Nov. 9, 1971 J. P. FREIN ET AL 3,618,327

CAISSON STRUCTURE AND PIER CONSTRUCTION METHODS

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FIG. 1

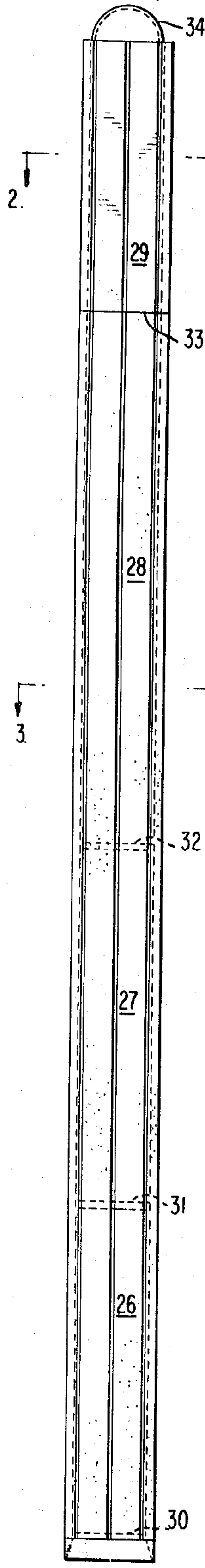


FIG. 2

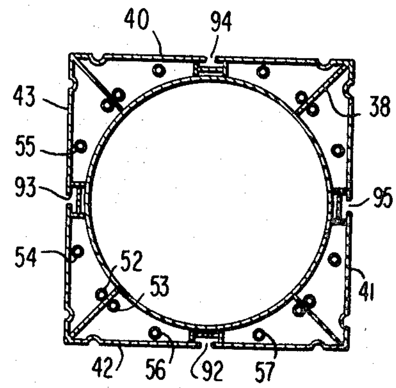


FIG. 4

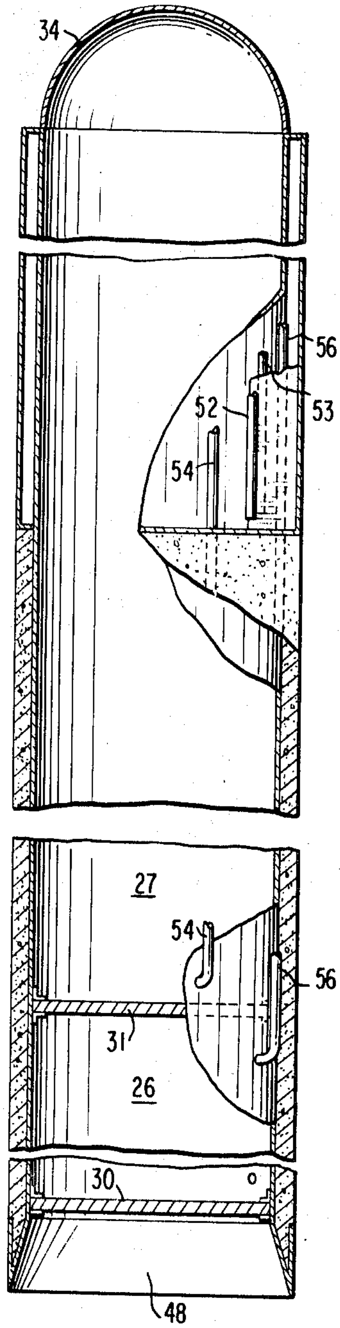


FIG. 3

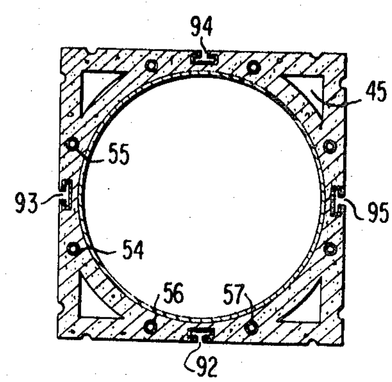
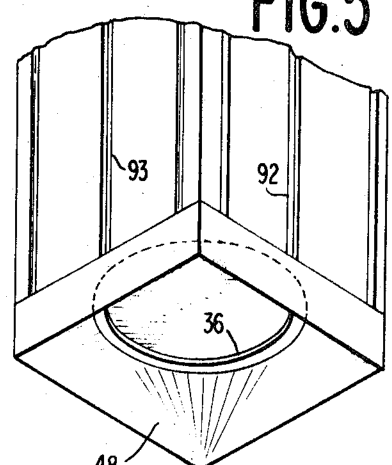


FIG. 5



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ATTORNEYS

CAISSON STRUCTURE AND PIER CONSTRUCTION METHODS

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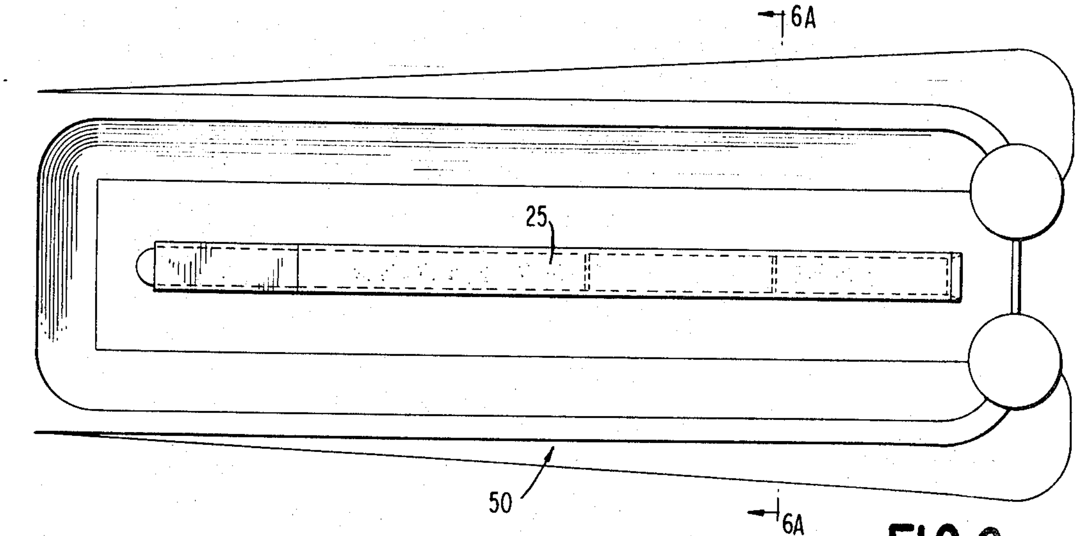

FIG.6

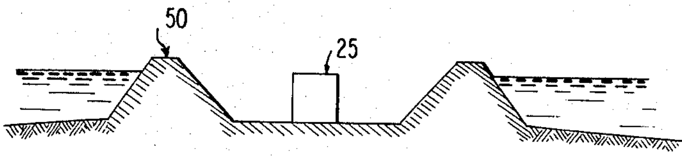

FIG.6A

FIG.7

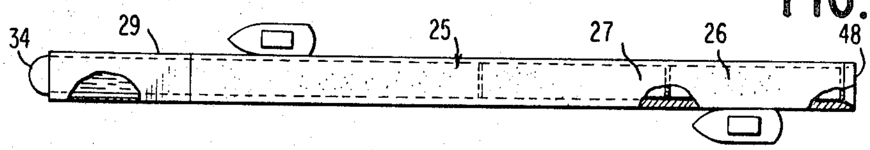

FIG.8

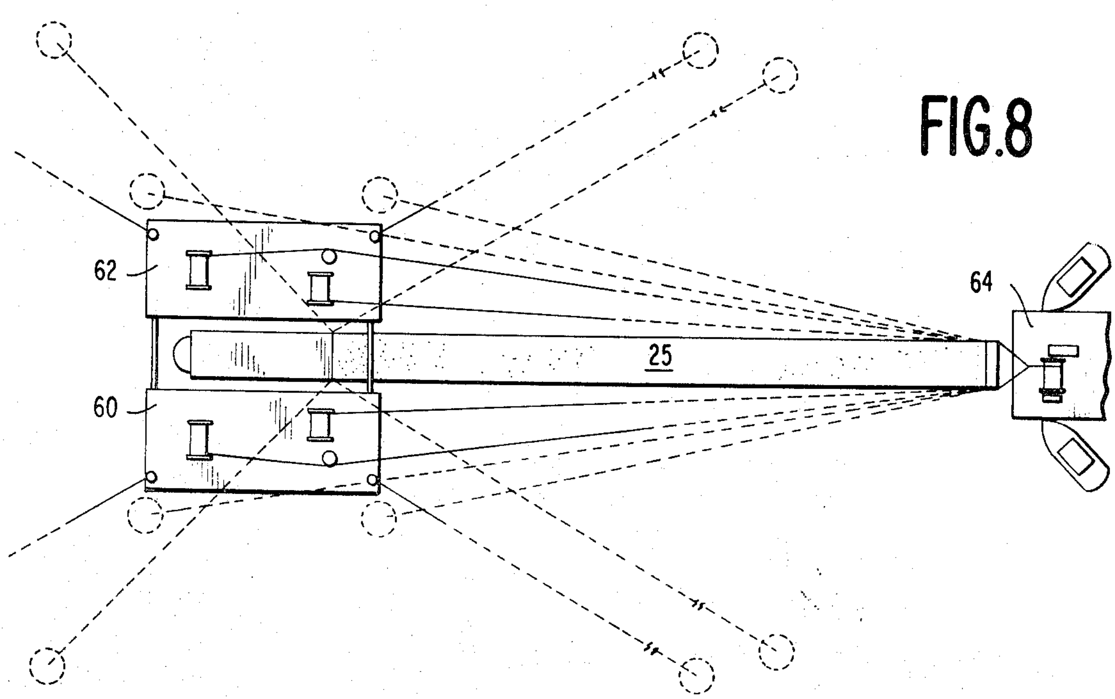

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FIG.9

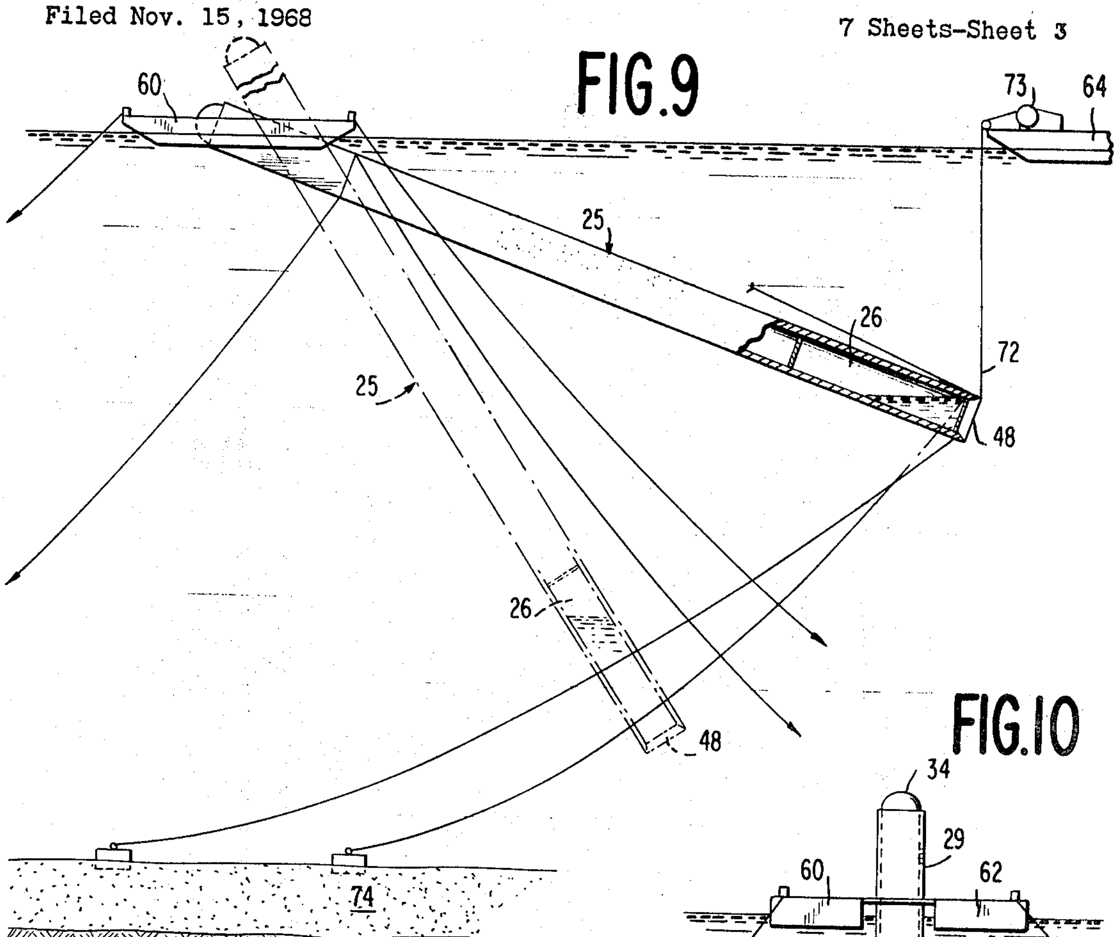

FIG.10

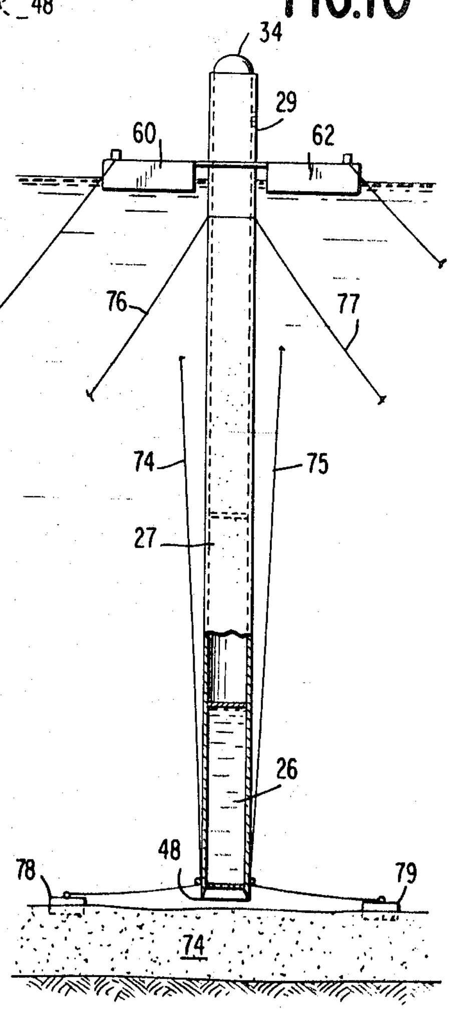

FIG.11

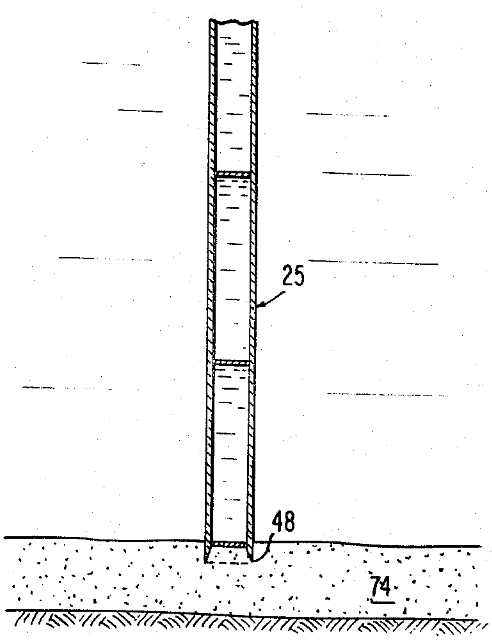

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FIG. 14

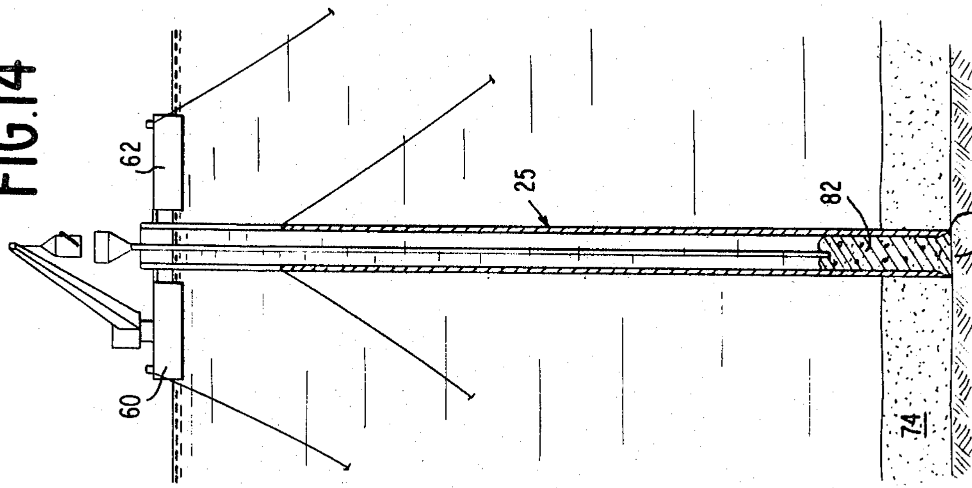


FIG. 13

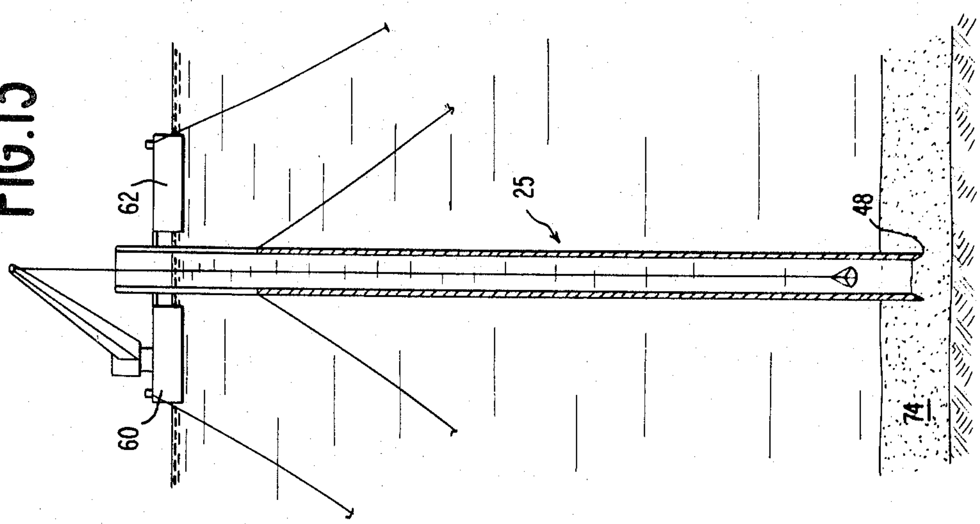


FIG. 12

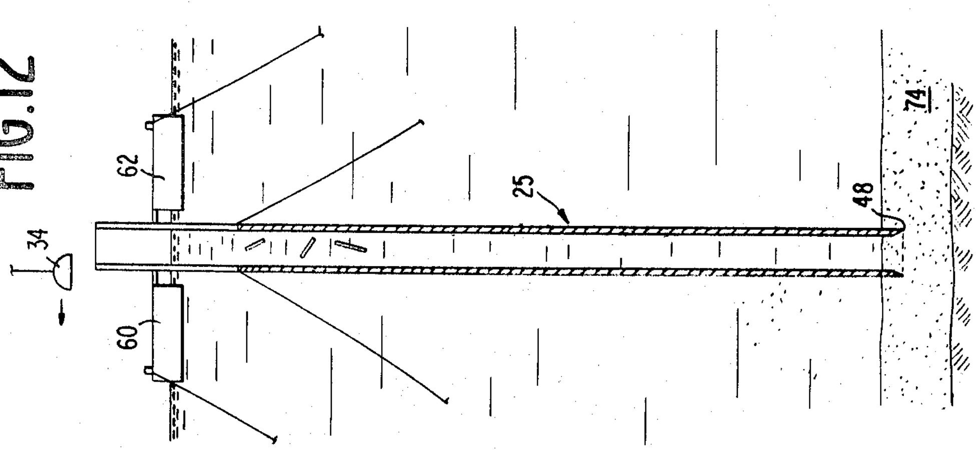
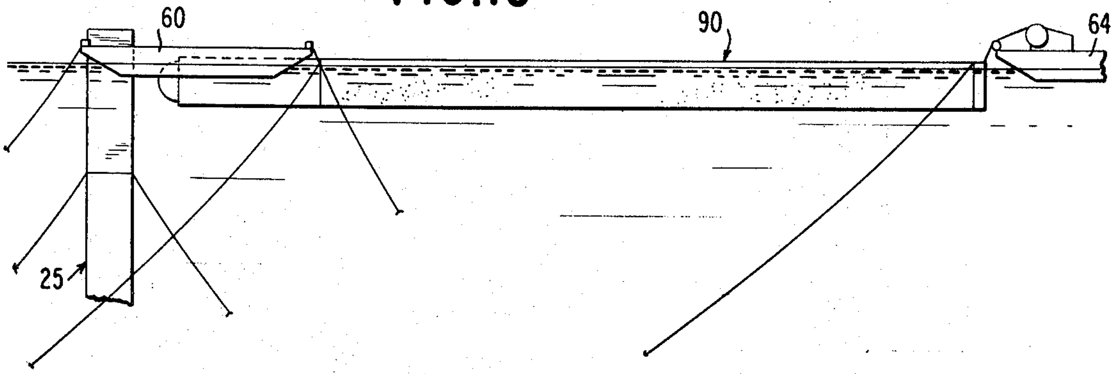


FIG.15



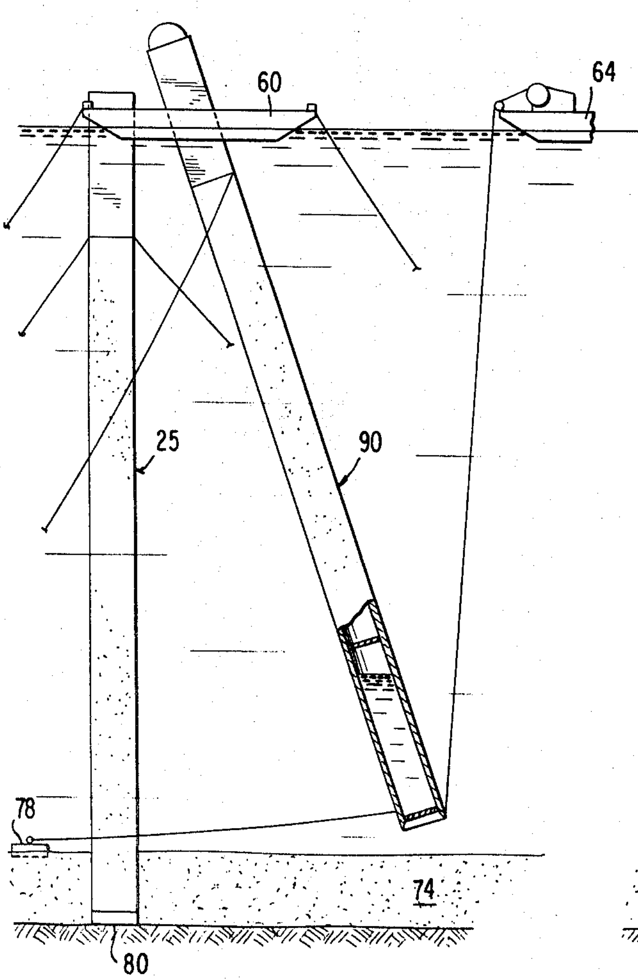


FIG.16

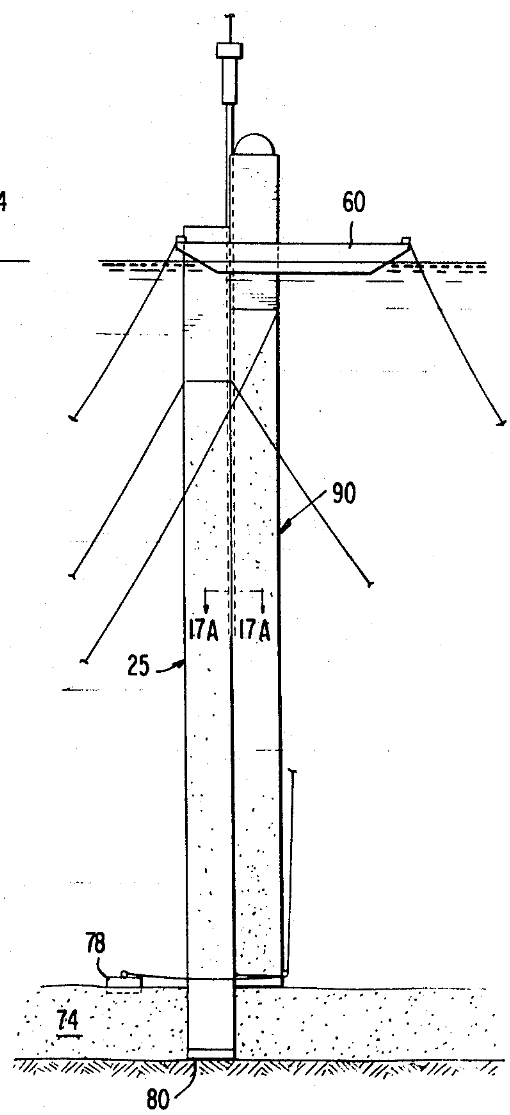


FIG.17

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FIG.17A

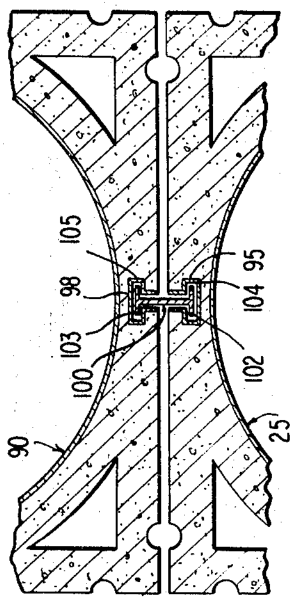


FIG.19A

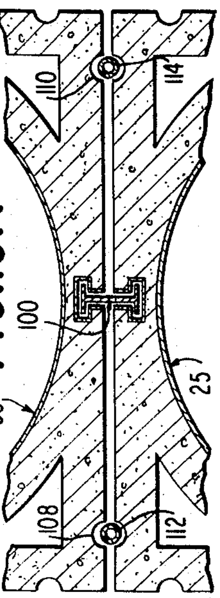


FIG.20

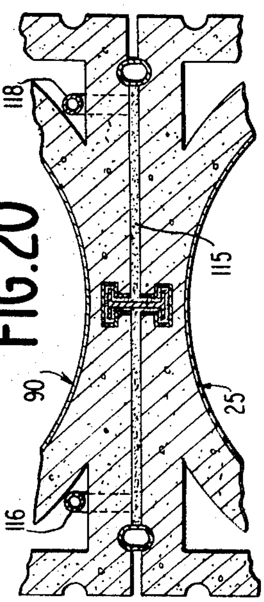


FIG.19

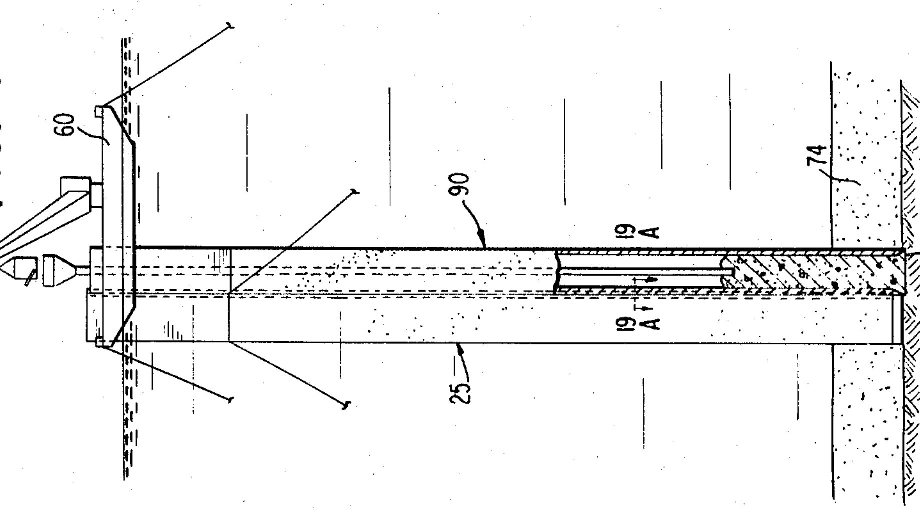


FIG.18

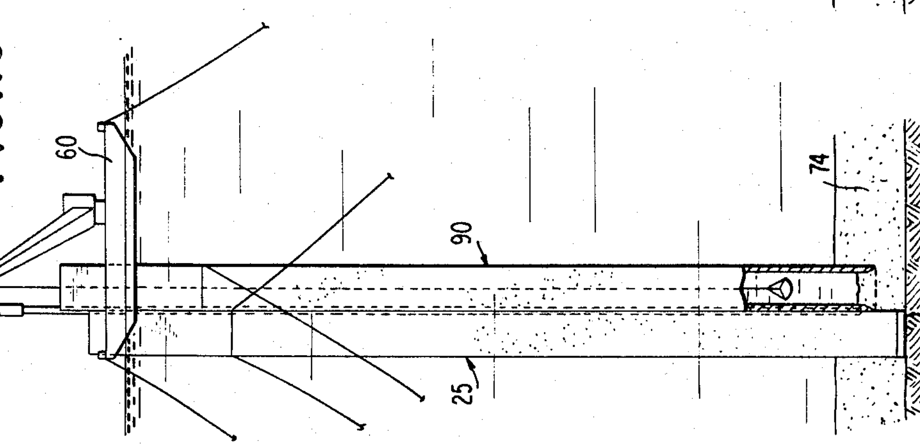


FIG.22

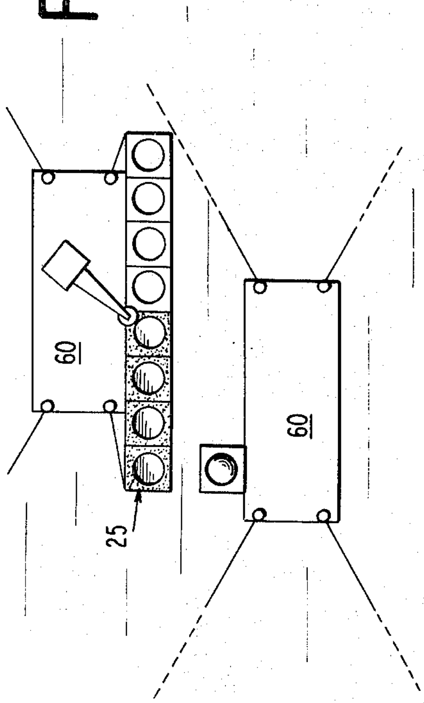


FIG.23

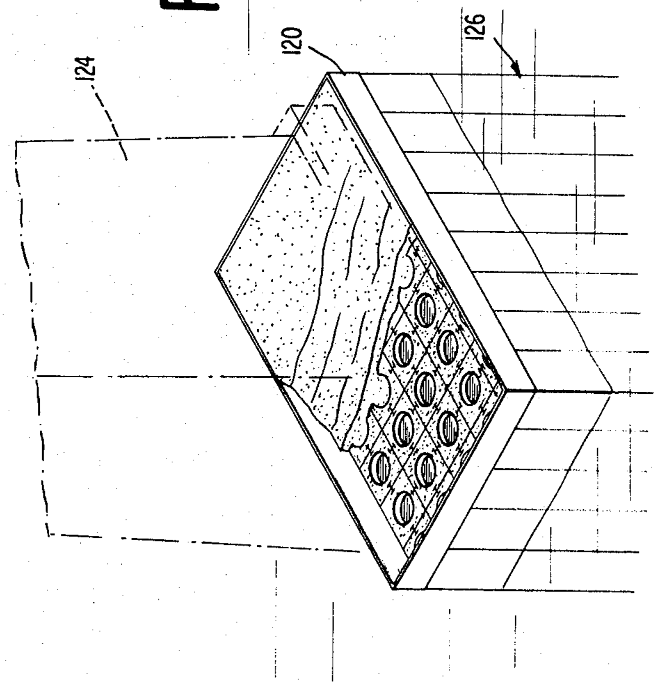
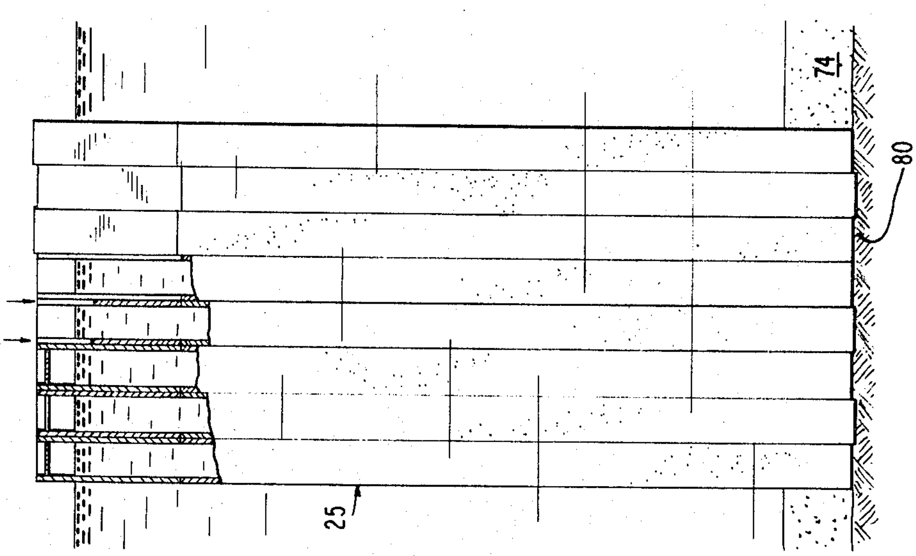


FIG.21



United States Patent Office

3,618,327

Patented Nov. 9, 1971

3,618,327

CAISSON STRUCTURE AND PIER CONSTRUCTION METHODS

Joseph P. Frein and Thomas Kinter, Boise, Idaho, assignors to Morrison-Knudsen Company

Filed Nov. 15, 1968, Ser. No. 776,222
Int. Cl. E02d 5/00, 5/20, 23/00
U.S. Cl. 61—46 29 Claims

ABSTRACT OF THE DISCLOSURE

Methods for over-water construction of bridge piers, and the like, especially adapted for use at deep-water, shallow-overburden sites utilizing a unitary full-depth caisson which is prefabricated off site. Floatation and ballast chambers in the caisson facilitate movement to location, accurate placement on site, and initial sinking. A plurality of full-depth caissons are interlocked longitudinally during on-site assembly to produced a pier of desired cross-sectional configuration. Lengths of individual caissons are selected to conform to subterranean support topography. A weight distribution block is cast-anchored to the caissons.

This invention is concerned with novel caisson structure and pier construction methods which permit pier construction at unprecedented water depths and under conditions which have precluded use of full-dimensioned air floated caisson or other prior art methods.

The present invention overcomes obstacles such as deep water, shallow overburden, strong currents, and the like, which have prevented pier construction at many sites for bridges or other desired over-water construction because of physical limitations and construction hazards.

The inventive concept involves prompt founding of a specially prefabricated, small cross-section, full-depth caisson and on-site assembly of numerous such caissons to form the desired configuration. The capabilities and advantages of the invention will be more fully understood from a description of a particular embodiment. Various views of the accompanying drawings to be used in such description are identified below:

FIG. 1 is a side view of a full-depth caisson embodying the invention, with portions of internal structure shown in dotted lines,

FIG. 2 is a cross-sectional view taken along the lines 2—2 of FIG. 1,

FIG. 3 is a cross-sectional view taken along the lines 3—3 of FIG. 1,

FIG. 4 is an enlarged view of the caisson of FIG. 1 with portions cut away.

FIG. 5 is a perspective view of an end portion of the caisson shown in FIG. 1,

FIG. 6 is a plan view of dry dock structure used for constructing a caisson of the type shown in FIG. 1, with a caisson in place,

FIG. 6(*a*) is a cross-sectional view taken along the lines 6(*a*)—6(*a*) of FIG. 6,

FIG. 7 is a plan view, partially cut away, of the caisson of FIG. 1 being moved to location,

FIG. 8 is a plan view of the caisson of FIG. 1 connected to control means for lowering one end of such caisson,

FIG. 9 is a side view of the caisson of FIG. 1, partially cut away, shown in two positions during lowering of one end with control means connected to such caisson,

FIG. 10 is a side view, partially cut away, of the caisson of FIG. 1 in a floating upright position with position control means connected to such caisson,

FIG. 11 is a cross-sectional view of a portion of the caisson of FIG. 1 with its lower end at the initial stage of being sunk into subsurface overburden,

FIG. 12 is a cross-sectional view of the caisson of FIG. 1 and top connected securing means, with compartmentation means and upper end closure means in the process of being removed,

FIG. 13 is a cross-sectional view of the caisson of FIG. 1 in the process of being lowered through sub-surface overburden,

FIG. 14 is a cross-sectional view of the caisson of FIG. 1 sunk through the overburden and resting on subterranean support in the process of being sealed at its lower end,

FIG. 15 is a view of an additional caisson of the type shown in FIG. 1 being floated to location,

FIG. 16 is a side view, partially cut away, of the additional caisson of FIG. 15 being lowered into position adjacent to the caisson of FIG. 1 which is resting on subterranean support,

FIG. 17 is a cross-sectional view of the two caissons of FIG. 16 in the process of being interconnected,

FIG. 17(*a*) is a cross-sectional view of portion of FIG. 17 taken along the lines 17(*a*)—17(*a*) of FIG. 17,

FIG. 18 is a cross-sectional view, partially cut away, of the two caissons of FIG. 17 illustrating one caisson being lowered through overburden,

FIG. 19 is a cross-sectional view, partially cut away, of the two caissons of FIG. 18 illustrating one caisson being sealed at its lower end,

FIG. 19(*a*) is a cross-sectional view of a portion of the structure shown in FIG. 19 taken along the lines 19(*a*)—19(*a*),

FIG. 20 is a cross-sectional view of a portion of the two caissons of FIG. 18(*a*) interconnected and grouted,

FIG. 21 is a side view, partially cut away, of a plurality of caissons of the type shown in FIG. 1 interlocked into an integral pier founded on uneven subterranean support,

FIG. 22 is a schematic plan view showing sequential placement of a plurality of caissons of the type shown in FIG. 1, and

FIG. 23 is a perspective view of a portion of an integral pier made up of a plurality of interlocked caissons of the type shown in FIG. 1, with a partially cut away weight distribution block supporting a bridge tower shown in dot-dash lines.

Caisson **25** of FIG. 1 is prefabricated to full-depth length as determined by the depth of the water and overburden at the construction site. This length is subdivided longitudinally into compartments **26** through **29** by watertight bulkheads **30** through **33**. Bubble top **34** seals the remaining end of the caisson. Watertight compartment **26** is located at the lower or founding end of the caisson and compartment **29** at the upper or water surface end of the caisson. The wall structure of compartments **26, 27, 28** is fabricated from reinforced concrete while upper chamber **29** comprises a steel floatation tank which is secured to the concrete portion of the caisson so as to form a unitary structure.

Referring to FIGS. 2 and 3, a cylindrical dredging well with steel cylindrical liner **36** extends over the full length of the caisson **25**. Steel cylinder **36** is secured within floatation tank **29** by bracing means shown in part as corner braces **38**. Referring to FIG. 3, voids such as **45** are formed intermediate steel cylinder **36** and the sidewalls of chambers **26, 27,** and **28.**

For purposes to be described later a cutting edge is built into the founding end of the caisson. As shown in perspective in FIG. 5 the cutting edge comprises a steel shell **48** tapered longitudinally from inner steel cylinder **36** toward the outer sidewalls. Cutting edge means **48** is shown in cross section in FIG. 4.

The caisson section is formed in a dry dock structure **50** as shown in FIGS. 6 and 6(*a*). In practice a plurality of such dry dock structures and/or multiple section dry docks are used for production line operations. These can be suitably located at shoreline facilities adjacent to a bridge building site, for example.

Floatation tank **29** serves a number of important functions. For example, as shown in FIG. 7 this tank is filled with ballast to the extent necessary to permit horizontal floatation of a caisson to a construction site. Other functions of this steel tank will be considered later in the description.

Ballast and air lines for the various chambers of the caisson are shown in FIGS. 2, 3, and 4. Lines **52** and **53** extend longitudinally to floatation tank **29**. Lines **54** and **55** communicate with chamber **27**. Lines **56** and **57** extend longitudinally to lower chamber **26**. These lines provide for ballast control for controlled leveling, lowering, floatation, and sinking of a caisson.

Referring to FIG. 8, control barges **60** and **62** are located at the upper end of caisson **25** and control barge **64** at its lower end. Anchor lines are connected as shown at the upper and lower ends of caisson **25** for control of lowering and positioning of the caisson.

Referring to FIG. 9, after arrival at location and connection of the anchor lines as shown in FIG. 8, ballast is pumped from floatation tank **39** into the lower chamber **26**. The rate of descent of the lower end of caisson **25** is con trolled by line **72** operated from power windlass means **73** on barge **64**.

FIG. 10 shows the caisson in its upright floating position with cutting edge **48** in close proximity to overburden **74**.

Anchor lines **74** and **75** are used for accurate positioning of the lower end of caisson **25** while positioning of the upper end is controlled by positioning barges **60** and **62** with their respective anchor lines and by caisson anchor lines **76**, **77** connected to the upper end of caisson **25**. Ballast control means described earlier are utilized to maintain the caisson slightly buoyant which facilitates accurate positioning. When accurately positioned, the watertight chambers are flooded to cause initial founding in the overburden.

In practice, anchors **78** and **79**, used in positioning caisson **25**, are located outside the final boundary of the pier being constructed so as to permit their usage with subsequent caissons.

Initial sinking of caisson **25** into the overburden **74** anchors the lower end of the caisson and bubble top **34** and other watertight bulkheads are removed as shown in FIG. 11. Removal of bulkheads **30**, **31**, **32** and **33** can be accomplished by lowering a drilling blade or bit to fragment the bulkheads or by providing release mechanisms.

As shown in FIG. 13, as overburden **74** is removed from within caisson **25**, the weight of the caisson and cutting edge **48** cause caisson **25** to sink into the overburden until it comes to rest on subterranean support such as rock foundation **80**.

After location on subterranean support **80**, the lower internal portion of the caisson is thoroughly washed to remove all overburden. As shown in FIG. 14, the founded end of caisson **25** is then sealed using tremie concrete **82** which is pumped into the caisson at its lowermost end and rises within the caisson.

After the initial caisson section **25** is firmly anchored at its lower end, the upper end control lines are maintained in position and the water is maintained within caisson **25**. A substantially identical caisson **90** of preselected length is then floated to location as shown in FIG. 15. Using control lines and control ballasting as described earlier in relation to caisson **25**, the second caisson **90** is lowered as shown in FIG. 16 into a substantially parallel relationship with caisson **25** as shown in FIG. 17.

Referring to FIGS. 1, 2, and 3, it will be seen that slot **92** extends over the full length of caisson **25**. Similar slots **93**, **94** and **95** extend over the full length of the remaining sidewalls of caisson **25**, and about caisson **90**.

Referring to FIG. 17(*a*), the two caissons **25** and **90** are arranged in side-by-side relationship with their longitudinal axes in substantially parallel relationship. Slot **98** of caisson section **90** is placed in opposed relationship to slot **95** of caisson **25**. The two caissons are interconnected, and positioning of caisson **90** in relation to founded caisson **25** is assisted, by inserting I beam **100** into the slot means **95** and **98**.

Web **101** of I beam **100** extends between flanges **102** and **103** which are located in the cross sections **104** and **105** of the slots **95** and **98** in caissons **25** and **90** respectively. The slots are lined with heavy steel plate anchored to the concrete and steel sidewalls of the caissons. The steel lining adds strength to the wall structure and decreases abrasive resistance during insertion and driving of the I beam. In practice the I beam is lowered or driven in longitudinal sections which are welded together so as to extend over substantially the full length of the caissons.

In the cross-sectional view of the juncture between caisson **25** and caisson **90** shown in FIG. 19(*a*) it will be seen that grout stop grooves **108** and **110** are in opposed relationship. Inflatable sleeves **112** and **114** are inserted into these grooves throughout substantially the full length of the caissons. After insertion these sleeves are inflated and the confined interstice between the caissons is filled with grout **115** as shown in FIG. 20. The grout is added from the bottom and should extend over substantially the full length of the caissons. Grout fill can be added through tubes **116** and **118** shown in FIG. 20.

FIG. 21 illustrates the preselection of caisson lengths based on the topography of the subterranean support **80**. The lengths of individual caissons are prefabricated to match such topography. After placement of the caissons, the upper end of the structure can be leveled, if desired, by cutting off a portion of steel floatation tanks which extend beyond a desired plane.

FIG. 22 shows a suggested placement sequence for a plurality of caisson sections. Preferably a centrally located caisson section is founded and caisson sections are added along a line which runs in the same direction as the prevailing water current. After a plurality of such caisson sections are placed, the need for upper anchoring lines is relieved and the founded caissons provide a pier for docking of surface vessels, a working platform, and the like. Portions of the floatation tank within its sidewalls and external to the dredging wells are filled with concrete and become load-bearing with the load being transferred to the substantially thicker structure of the concrete portion of the caisson.

Referring to FIG. 23, after a plurality of caissons are joined together by I beams, as shown, a concrete weight distribution block is cast on the structure and extends into the caisson dredge wells so that the weight distribtuion block is locked to the caissons.

The weight distribution block **120** shown in FIG. 23 can be poured in sections during construction of the pier. After completion of the distribution block, a bridge tower **124** or other superstructure **124** is built directly on the block.

In the embodiment described pier **126** of FIG. 23 has a cross-sectional configuration of 100 feet by 160 feet with each caisson having a 20-foot square configuration. Other peripheral configurations for the individual caissons can be used. Preferably the configuration is rectilinear for greater abutting surface and grouting purposes but not limited to rectangular; e.g. a triangular configuration could be used. Piers of larger or smaller cross section can be constructed, depending on the need, merely by increasing or decreasing the number of caissons. One of the most important advantages of the invention is dimensional flexibility permitting differing size and configuration piers to be constructed without change in construction method. Also, multiple level piers can be readily built by selection of individual caisson length. The teachings of the invention also lend themselves to future expansion at a site since caissons can be readily added to an earlier construction.

As is known in the art, air floated full-dimensional caissons are confronted with insurmountable air pressure problems as depth of construction exceeds 250 to 300 feet. In addition, navigational, stability, and anchoring hazards are created by large full-dimensional caissons which place practical limits on their usage. For example, a full-dimensional caisson of the size described in relation to FIG. 23 could not be safely or accurately handled in deep waters, such as in excess of 300 feet, subject to tidal currents. The teachings of the present invention greatly multiply the present limits of over-water construction as will be apparent to those skilled in the art from this disclosure.

Assuming a building site with water depth in excess of three hundred feet and overburden of twenty-five to fifty feet, typical data for the embodiment shown would be as follows:

Caisson length—approximately 325 to 375 feet, or longer, dependent on depth of water and overburden and desired clearance above waterline.
Caisson cross section—approximately 20-foot square.
Dredging well diameter—approximately 15 to 17 feet.
Dredging well liner, slot liner, and floatation tank walls—steel plate 1/4" to 3/8" thickness.
Wall thickness for concrete portion of caissons—approximately 18".
I beam—24" wide flange beam (14" flanges).
Chamber **26** length—75' ±
Chamber **27** length—80' ±
Chamber **28** length—120' ±
Floatation tube length—60' ±
Cutting edge depth—approximately 5'
Distribution block depth—approximately 15'
Weight per caisson—approximately 3300 tons.

In carrying out the invention borings are made at each site to determine accurate mud and rock profiles along each row of member caissons. Individual caissons are prefabricated to required length. Temporary bulkheads are installed to facilitate floatation. Individual caissons are floated horizontally to the installation site and, by controlled lowering of one longitudinal end, oriented vertically. Individual caissons are then maneuvered into accurate position by controlling buoyancy while simultaneously moving a caisson in the horizontal plane until coupling means in sidewalls of the caissons are aligned. Interlocking means, such as I beams, are inserted longitudinally from the upper exposed ends of the caissons. I beams of the longest feasible length are used and welded together with the welded lengths being driven as necessary until the I beam fills the caisson sidewall slots from top to bottom. A small amount of play is provided between the I beam and the slots to permit a buoyancy-controlled, slight vertical movement of a caisson to facilitate insertion of the I beam and alignment. After internal excavation through a hollow dredge well, each caisson is sealed at its lower end with tremie concrete to required height which is generally above the level of the overburden. The process is repeated, bringing in and joining subsequent caissons until the desired configuration is obtained. Grout joints between caissons are filled when all caissons are positioned.

While a specific embodiment has been described for purposes of disclosing the invention, it is understood that various modifications in dimensions, materials, and configurations can be made without departing from the scope of the invention which is to be determined from the appended claims.

What is claimed is:

1. A full-depth caisson for use in over-water construction comprising

an elongated, partially-hollow, unitary structure having a longitudinal axis, longitudinal ends, and watertight sidewall means,

a hollow dredging well within the watertight sidewall means extending longitudinally in substantially parallel relationship with the longitudinal axis of the elongated unitary structure,

removable bulkhead means for temporarily closing the longitudinal ends of the elongated unitary structure and for subdividing such structure longitudinally into hollow watertight compartments,

a hollow steel floatation tank being located at the longitudinal end of the elongated unitary structure to be disposed at water surface when the elongated structure is in an upright position,

the hollow steel floatation tank being secured to an adjoining castable masonry material watertight compartment of the elongated unitary structure,

the hollow steel floatation tank having substantially the same cross-sectional configuration as such castable masonry portion of the elongated unitary structure, and

cutting edge means located at the longitudinal end of the elongated structure to be submersed to subsurface bottom.

2. The structure of claim **1** in which the cutting edge means comprises a steel shell tapered longitudinally from the dredging well toward the periphery of the sidewall means of the elongated structure.

3. The structure of claim **1** in which the dredging well has a cylindrical configuration and extends in co-axial relationship with the longitudinal axis of the elongated structure over substantially the full length of the caisson from the cutting edge longitudinal end to the longitudinal end to be disposed at water surface.

4. The structure of claim **1** in which the sidewall means has a rectilinear cross-sectional configuration.

5. The structure of claim **3** in which the dredging well has a steel cylindrical liner.

6. The structure of claim **4** in which corner portions of the structure between the cylindrical dredging well and the rectilinear cross-sectional sidewall means are hollow.

7. The structure of claim **1** further including means for controlling ballast in the watertight chambers.

8. Structure for use in over-water construction of an integral full-depth pier from a plurality of independent full-depth caissons of the type set forth in claim **1** and further including

coupling means located contiguous to an external surface of the sidewall means for interconnecting such elongated caisson with a similar elongated caisson in side-by-side relationship and holding such caissons so as to prevent substantial lateral movement relative to each other with their longitudinal axes in substantially parallel relationship.

the coupling means defining a longitudinally extended opening for receiving elongated interlocking means from one longitudinal end of the elongated caisson.

9. The structure of claim **8** in which the cutting edge means comprise a steel shell tapered longitudinally from the co-axial cylindrical chamber toward the periphery of the sidewall means.

10. The structure of claim **8** in which the sidewall means have a rectilinear configuration in a cross-sectional plane substantially perpendicular to the longitudinal axis of the unit.

11. The structure of claim **8** in which the coupling means comprise steel lined slot means opening on the external surface of the sidewall means.

12. The structure of claim **11** in which the slot means of such caisson when positioned in opposed relationship to slot means of another similar caisson form an enlarged

I configuration in a cross-sectional plane substantially perpendicular to the longitudinal axes of the caissons.

13. An integral full-depth pier comprising at least two elongated caissons as recited in claim **8** interconnected longitudinally in side-by-side relationship with their longitudinal axes substantially parallel.

14. The structure of claim **12** in which the plurality of caissons are interconnected at their upper longitudinal ends by weight distributor means.

15. The structure of claim **14** supporting a load, such as a bridge tower, on the weight distributor means.

16. An integral structure comprising at least two elongated caissons as recited in claim **12** with elongated I beam means positioned within the respective slot means of the caissons interlocking the caissons, the elongated I beam means extending substantially parallel to longitudinal axes of the caissons.

17. An integral bridge pier comprising at least two elongated caissons as recited in claim **8** with their cutting edge longitudinal ends embedded in overburden and resting on subterranean support and interconnected by elongated interlocking means held by respective coupling means of the elongated caissons.

18. The structure of claim **16** in which abutting sidewall portions of the elongated sections are sealed with a grouting compound.

19. The structure of claim **8** in which the sidewall means of the elongated caisson has an equilateral configuration in a cross-sectional plane substantially perpendicular to the longitudinal axis of such caisson.

20. Method for constructing an integral structure for use as an over-water pier, or the like, from a plurality of elongated full-depth caissons having coupling means located along their respective longitudinal sidewalls, each caisson having a hollow chamber extending along its longitudinal axis over its entire length, such chamber being initially subdivided longitudinally to form water-tight compartments distributed along the longitudinal axis, comprising the steps of

positioning an elongated full-depth caisson in substantially vertical position with one longitudinal end contiguous to subsurface overburden,

lowering the elongated caisson in its substantially vertical position to subterranean support level,

removing compartmenting bulkheads positioned along the longitudinal axis of the caisson, then

removing subsurface overburden from within the caisson through the hollow chamber extending along the longitudinal axis of the caisson,

positioning an additional elongated full-depth caisson substantially vertically in substantially parallel side-by-side relationship with the first positioned elongated caisson, and

intercoupling such elongated caissons with the coupling means located along their respective side-walls so as to prevent substantial lateral movement of the caissons with relation to each other.

21. The method of claim **20** in which the coupling means are longitudinally extended for receiving an elongated interlocking means and the caissons are intercoupled by inserting such elongated interlocking means longitudinally from the upper longitudinal ends of elongated caissons.

22. The method of claim **20** including the steps of surface floating an individual caisson to location, and lowering one longitudinal end of the caisson for substantially vertical positioning by adding pumpable ballast to a water-tight compartment located contiguous to the longitudinal end of the caisson to be embedded in overburden.

23. The method of claim **20** in which pumpable ballast is being removed from a water-tight compartment contiguous to the upper longitudinal end of the caisson simultaneously with addition of pumpable ballast to the water-tight compartment located contiguous to the longitudinal end of the caisson to be embedded in overburden.

24. The method of claim **20** including the step of sealing the lower end of the elongated caisson after positioning on subterranean support level.

25. The method of claim **24** in which the caisson is sealed by filling the lower end of the caisson section with a settable grouting compound.

26. The method of caim **20** in which a plurality of individual caissons are placed in side-by-side interlocked relationship including the step of applying a grouting compound intermediate the plurality of individual sections so as to seal interstices between abutting caissons.

27. The method of claim **20** including the steps of forming upper longitudinal ends of the plurality of interlocked caissons to establish the desired level at such longitudinal end of the integral structure, and placing weight distributor means on such upper longitudinal ends.

28. The method of claim **27** in which the weight distributor means is cast in place from settable masonry material and such cast masonry material extends into the hollow portions of the elongated caissons at their upper ends.

29. The method of claim **20** including the steps of measuring the depth of desired subterranean support at selected positions to establish subterranean topography at the desired location for the integral pier, and assembling individual caissons of selected lengths with the length of each caisson being determined by topography at the desired location.

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