SUMMARY

According to a first aspect of the present invention, there is provided an apparatus for densifying and compacting granular materials comprising a drive shaft, a compaction chamber, one or more diametric restriction elements, and a ring comprising an arrangement of the diametric restriction elements, wherein the ring is secured to the compaction chamber and positioned near the end of the drive shaft and is removable, and wherein the compaction chamber comprises a pipe and the drive shaft is fitted into one end of the pipe.

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 drive shaft, a compaction chamber, one or more diametric restriction elements, and a ring comprising an arrangement of the diametric restriction elements, wherein the compaction chamber comprises a pipe and the drive shaft is fitted into one end of the pipe, and wherein the ring is secured to the compaction chamber and positioned near the end of the drive shaft and is removable;

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

c. lifting the compaction apparatus a specified distance such that the one or more diametric restriction elements move downward relative to the compaction apparatus to hang from connections to the compaction apparatus thereby allowing granular materials located above a top portion of the compaction chamber to flow around the outside of the drive shaft and into the compaction chamber;

d. re-driving the apparatus downwardly into the free-field soils causing the one or more diametric restriction elements to bunch-up forming compaction surfaces; and

e. 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 drive shaft, a compaction chamber, one or more diametric restriction elements, and a ring comprising an arrangement of the diametric restriction elements, wherein the ring is secured to the compaction chamber and positioned near the end of the drive shaft and is removable, and wherein the compaction chamber comprises a pipe and the drive shaft is fitted into one end of the pipe.

2. The apparatus of claim 1 wherein the apparatus is configured to be inserted in a pre-drilled cavity.

3. The apparatus of claim 1 wherein the drive shaft comprises an I-Beam configuration.

4. The apparatus of claim 3, wherein the drive shaft comprises an opening in the I-beam configuration and further wherein at least a portion of the opening in the drive shaft extends into the pipe.

5. The apparatus of claim 1 further comprising a reinforcing ring fitted around a bottom end of the compaction chamber.

6. The apparatus of claim 5 further comprising a substantially ring-shaped wearing pad abutting the reinforcement ring.

7. The apparatus of claim 1 wherein a second arrangement of the diametric restriction elements is secured to the drive shaft.

8. An apparatus for densifying and compacting granular materials comprising a drive shaft, a drive pipe affixed to a lower end of the drive shaft, a compaction chamber, and one or more diametric restriction elements, wherein a bottom end of the drive pipe extends into the compaction chamber, and further wherein the drive pipe is 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.

9. The apparatus of claim 8 wherein the one or more struts or plates 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.

10. The apparatus of claim 8, wherein a bottom end of the drive pipe is closed using a plate or cap and the plate or cap extends below a lower end of the one or more struts or plates.

11. The apparatus of claim 8 further comprising a perimeter ring inside the compaction chamber, the ring comprising 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.

12. The apparatus of claim 11 wherein the ring is removable.

13. The apparatus of claim 11 wherein the diametric restriction elements are coupled to the lower end of the one or more struts or plates and the perimeter of the plate or cap.

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

a. providing a compaction apparatus comprising a drive shaft, a compaction chamber, one or more diametric restriction elements, and a ring comprising an arrangement of the diametric restriction elements, wherein the compaction chamber comprises a pipe and the drive shaft is fitted into one end of the pipe, and wherein the ring is secured to the compaction chamber and positioned near the end of the drive shaft and is removable;

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

c. lifting the compaction apparatus a specified distance such that the one or more diametric restriction elements move downward relative to the compaction apparatus to

hang from connections to the compaction apparatus thereby allowing granular materials located above a top portion of the compaction chamber to flow around the outside of the drive shaft and into the compaction chamber;

d. re-driving the apparatus downwardly into the free-field soils causing the one or more diametric restriction elements to bunch-up forming compaction surfaces; and

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

15. The method of claim 14 wherein the compaction apparatus is inserted or driven into one or more of free-field soils or into a predrilled cavity.

16. The method of claim 14 wherein the compaction apparatus is lowered into an existing cavity, and wherein aggregate is then poured into the existing cavity to form a mound on top of the compaction chamber of the mandrel within the cavity, and further wherein as the compaction apparatus is lifted, the aggregate is allowed to flow through and around the flow-through passage and into an interior of the compaction chamber and as the compaction apparatus is further lifted aggregate is allowed to flow below a bottom portion of the compaction chamber.

17. The method of claim 16 further comprising driving the compaction apparatus downwards into the aggregate, wherein the one or more diametric restriction elements are caused to move inwardly to "bunch" together to form a compaction surface.

18. The method of claim 17 wherein the compaction apparatus remains in the cavity during the lifting and driving movements of the densifying and compacting process without the need to remove the compaction apparatus out of the cavity.