SUMMARY

According to a first aspect of the present invention, there is provided an apparatus for densifying and compacting granular materials comprising a closed end drive shaft having a first diameter and one or more diametric expansion elements wherein the one or more diametric expansion elements, in their expanded state, form compaction surfaces having a second diameter greater than the first diameter of the drive shaft and wherein the one or more diametric expansion elements are configured and sized accordingly to achieve desired lift thickness, compaction surface area, and/or soil flow based on material type and/or project requirements.

According to a second aspect of the present invention, there is provided a method of densifying and compacting granular materials, the method comprising:

a. providing a compaction apparatus comprising a closed end drive shaft having a first diameter and one or more diametric expansion elements, wherein the one or more diametric expansion elements expand when the apparatus is driven downward forming compaction surfaces having a second diameter greater than the first diameter of the drive shaft and wherein the one or more diametric expansion elements are configured and sized accordingly to achieve desired lift thickness, compaction surface area, and/or soil flow based on material type and/or project requirements;

b. driving the compaction apparatus into free-field soils to a specified depth;

c. lifting the compaction apparatus a specified distance; and

d. repeating the driving and lifting of the compaction apparatus.

There is disclosed an apparatus for densifying and compacting granular materials. In some embodiments, the apparatus may include a closed end drive shaft and one or more diametric expansion elements. The diametric expansion elements, in their expanded state, may form compaction surfaces having a diameter greater that he diameter of the drive shaft. The diametric expansion elements may be attached to a bottom surface of the drive shaft, or attached to a base plate attached to the bottom end of the drive shaft. The base plate may be changeable.

The diametric expansion elements may include any one or more of chains, cables, wire rope, and/or a lattice of vertically and/or horizontally connected chains, cables, or wire rope. The diametric expansion elements may be configured and sized accordingly to

achieve desired lift thickness, compaction surface area, and/or soil flow based on material type and/or project requirements. Additionally, the diametric expansion elements may be housed within a sacrificial tip that may be releasably connected to a bottom portion of the drive shaft. The apparatus may also include one or more wing structures attached to the drive shaft that are configured to loosen free-field soils around the drive shaft.

In certain other embodiments, the apparatus may include a drive shaft, a compaction chamber at a lower end of the drive shaft, and one or more diametric expansion elements, wherein the apparatus further includes an opening in an upper surface of the compaction chamber forming a flow-through passage exterior of the drive shaft and configured for accepting granular materials from outside of the drive shaft. The drive shaft may be the same size and/or diameter, a larger size and/or diameter, or a smaller size and/or diameter than the compaction chamber. Additionally, the compaction chamber may be connected to the drive shaft through a load transfer plate, and may further incorporate one or more stiffener plates connected to the drive shaft and the load transfer plate.

Certain embodiments of the apparatus may include one or more diametric expansion and restriction elements attached to one or both of an interior or exterior of the compaction chamber. The one or more diametric expansion and restriction elements may

also be attached to the load transfer plate. The apparatus may include both interior diametric restriction elements and exterior diametric expansion elements. Moreover, the interior diametric restriction elements and exterior diametric expansion elements may or may not be connected to one another. The drive shaft may include a hollow tube, a substantially I-beam configuration that may further include an opening in the I-beam configuration, or a solid cylindrical shaft configuration. The apparatus may further be configured to be inserted in a pre-drilled cavity.

There is disclosed an apparatus for densifying and compacting granular materials is presented according to other embodiments. The apparatus may include a drive shaft, a compaction chamber, and one or more diametric restriction elements, wherein the compaction chamber comprises a pipe and the drive shaft is fitted into one end of the pipe. The apparatus may be configured to be inserted in a pre-drilled cavity. In some embodiments, the drive shaft includes an I-Beam configuration, and may further include an opening in the I-Beam configuration wherein at least a portion of the opening in the drive shaft may extend into the pipe. Certain embodiments may also include a reinforcing ring fitted around a bottom end of the compaction chamber, and may further include a substantially ring-shaped wearing pad abutting the reinforcement ring.

Embodiments of the apparatus may also include a ring that may be secured to the compaction chamber and positioned near the end of the drive shaft that includes an arrangement of the diametric restriction elements. A second arrangement of diametric restriction elements may be secured to the drive shaft. The ring may be optionally removable.

In certain other embodiments, the apparatus may include a drive pipe affixed to a lower end of the drive shaft, wherein a bottom end of the drive pipe may extend into the compaction chamber, and further wherein the drive pipe may secured to the compaction chamber by one or more struts or plates extending from sides of the compaction chamber radially inward to the drive pipe. The one or more struts or plates may extend along the drive pipe above the compaction chamber to a termination point, tapering from the sides

of the compaction chamber to the termination point. Additionally, a bottom end of the drive pipe may be closed using a plate or cap and the plate or cap extends below a lower end of the one or more struts or plates.

Other embodiments of the apparatus may also include a perimeter ring inside the compaction chamber, the ring including an arrangement of the diametric restriction elements and being disposed along the inner perimeter of the compaction chamber at substantially the lower end of the one or more struts or plates. The ring may be removable. The apparatus may also include diametric restriction elements that are coupled to the lower end of the one or more struts or plates and the perimeter of the plate or cap.

There is disclosed a method of densifying and compacting granular materials, the method including the steps of (a) providing a compaction apparatus comprising a closed end drive shaft having a first diameter and one or more diametric expansion elements, wherein the one or more diametric expansion elements expand when the apparatus is driven downward forming compaction surfaces having a second diameter greater than the first diameter of the drive shaft, (b) driving the compaction apparatus into free-field soils to a specified depth, (c) lifting the compaction apparatus a specified distance, and (d) repeating the driving and lifting of the compaction apparatus. The method may also include repeating the driving and lifting steps incrementally until the compaction apparatus has been lifted to or near an original ground elevation. In such embodiments, each of the repeated driving of the compaction apparatus may be to a distance generally less than a distance the compaction apparatus was previously lifted.

Driving of the compaction apparatus may be effectuated using one of an impact or vibratory hammer. In certain embodiments, the lifting of the compaction apparatus allows for surrounding materials to flow around the compaction apparatus to fill a void created by lifting the compaction apparatus. In some embodiments, the one or more diametric expansion elements may be placed within a sacrificial tip and upon the initial lifting of the compaction apparatus the one or more diametric expansion elements are

CLAIMS

1. An apparatus for densifying and compacting granular materials comprising a closed end drive shaft having a first diameter and one or more diametric expansion elements wherein the one or more diametric expansion elements, in their expanded state, form compaction surfaces having a second diameter greater than the first diameter of the drive shaft and wherein the one or more diametric expansion elements are configured and sized accordingly to achieve desired lift thickness, compaction surface area, and/or soil flow based on material type and/or project requirements.

2. The apparatus of claim 1 wherein the one or more diametric expansion elements are attached to a bottom surface of the closed-end drive shaft.

3. The apparatus of claim 1 further comprising a base plate positioned at a bottom end of the closed-end drive shaft.

4. The apparatus of claim 3 wherein the one or more diametric expansion elements are attached to the base plate.

5. The apparatus of claim 3 wherein the base plate comprises a changeable base plate.

6. The apparatus of claim 1 wherein the one or more diametric expansion elements comprise any one or more of chains, cables, wire rope, and/or a lattice of vertically and/or horizontally connected chains, cables, or wire rope.

7. The apparatus of claim 1 wherein the mandrel further comprises a sacrificial

tip releasably connected to a bottom portion of the drive shaft.

8. The apparatus of claim 7 wherein the one or more diametric expansion elements are housed within the sacrificial tip.

9. The apparatus of claim 1 further comprising one or more wing structures attached to the drive shaft that are configured to loosen free-field soils around the drive shaft.

10. A method of densifying and compacting granular materials, the method comprising:

a. providing a compaction apparatus comprising a closed end drive shaft having a first diameter and one or more diametric expansion elements, wherein the one or more diametric expansion elements expand when the apparatus is driven downward forming compaction surfaces having a second diameter greater than the first diameter of the drive shaft and wherein the one or more diametric expansion elements are configured and sized accordingly to achieve desired lift thickness, compaction surface area, and/or soil flow based on material type and/or project requirements;

b. driving the compaction apparatus into free-field soils to a specified depth;

c. lifting the compaction apparatus a specified distance; and

d. repeating the driving and lifting of the compaction apparatus.

11. The method of claim 10 wherein the compaction apparatus is repeatedly driven and lifted incrementally until the compaction apparatus has been lifted to or near an original ground elevation.

12. The method of claim 10 wherein each of the repeated driving of the compaction apparatus is to a distance generally less than a distance the compaction apparatus was previously lifted.

13. The method of claim 10 wherein the compaction apparatus is driven into the ground using one of an impact or vibratory hammer.

14. The method of claim 10 wherein the lifting of the compaction apparatus allows for surrounding materials to flow around the compaction apparatus to fill a void created by lifting the compaction apparatus.

15. The method of claim 10 wherein the one or more diametric expansion elements may be placed within a sacrificial tip and upon the initial lifting of the compaction apparatus the one or more diametric expansion elements are removed from the sacrificial tip and move downward relative to the compaction apparatus so as to hang from a bottom portion of the compaction apparatus.

16. The method of claim 10 wherein the compaction apparatus further comprises one or more wing structures attached to the drive shaft that loosen the free-field soils around the drive shaft during the driving and lifting.

17. The method of claim 10 wherein the process creates a well compacted column of densified soil below and around the one or more diametric expansion elements.

18. The method of claim 10 wherein the compaction apparatus is inserted or driven into one or more of free-field soils or into a predrilled cavity.