec la tête de dameuse durant les opérations de tassement.

3. Système selon la revendication 1, comprenant en outre des éléments de rigidification (6) fixés entre la surface de réduction et le mandrin pour fournir un support de charge durant les opérations de tassement.

4. Système selon la revendication 1, comprenant en outre des chaînes (8) fixées à l'intérieur de la tête de dameuse destinées à limiter l'écoulement vers le haut de matériau dans le tube d'alimentation durant une descente du mandrin.

5. Système selon la revendication 1, comprenant en outre des encoches à l'intérieur de la tête de dameuse destinées à limiter l'écoulement vers le haut de matériau dans le tube d'alimentation durant une descente du mandrin.

6. Système selon la revendication 1, comprenant en outre un second tube (9) s'étendant à travers le mandrin sur le côté du tube d'alimentation permettant à un matériau cimentaire de s'écouler vers le haut à travers le second tube pour l'inspection du matériau cimentaire durant le pompage ou comprenant en outre un trémie situé en haut du mandrin destiné à alimenter en agrégat le tube d'alimentation du mandrin.

7. Procédé de construction d'une colonne de support comprenant l'utilisation d'un ensemble mandrin (1) possédant un tube d'alimentation (4) raccordé à une tête de dameuse (2) au niveau d'une ouverture de celui-ci pour permettre à un agrégat, du béton, du mortier liquide ou à tout autre matériau pouvant être fluidifié de s'écouler dans la tête de dameuse, ledit procédé comprenant :

(a) l'obtention d'une tête de dameuse d'une certaine forme avec une chambre basse élargie (3) déterminée possédant une surface de réduction (5) au niveau d'une partie supérieure de celle-ci destinée au compactage et permettant de limiter l'écoulement vers le haut du matériau dans le tube d'alimentation durant le tassement, la tête de dameuse étant en outre dimensionnée pour fournir une zone confinée permettant au matériau cimentaire d'être placé dans celle-ci ;
(b) l'obtention d'un bouchon de fermeture (21) sur une extrémité du tube d'alimentation opposée à la tête de dameuse et un tube d'approvisionnement en béton raccordé au tube d'alimentation et une source de pression d'air (24) raccordée au tube d'alimentation pour l'évacuation du béton du tube d'alimentation par une pression d'air fournie à celui-ci ;
(c) l'entraînement de l'ensemble mandrin dans une surface de sol jusqu'à une profondeur donnée formant ainsi une cavité ;
(d) la levée de l'ensemble mandrin pour libérer la charge initiale d'agrégat ou de béton depuis la tête de dameuse jusque dans le fond de la cavité ;
(e) l'entraînement de nouveau de l'ensemble mandrin pour compacter l'agrégat ou le béton au fond de la cavité et pour former une base élargie, ladite base élargie possédant une largeur supérieure à la tête de dameuse ; et
(f) le retrait de l'ensemble mandrin tout en alimentant continuellement en matériau cimentaire ou en agrégat à être traité par la suite, soit entièrement soit partiellement, avec du mortier liquide par l'intermédiaire du tube d'alimentation, formant ainsi une inclusion cimentaire au moins partiellement dans la cavité, ladite inclusion cimentaire possédant une largeur de la cavité et étant formée sur le dessus de la base élargie.

8. Procédé selon la revendication 7, ladite tête de dameuse étant remplie de la charge initiale d'agrégat ou de béton avant l'entraînement.

9. Procédé selon la revendication 7, ledit matériau cimentaire étant l'un choisi dans le groupe constitué par le béton, le mortier liquide ou l'agrégat qui est par la suite entièrement ou partiellement traité avec du mortier liquide.

10. Procédé selon la revendication 7, comprenant en outre la disposition d'un mécanisme de soupape (7) mobile entre une position ouverte et une position fermée au niveau de l'ouverture entre le tube d'alimentation et la tête de dameuse, destiné à restreindre le passage d'un écoulement dans la tête de dameuse et à déplacer l'élément de fermeture en une position ouverte permettant d'introduire le matériau cimentaire dans la tête de dameuse et dans une position fermée durant le compactage vers le bas.

11. Procédé selon la revendication 7, comprenant en outre l'introduction de matériau cimentaire dans la zone confinée.

12. Procédé selon la revendication 7, comprenant en outre l'introduction d'un tuyau (14) par le tube d'alimentation et la tête de dameuse après la formation de la base élargie, le positionnement de l'agrégat durant l'étape de retrait pour entourer partiellement le tuyau et l'introduction de matériau cimentaire dans le tuyau après le positionnement d'agrégat pour traiter l'agrégat.

13. Procédé selon la revendication 7, comprenant en outre des chaînes (8) fixées à l'intérieur de la tête de dameuse destinées à limiter l'écoulement de matériau vers le haut dans le tube d'alimentation durant la descente du mandrin.

14. Procédé selon la revendication 7, comprenant en outre des encoches à l'intérieur de la tête de dameuse destinées à limiter l'écoulement de matériau vers le haut dans le tube d'alimentation durant la descente du mandrin.

15. Procédé selon la revendication 7, comprenant en outre la fourniture au mandrin d'un second tube (9) adjacent au tube d'alimentation pour permettre l'inspection de matériau cimentaire durant un pompage ou comprenant en outre un trémie situé en haut du mandrin destiné à l'alimentation en agrégat du tube d'alimentation du mandrin.

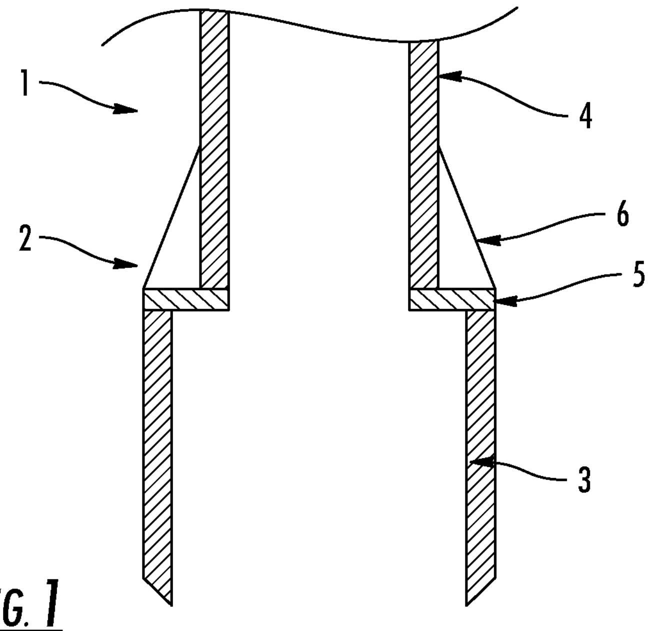


FIG. 1

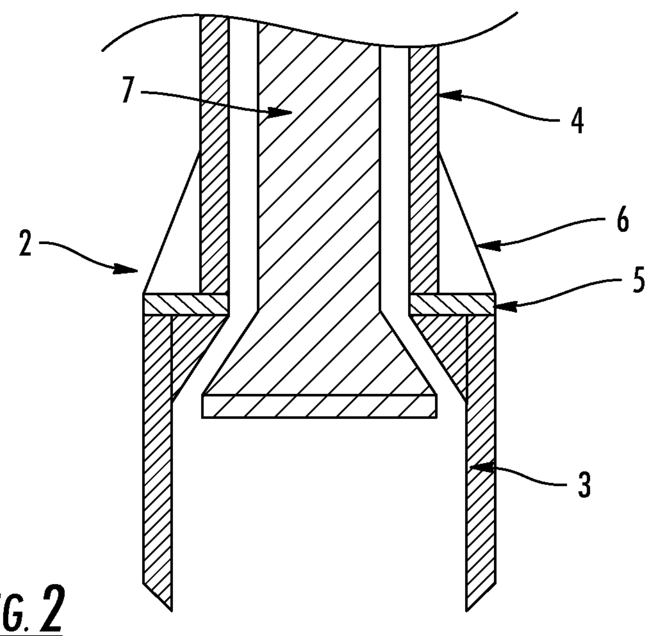


FIG. 2

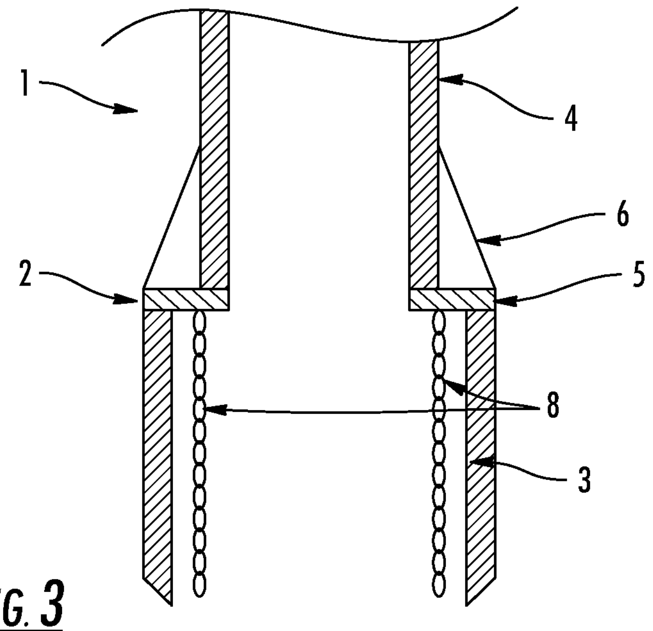


FIG. 3

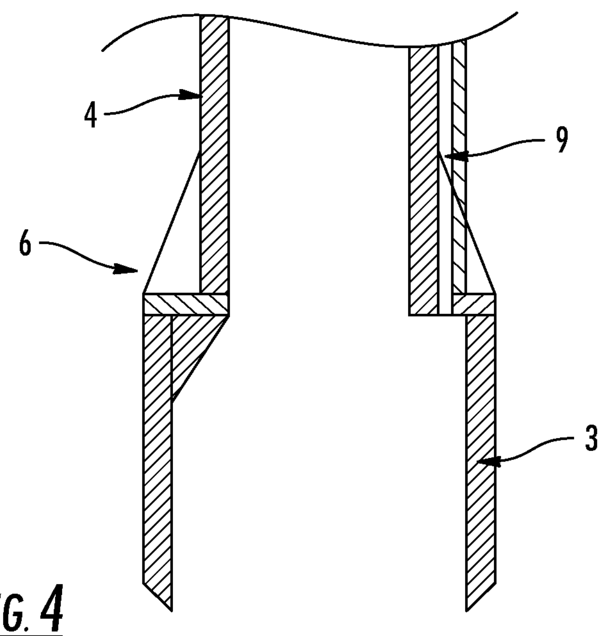


FIG. 4

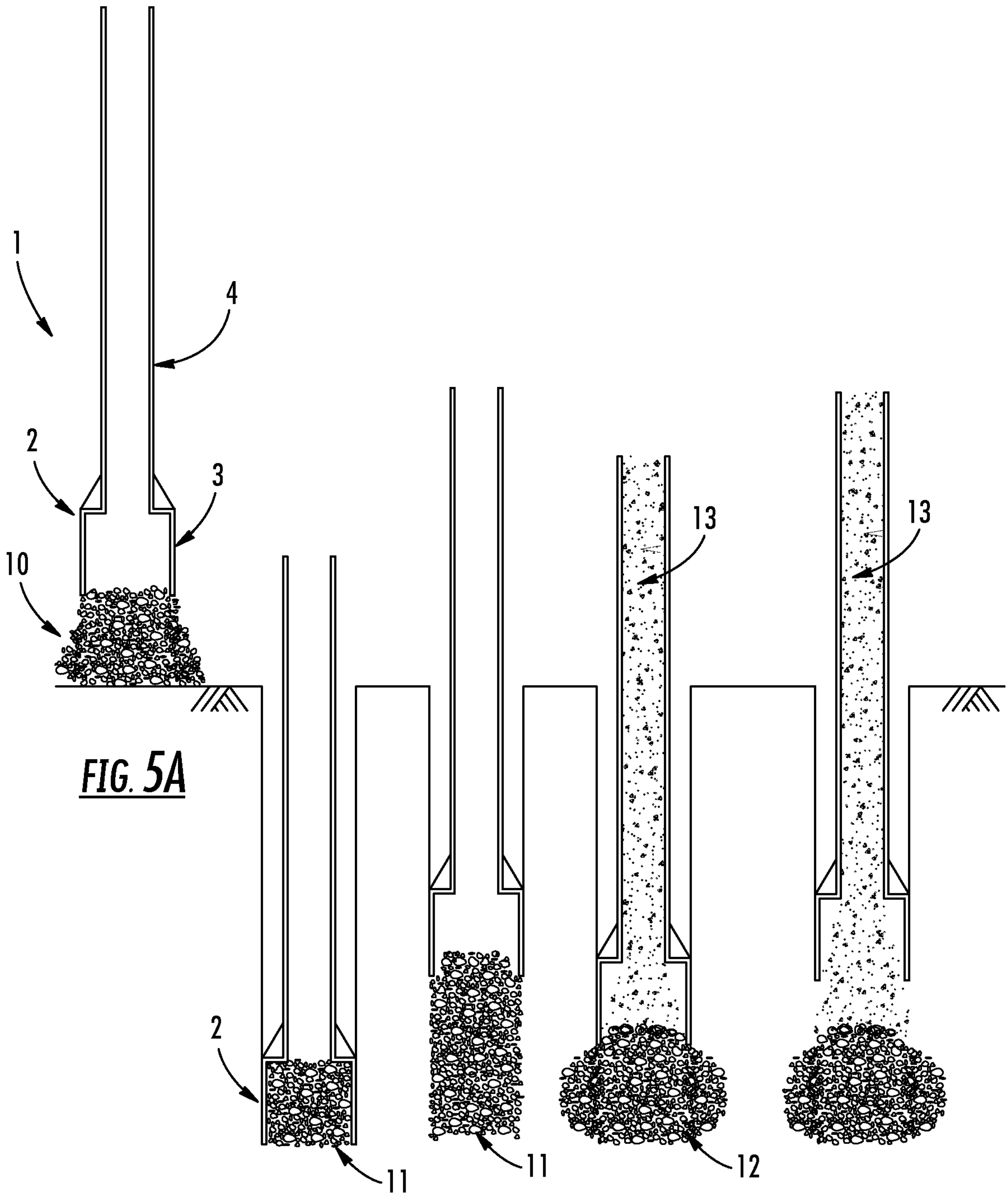


FIG. 5A
FIG. 5B
FIG. 5C
FIG. 5D
FIG. 5E

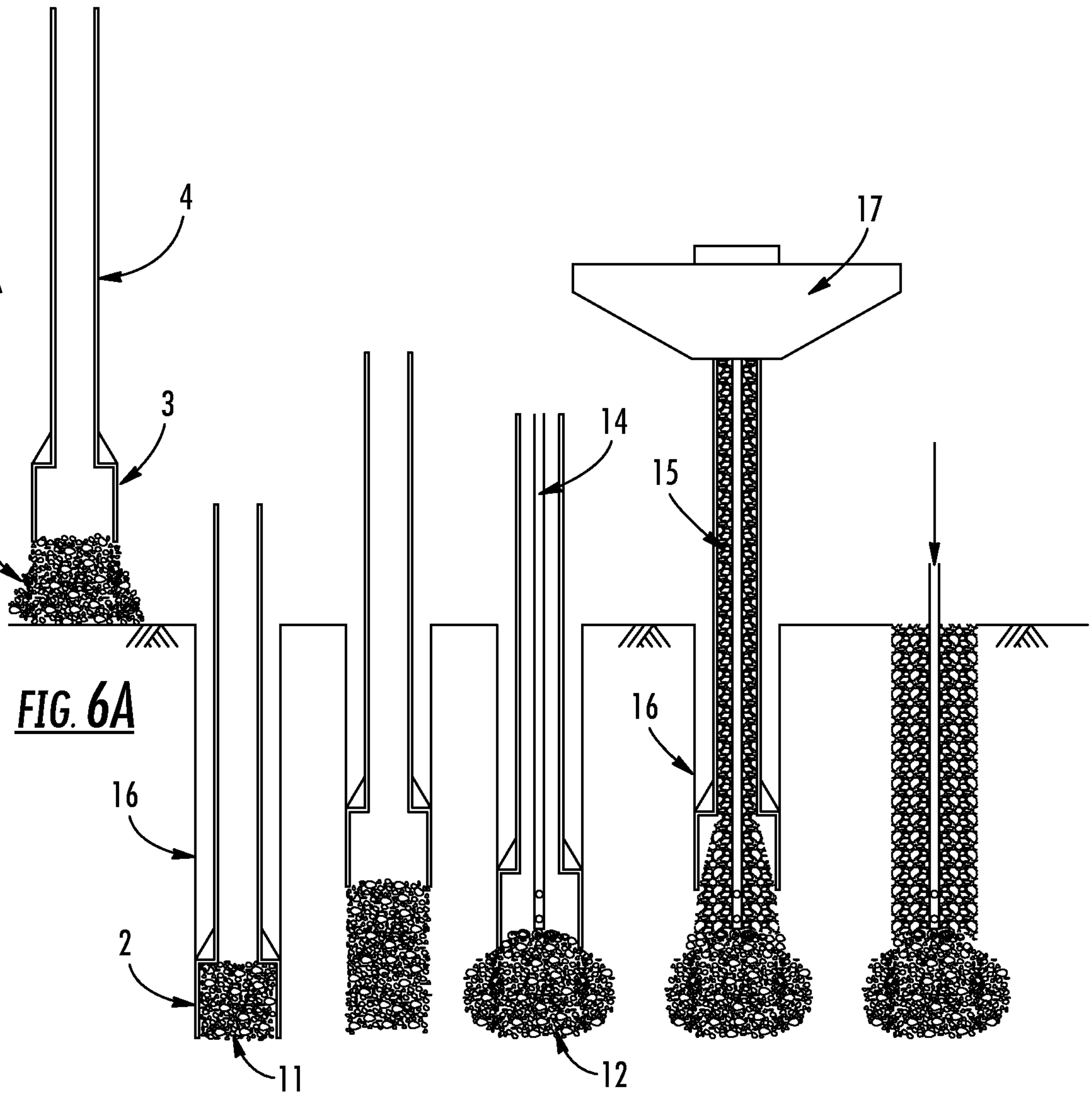


FIG. 6A

FIG. 6B FIG. 6C FIG. 6D FIG. 6E FIG. 6F

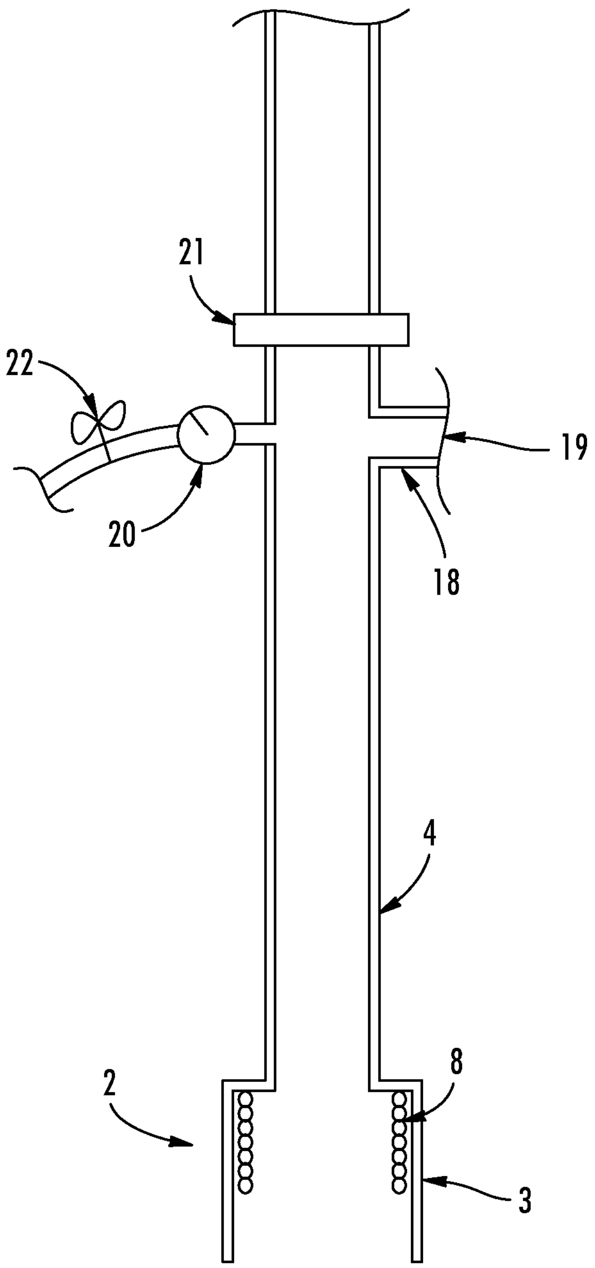


FIG. 7

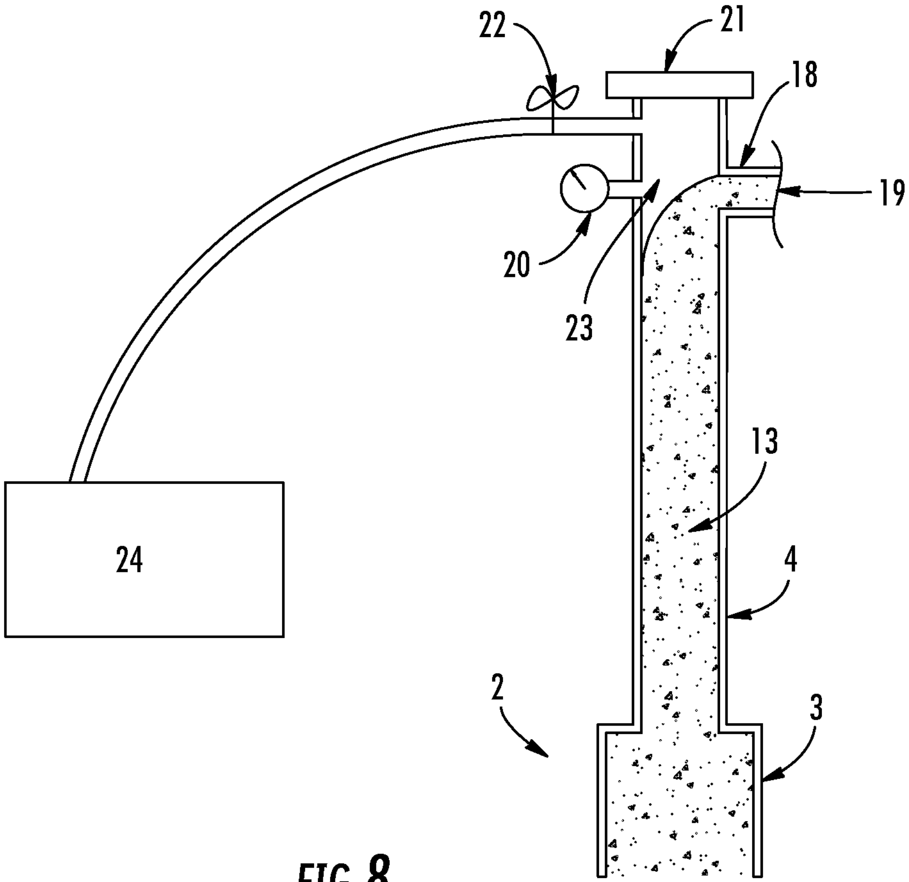
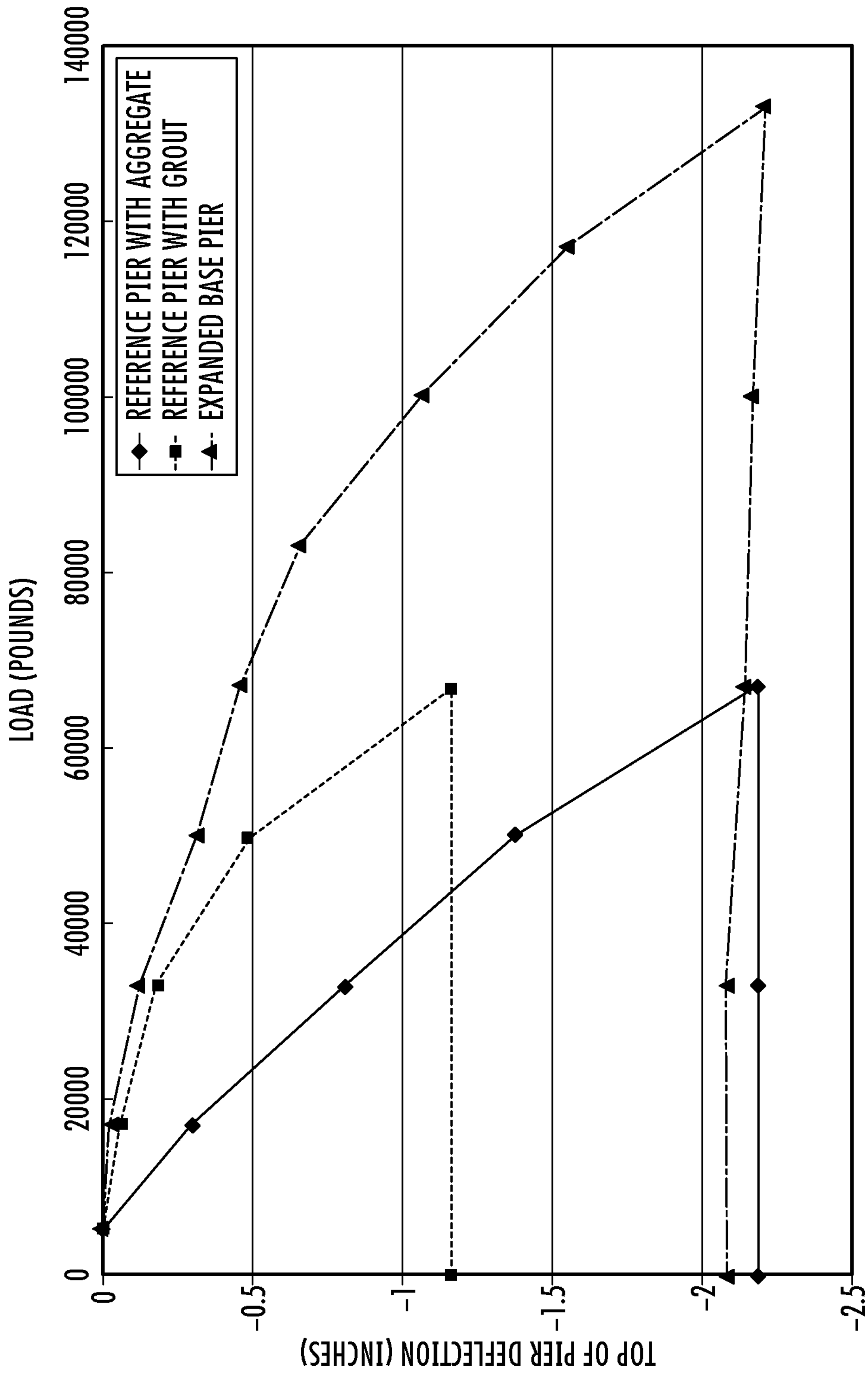


FIG. 8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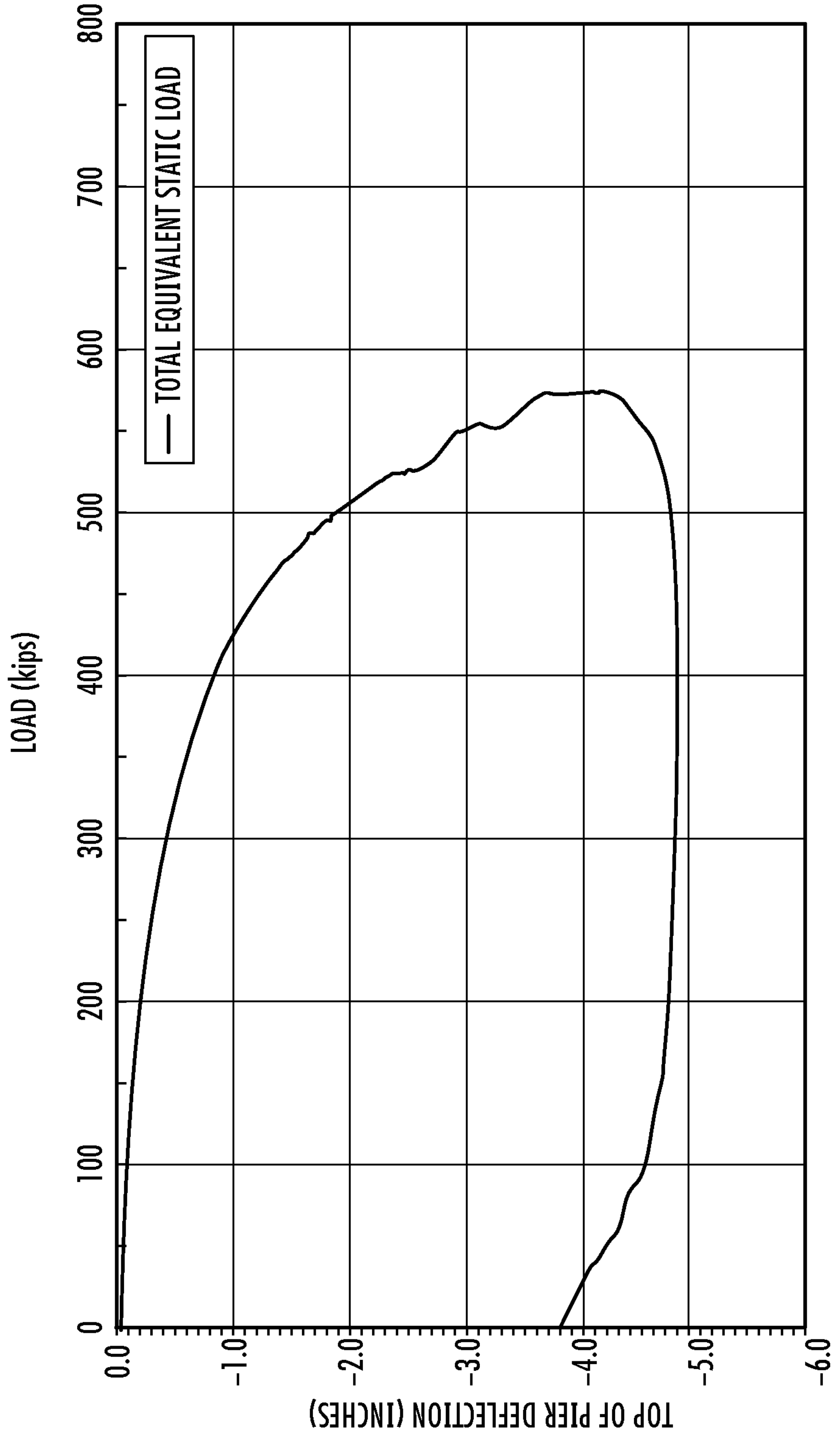
20000
40000
60000
80000
100000
120000
140000
REFERENCE PIER WITH AGGREGATE
REFERENCE PIER WITH GROUT
EXPANDED BASE PIER
TOP OF PIER DEFLECTION (INCHES)
0
-0.5
-1
-1.5
-2
-2.5

FIG. 9


TOTAL EQUIVALENT STATIC LOAD
LOAD (kips)
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100
200
300
400
500
600
700
800
TOP OF PIER DEFLECTION (INCHES)
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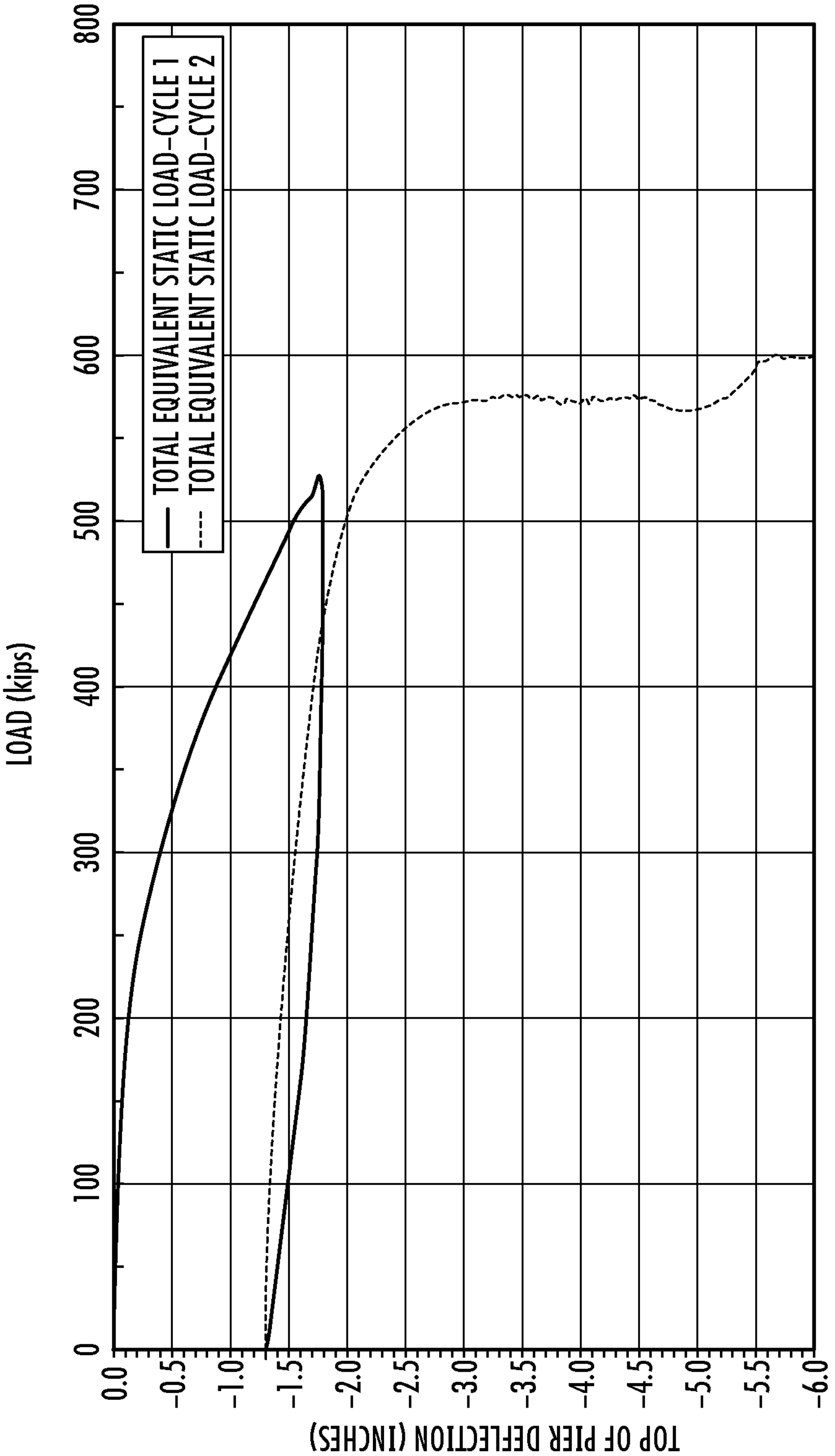
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0

FIG. 10


LOAD (kips)
TOP OF PIER DEFLECTION (INCHES)
TOTAL EQUIVALENT STATIC LOAD–CYCLE 1
TOTAL EQUIVALENT STATIC LOAD–CYCLE 2
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100
200
300
400
500
600
700
800
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
-6.0

FIG. 11

REFERENCES CITED IN THE DESCRIPTION

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