

1,036,680.

Patented Aug. 27, 1912.  
 2 SHEETS—SHEET 1.

Fig. 1.

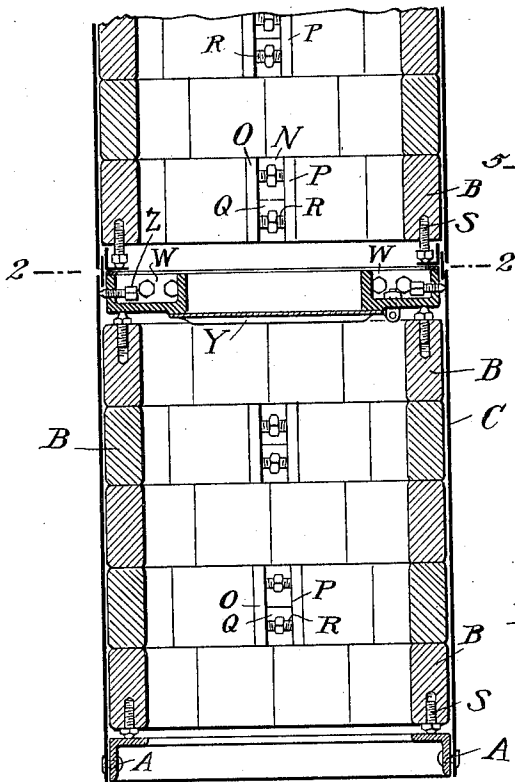


Fig. 4.

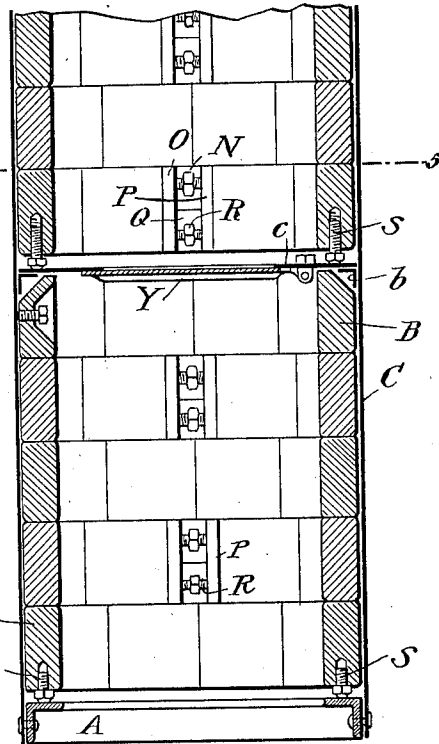


Fig. 2.

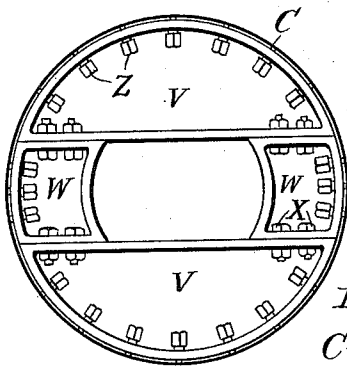


Fig. 5.

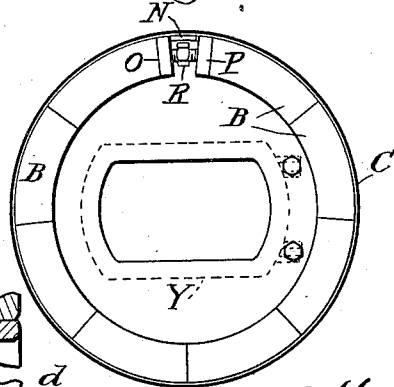
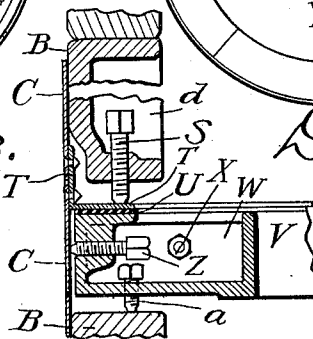


Fig. 3.



WITNESSES  
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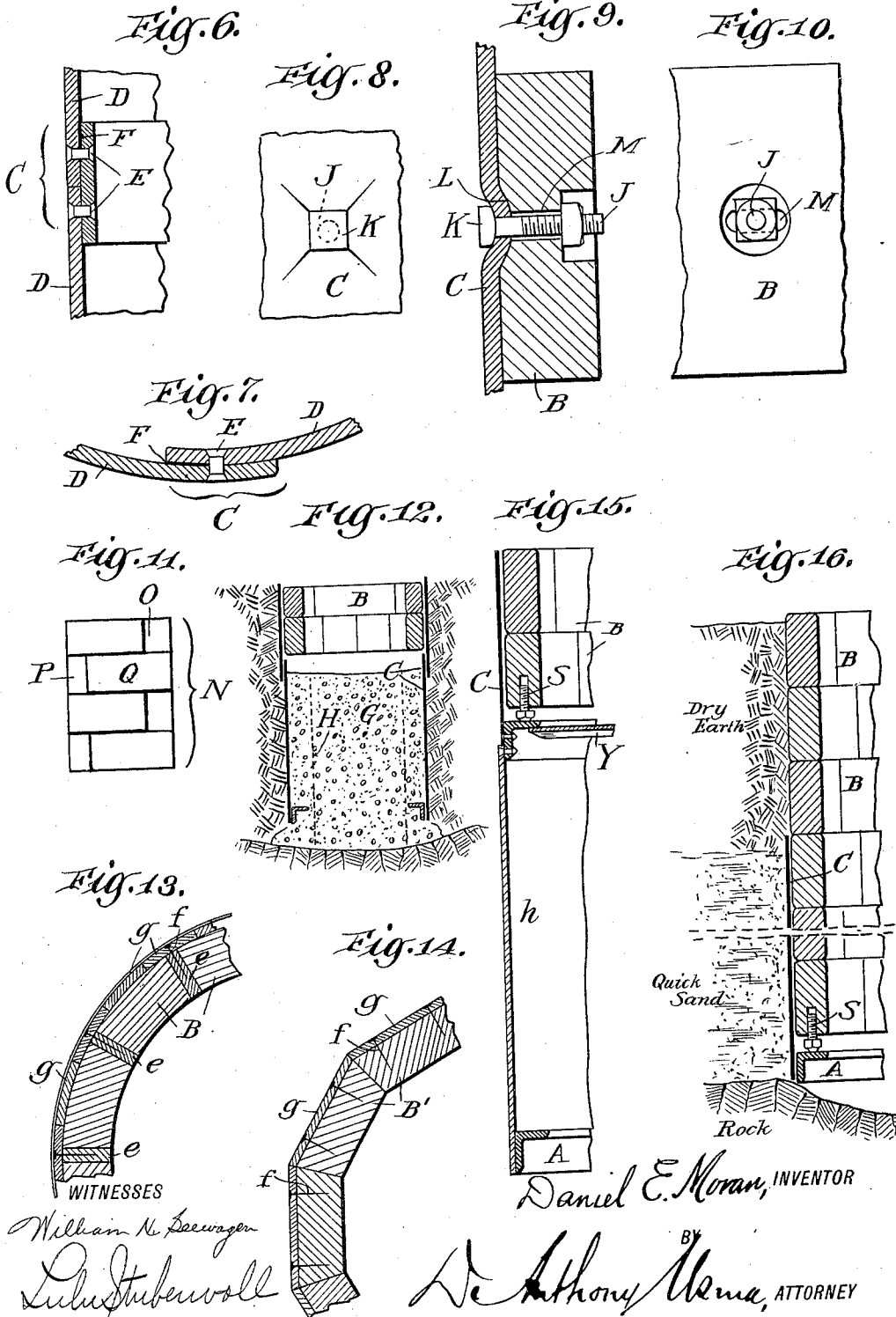
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BUILDING PIERS, SHAFTS, &c.  
APPLICATION FILED MAR. 4, 1911.

1,036,680.

Patented Aug. 27, 1912.  
2 SHEETS—SHEET 2.



# UNITED STATES PATENT OFFICE.

DANIEL E. MORAN, OF MENDHAM, NEW JERSEY.

BUILDING PIERS, SHAFTS, &c.

1,036,680.

Specification of Letters Patent.

Patented Aug. 27, 1912.

Application filed March 4, 1911. Serial No. 612,329.

*To all whom it may concern:*

Be it known that I, DANIEL E. MORAN, a citizen of the United States, residing in Mendham, county of Morris, State of New Jersey, have invented new and useful Improvements in Building Piers, Shafts, &c., of which the following is a specification.

This invention relates to the building of piers, columns shafts or the like, by first sinking caissons, cofferdams, underpinning cylinders or tubes of various cross-sections, and then introducing the usual concrete or other masonry; the sinking being accomplished either by open dredging or excavation or by the pneumatic method under a pressure of air sufficient to keep out the surrounding water. There is no definite limitation of the size of such caissons. That is to say, they can be made as large as desirable. But when very small piers are required the central opening for the passage of men or materials occupies so large a proportion of the cross section that the structure used in sinking becomes simply a shell constituting the outside of the pier and at the same time forming the shaft. Such caissons have been used, in underpinning work for example as small as three feet in diameter, the exterior shell being of cast iron and providing an important part of the structural strength of the finished pier. In such work, as well as in some types of larger caissons the shell used in sinking, and remaining in the finished pier, is expensive.

The present invention, though more or less advantageous for large piers, is especially advantageous for small cross-sections such as are sometimes used in underpinning old walls. The invention makes it feasible to remove all or the greater part of the structure used in the sinking operations, thus effecting a considerable economy and has other advantages which are referred to in detail hereinafter.

Another important possibility of the invention is the use of a shell which remains permanently in place in combination with the above referred to removable structure which is used only in the sinking operations and which is withdrawn and subsequently replaced by the concrete or other masonry in such a way as to support the shell as well as to form the body of the finished pier or shaft lining. This method permits of the use of a permanent shell so thin as to con-

stitute practically only a skin over the finished pier and which, though watertight, may be so thin and flexible as to be incapable by itself of withstanding the pressures encountered. In the case of pneumatic operations the shell should also be substantially air tight, and in either case it should possess some tensile strength and should be able to resist the abrasion to which it is subjected by contact with the earth in sinking. Thin sheet iron is the best material for the purpose. The cross section may be of any usual or suitable shape, according to the desired cross section of the pier. If the shell be sufficiently thin and flexible it may be made to take its shape from the interior structure. The latter provides the strength necessary to resist collapsing and, where the caisson is to be forced down by means of vertical loads, should have the necessary compressive strength in a vertical direction. It is advantageous also that this structure should be heavy so that its weight may cause or assist in causing the descent of the caisson against the external friction of the soil. The best material for this purpose is cast iron.

Other features of advantage are referred to hereinafter in connection with the accompanying drawings which illustrate practical embodiments of the invention.

Figures 1 and 2 are respectively a longitudinal section and a cross section (approximately on the line 2—2 of Fig. 1) of a pneumatic caisson with a removable diaphragm. Fig. 3 is a detail of Fig. 1, enlarged. Figs. 4 and 5 are respectively a longitudinal section and a cross-section on the line 5—5, Fig. 4, of a pneumatic caisson with a non-removable diaphragm. Figs. 6 and 7 are enlarged details of vertical and horizontal joints of the shell. Figs. 8, 9 and 10 are respectively an outside elevation, a vertical section and an inside elevation of a mode of attachment of the inside structure to the shell. Fig. 11 is an outside elevation of an adjustable key block for one of the removable rings. Fig. 12 is a view similar to Fig. 1 showing the placing of the concrete body within the shell and the removal of the interior structure. Fig. 13 is a cross section showing a mode of using a shell of wood with inside blocks of iron or other suitable materials. Fig. 14 is a similar view showing the use of an outside shell of wood with interior blocks also of wood. Fig. 15

is a vertical section of a type of caisson utilizing only in part the principle of the invention. Fig. 16 is a similar view of a construction suitable for favorable situations.

Referring to the case illustrated in the drawings, representing the building of a small circular pier, the caisson is built from the bottom up. An angle iron ring A is provided similar to the cutting edge used in the ordinary caisson construction. Upon the horizontal flange of the angle iron a series of collapsible rings is made up, each ring composed of a number of cast iron blocks B. There might be, for example, nine or ten of these blocks in a ring and each ring a foot high and three inches thick for a caisson of three feet outside diameter. Each ring would weigh about one thousand pounds. The wall composed of the series of rings would have considerable weight and considerable utility in sinking the pier. By reason of its horizontal arch-shape (the joints being preferably radial whether the cross section of the caisson is a circle or otherwise) it will resist external pressure and maintain itself in shape. Starting also from the cutting edge A the outer shell, indicated as a whole by the letter C, is built up of thin plates of sheet iron with vertical and horizontal joints spliced or lapped and riveted together. The individual plates D constituting the shell are indicated on an enlarged scale in Figs. 6 and 7 fastened together by countersunk rivets E and calked with packing material F to make the joints water-tight and preferably air tight. This shell fits the cast iron rings. As the sinking progresses the removable structure is built up and maintained at a convenient height, preferably above the level of the ground, and the shell is similarly built up. The excavation proceeds in any usual or suitable way through the caisson, removing the earth and sinking the shell and removable structure until rock is reached or the caisson is carried to the required depth. The reinforcing rings are separately held in position by their engagement with the shell, and each ring is collapsible or breakable, as hereinafter described. Having gotten to the depth required one or more of the rings at the bottom is removed leaving a certain height of the shell without support; this height, however, being so little that its support above and below the unsupported portion will prevent its collapsing. The unsupported portion for example in case of removal of a single ring would be only one foot in height. A layer of concrete is then laid in the bottom, extending through the open lower end of the shell, to the rock or other sub-foundation as indicated in Fig. 12, and filling the shell so as to support the latter, just as it was previously supported by the ring of cast iron blocks. In building a

pier the body of concrete G will extend solidly across the space within the shell. In building a curb or lining for a shaft the body of concrete will be provided with a central opening as indicated by the dotted lines H in Fig. 12. The next higher ring or rings of the removable structure are then removed, leaving the shell supported below by the body of concrete G and above by the next unremoved ring. The concrete is then built up farther throughout the height of the unsupported portion of the shell, and the foregoing operation is repeated to the desired height. In the finished pier the only part of the original structure remaining in the ground is the external shell, the cutting edge, and in some cases the whole or a part of any diaphragm used in pneumatic work. If each of the rings carried the entire weight of all the rings above it it would be impossible to remove the lower rings on account of the friction; and the lowering of one ring would cause those above it to fall into its place and to defeat the intended operation. It must be made possible, therefore, to hold the weight of the rings above the one which is to be removed. This is preferably accomplished by holding each of the rings in engagement with the shell in such a way as to support its weight. The engagement for example may be a frictional one if the weight and proportions of the parts permit, or, and preferably, it may be a positive engagement such as is illustrated in Figs. 8, 9 and 10.

Each block B, according to the construction illustrated in these figures, is bolted to the shell C preferably by means of a bolt J with a countersunk head K fitting in a dimple formed in the thin sheet metal of the shell, the block being also dimpled as at L to accommodate the inwardly projecting portion of the shell. Preferably the bolt passes through a circumferentially elongated slot M in the block B to permit a slight circumferential movement in expanding the ring as hereinafter described. With this construction a thin shell can be secured to the cast iron blocks in a way to permit the removal of the latter from the inner side and without materially disturbing the continuity of the outer surface of the shell. The dimpling of the shell may be effected by simply screwing up the bolt, bending the metal of the shell into the block, or by merely driving the shell into the dimple of the block by a hammer blow from the outside. This dimpled engagement has also the advantage that it would prevent the block from slipping down even if the bolt were removed; and indeed such an engagement may be depended upon alone, omitting the bolts and using other means for holding the blocks out against the shell. Or, as stated above, with certain weights and proportions of the parts the blocks may be

pressed outward against the shell with such force that the frictional engagement without any dimpling or equivalent device would prevent them from slipping downward.

5 While it may be feasible to support some or all of the weight of the blocks independently of the shell yet there is no objection to supporting them entirely from the shell, a very thin shell serving the purpose because  
10 it can not fail by buckling, being rigidly held in place by the cast iron blocks, and because the weight above, which would tend to collapse the shell vertically, is held up by the friction of the surrounding earth  
15 with a force approximately equal to and in some cases greater than the weight.

To press the removable structure out firmly against the shell so as to hold the latter in shape and to assist in holding up  
20 the rings, and for the purpose of withdrawing the rings, they are preferably made in a series of blocks as shown, with radial joints between them and with an extensible and collapsible key block, indicated as a whole  
25 at N, Figs. 1, 4, and 5; and shown in outside elevation in Fig. 11. This collapsible block consists essentially of two plates O and P with radial joints corresponding to those of the remaining blocks in the ring and preferably  
30 with over-lapping tongues Q at the outside, to guide the plates, these two plates being adjustably separated or drawn together by means of turnbuckle screws R with central square portions, on the opposite  
35 sides of which are respectively right and left handed threads screwing into corresponding sockets in the plates. Such a collapsible block is provided in each ring and is first expanded to bring the ring into good  
40 frictional contact with the shell, and is subsequently contracted and removed to permit the collapsing and removal of the ring, block by block. The ring to be first removed, however, would be held tightly between  
45 its lower abutment and the next ring above it and it is preferable to provide means for first loosening this first ring vertically. After the removal of the first ring the next higher one can be easily dropped  
50 in the space thereby provided, to permit its removal. For the lowermost ring, therefore, and for the ring which rests on the diaphragm, as in Figs. 1 and 4, I have shown stud bolts S tapped into the blocks and with  
55 their squared heads exposed so that by starting them with the screws partly withdrawn from the blocks and afterward screwing them in a direction to enter the blocks, the latter can be dropped sufficiently to free  
60 them from the ring above. A further security against the slipping of the blocks or rings downward, when lower rings are removed, is provided by the horizontal joints in the shell which may be arranged, as  
65 shown in Fig. 12 so that certain rings (or

each single ring if desired) would designedly come in contact with the edge of the inner plate of a lapped joint, or of an interior splice plate (E Fig. 6) of a butt joint.

Where the caisson is to be sunk by open  
70 methods the simple structure of shell and rings may be continued uninterruptedly from bottom to top. Where the excavation is to proceed under pneumatic pressure, however, one or more diaphragms must be  
75 provided. The shell must be capable of resisting the internal air pressure, which would be forty pounds per square inch in an extreme case. For a three foot cylinder  
80 a shell of less than one-eighth of an inch in thickness would be theoretically sufficient, and this thickness would also be sufficient to span the unsupported distance between the  
concrete filling and the lowest remaining  
85 ring, as well as to carry the weight of the rings. Generally it would be desirable to have the air lock formed in the same structure, which would require a second diaphragm similar to the one illustrated. The  
90 diaphragm has to resist a considerable upward pressure of air and must make a substantially air tight connection with the shell or with the interior rings, in which case the  
latter must be made substantially air tight;  
95 or one of the rings must be specialized so as to form the diaphragm or a part of the diaphragm and to make an air tight connection with the shell. The diaphragm in any case must carry a substantially air tight door for  
100 the passage of men and materials.

Referring to Figs. 1, 2 and 3 an angle iron  
ring T is provided, riveted on the inside of the shell and forming a connection between  
105 two sections of the shell C. The joint between the vertical face of the angle iron ring T and the vertical adjacent face of the shell C may be calked to make it substantially air tight. The diaphragm bears up against the  
underside of the horizontal side of the angle  
110 iron, a strip of rubber or other packing material U being inserted to make a substantially air tight connection. The diaphragm is formed of cast iron plates V and W flanged and stiffened by ribs. When the  
115 several plates or sections are assembled they constitute a complete circular head fitting loosely the inside surface of the shell. The sections join each other with plain surfaced vertical joints with packing strips between  
120 them, and are attached to each other by means of bolts X passing through vertical flanges of the several sections. The door Y is hinged at one end and supported by one  
125 of the plates W as shown, and will carry the usual packing strips to make an air tight closure. The door and the opening are made with one long axis and one short axis so that the door can be detached and passed through  
the opening. The external shell is erected  
130 at least to the point where the angle iron

ring T is attached. The cast iron blocks B are erected to within a short distance, say six inches, of the angle iron ring. The diaphragm, is introduced into position in separate sections and then introduced under the angle iron ring and there fastened together, resting on the uppermost ring of the blocks B. The packing between these sections may be of red lead or thin paper. This diaphragm fits the shell fairly closely, sufficient clearance being allowed, however, to permit of the assembling of it in place. To facilitate this work and to adjust the relation of the assembled diaphragm to the shell, set screws Z are provided passing through the circumferential flanges of the diaphragm sections. The diameter of the cast iron diaphragm being slightly less than the inside diameter of the shell, an air tight joint must be made by pressing the diaphragm up against the horizontal flange of the angle iron ring T. The angular cross section of this ring is convenient for the making of the vertical joint, but is not essential; a rectangular or other section being entirely practical so long as a suitable lower face is provided for making it tight with the top of the diaphragm. The angle iron or other ring need not be used to join the two plates of the shell C, though it may be conveniently used for this purpose. The air tight joint at the top of the diaphragm is made by setting in place suitable packing and then pressing the diaphragm upward against the ring by any suitable means, such as vertical set screws *a* bearing on the top of the ring of blocks B. Or the set screws *a* might be threaded in the block B and bear up against the underside of the diaphragm; or wedges, or other lifting means may be used. Instead of cast iron any other suitable material may be used for the diaphragm; the diaphragm may be made in any other convenient number of sections instead of the four sections shown and special beams, trusses or other designs may be used to give the diaphragm sufficient strength to carry its own weight and to resist the upward pressure of the air.

Another construction of diaphragm is shown in Figs. 4 and 5. An angle iron ring *b* is riveted within the shell and made tight by calking or packing. Upon this is bolted, also with a packed joint, a plate *c* constituting the diaphragm proper and made of heavy sheet metal and provided with an opening and a door Y similar to the opening and door of the previously described construction. The blocks B immediately below the angle iron ring *b* are chamfered on their outer edges to make room for the angle iron ring. The diaphragm of Fig. 1 is stiffer than that of Fig. 4 and better adapted for larger caissons and higher pressure of air. It has also the advantage of being removable when the concrete is to be placed

within the shell. The diaphragm *c* of Fig. 4 will ordinarily be left in place and be embedded in the concrete of the pier, or may be cut out. In both these constructions the blocks B which rest upon the diaphragm (or upon the ring T) should be provided with means for loosening them similar to the lowermost ring of blocks B which rest upon the cutting edge. In Fig. 4 bolts S identical with those used for the lowermost ring are shown. In Figs. 1 and 3 the blocks B in question are shown with a hollow space *d* into which the heads of the bolts S project, so as to provide easy access to the latter.

The invention is best adapted to caissons of circular cross section, especially in using the pneumatic method. In the case of piers with flat sides the shell would have to be stiffer or better supported than for a circular pier because of the greater tendency of such flat sides to be bent or bowed by the pressures encountered. This necessity for extra stiffness, however, could be avoided to a considerable extent by using oval shafts consisting for example of semi-circular ends connected by flat arcs.

It is not essential to have a separate set of cast iron blocks for each diameter of caisson. Blocks designed for a diameter of three feet high for example may be used in a shell of three and one-half feet in diameter by introducing wooden strips or packing in the vertical joints. The outside surface would not be exactly a true circle but would so closely approximate it that no harm would be done. These vertical wooden packing strips might also be used to fasten the shell to the interior structure by driving nails through the shell and into the wooden strips. Such a construction is shown in Fig. 13 in which the cast iron blocks B are provided with vertical strips *e* of wood in the vertical joints between them and these strips are fastened by nails *f* to the shell. This construction may be used with the steel shell previously described, or it may be used as shown in Fig. 13 with a wooden shell formed of staves or strips *g* bound together in any usual or suitable way and fastened to the strips *e*.

The metal rings described have two functions, stiffness and weight. These two functions, however, may be separately provided for, the removable supporting structure being of comparatively light weight but of sufficient vertical strength to carry extra loads such as weights or jacks on the top which are used in sinking and are withdrawn before withdrawing the supporting structure. For example, instead of the cast iron structure described wooden blocks or a heavy wooden skeleton, or a skeleton or solid structure of metal of other design may be used, either in connection with a shell of steel or with one of wood. Fig. 14 shows

wooden blocks B' in connection with the wooden shell formed of staves *g* fastened to the blocks by nails *f*. The interior structure may also be of masonry, such as concrete previously molded in blocks or rings or molded in place within the shell; such blocks being removable like the structure of metal and wood above described or being left in place within the shell and forming part of the finished pier. This method would utilize some of the advantages of my invention in permitting the use of only the thinnest sort of a shell sufficient, however, to give the necessary tensile strength and to reinforce the internal concrete structure in this respect so that the latter might be made of so small a size as to permit the use of a relatively large shaft in a small caisson. Likewise, the stiffening structure or blocks of iron and wood above referred to might remain in place (the wood only below the water line); but it is generally cheaper in case of metal and better in case of wood to replace them by concrete.

The invention may be very conveniently used in the sinking of telescoping or interior drop shafts, in which a larger shaft is first sunk to a convenient depth and a smaller shaft is carried to a greater depth, being passed downward through the larger shaft. In this case the invention may be utilized for the entire depth or only for the smaller shaft. Likewise in other cases the invention may be utilized in only part of the work. Fig. 15 illustrates such a case. To make more room for the workmen, a working chamber *h* is provided at the lower end from which the removable structure is omitted, and above the working chamber the system of Fig. 1 is followed. The working chamber might be of any usual or suitable construction, being made of heavy three-quarter inch sheet iron for example, where the conditions require only one-eighth inch sheet iron for the upper part of the shell. For pneumatic work the lower door of the air lock may be located at the top of the working chamber as illustrated, or such an enlarged chamber may be continued up to the upper door, so as to give plenty of room for the men in the lock between the doors.

The word concrete is used herein to include reinforced concrete and other kinds of masonry usual or suitable in this class of work.

The chief function of the shell, as above explained, is to keep out water. Under favorable circumstances, as where the work is to be done in substantially dry earth or impervious clay (of the character common in and around Chicago for example), the shell may be dispensed with in whole or in part. The removable structure becomes then simply a form or pattern occupying the

space which is to be subsequently occupied by the concrete of the pier and holding back the surrounding earth so as to maintain the form of the excavation and to preserve a passage through which earth may be removed; being subsequently withdrawn from the bottom up and replaced by concrete extending clear to the surrounding earth. Such a case is illustrated in Fig. 16. Previous borings having indicated a stratum of quicksand or wet earth on top of the rock and dry earth or impervious clay above the quicksand, the construction of Fig. 1 with the shell C and blocks B is used for the necessary height and above that height the shell is omitted. The blocks B of the upper portion are pressed outward against the surrounding earth or clay with sufficient friction to hold them in place and to permit their withdrawal from the bottom up and their step by step replacement by concrete the same as if the shell C were surrounding them.

Where conditions permit, the shell may be omitted throughout the depth of the work, or the blocks without a shell may be extended upward from the top of an ordinary working chamber, like the shell-inclosed structure of Fig. 15; and various other partial uses of this principle may be effected.

Instead of the expansible key block N illustrated a wooden or other wedge may be used.

The pier or shaft constituting the product of the herein described process is not claimed herein, being claimed in a separate application for patent pending concurrently herewith.

The present invention, as above stated, applies in a generic sense to all types of caissons or coffer-dams or so-called "cylinders" including tubes of various cross-sections as used for bridge piers, underpinning cylinders, building foundations and so forth.

The particular construction and mode of applying the invention to joint caissons is claimed in a separate application for patent pending concurrently herewith.

What I claim is:

1. An apparatus of the character described including a structure adapted to be sunk in an excavation and to be built up upon its upper end progressively as the lower end is sunk, and adapted to maintain the excavation of the same cross-section throughout its depth, said structure adapted to be withdrawn and replaced by concrete in sections from the bottom upward.

2. An apparatus of the character described including a structure composed of a series of rings adapted to be collapsed and withdrawn separately and replaced by concrete in corresponding sections from the bottom upward.

3. An apparatus of the character described including a structure adapted to maintain the form of the excavation and to be withdrawn and replaced by concrete in sections from the bottom upward in connection with a thin shell adapted to surround and to be sunk with said structure and to remain in place around the concrete.

4. An apparatus of the character described including a structure adapted to maintain the form of the excavation and having a passage through which excavation may proceed and adapted to be withdrawn and replaced by concrete, in combination with a substantially water-tight shell adapted to surround and to be sunk with said structure and to remain in place around the concrete.

5. An apparatus of the character described including a structure adapted to maintain the form of the excavation and having a passage through which excavation may proceed and adapted to be withdrawn and replaced by concrete, in combination with a substantially air-tight shell adapted to surround and to be sunk with said structure and a diaphragm for maintaining a pressure of air therein.

6. An apparatus of the character described including a structure adapted to maintain the form of the excavation and having a passage through which the excavation may proceed and adapted to be withdrawn and replaced by concrete, in combination with a substantially air-tight shell adapted to surround and to be sunk with said structure and a diaphragm for maintaining a pressure of air therein, said diaphragm being removably fastened in place

7. An apparatus of the character described including a structure adapted to maintain the form of the excavation and having a passage through which the excavation may proceed and adapted to be withdrawn and replaced by concrete, in combination with a substantially air-tight shell adapted to surround and to be sunk with said structure and a diaphragm for maintaining a pressure of air therein, said diaphragm being removably fastened in place, and means for adjusting the relation of the diaphragm to the shell radially.

8. An apparatus of the character described including a structure adapted to maintain the form of the excavation and having a passage through which excavation may proceed and adapted to be withdrawn and replaced by concrete, in combination with a substantially air-tight shell adapted to surround and to be sunk with said structure and a diaphragm for maintaining a pressure of air therein, and a ring attached to said shell with an air-tight joint and which said diaphragm engages with an air-tight joint.

9. An apparatus of the character described including a structure composed of a series of rings adapted to be collapsed and withdrawn separately and replaced by concrete in corresponding sections from the bottom upward, in combination with a substantially water-tight shell adapted to surround and to be sunk with said structure and to remain in place around the concrete.

10. An apparatus of the character described including a shell and a structure therein through which excavation may be effected and which is adapted to transmit the necessary vertical pressure to the lower edge of said shell to sink the same, said structure being removable and replaceable by concrete.

11. An apparatus of the character described including a structure composed of a series of rings adapted to be collapsed and withdrawn separately and replaced by concrete in corresponding sections from the bottom upward, in combination with a substantially water-tight shell adapted to surround and to be sunk with said structure and to remain in place around the concrete, an inwardly extending member connected to said shell and carrying the lowermost of a series of said rings and means for adjusting said lowermost ring downward.

12. An apparatus of the character described including a thin metal shell adapted to keep out water but not alone to withstand the pressures encountered and adapted to be sunk with the aid of vertical pressure, and a series of collapsible rings of heavy metal blocks adapted to brace said shell so as to maintain the form of the excavation and to transmit to said shell the necessary vertical pressure for sinking.

13. The method of building piers and the like which consists in sinking a suitable structure adapted to maintain the form of the excavation, sinking the lower part of said structure and extending its upper end as the excavation proceeds, and withdrawing said structure and replacing it by concrete in sections from the bottom upward.

14. The method of building piers and the like which consists in sinking a suitable structure of substantially uniform cross-section throughout its height and adapted to maintain the form of the excavation, sinking the lower part of said structure and extending its upper end as the excavation proceeds, and withdrawing said structure and replacing it by concrete.

15. The method of building piers and the like which consists in sinking a succession of collapsible rings and withdrawing said rings and replacing them by concrete successively from the bottom upward.

16. The method of building piers and the like which consists in sinking a suitable

structure adapted to maintain the form of the excavation and simultaneously sinking a thin shell around said structure, withdrawing said structure in sections from the bottom upward and replacing it by concrete, leaving said shell in place around the concrete.

17. The method of building piers and the like which consists in sinking a suitable structure adapted to maintain the form of the excavation, excavating through said structure and simultaneously sinking a water-tight shell around it, and withdrawing said structure and replacing it by concrete, leaving said shell in place around the concrete.

18. The method of building piers and the like which consists in sinking a suitable structure adapted to maintain the form of the excavation, and simultaneously sinking an air-tight shell surrounding said structure and provided with a diaphragm, excavating through said structure and under pneumatic pressure, and withdrawing said structure and replacing it by concrete, leaving the shell in place around the concrete.

19. The method of building piers and the like which consists in sinking a suitable structure adapted to maintain the form of the excavation, and simultaneously sinking an air-tight shell surrounding said structure and provided with a diaphragm, excavating through said structure and under pneumatic pressure, and withdrawing said structure and diaphragm and filling the shell with concrete.

20. The method of building piers and the

like which consists in sinking a succession of collapsible rings and a surrounding substantially water-tight shell around them and withdrawing said rings and replacing them by concrete successively from the bottom upward, leaving said shell in place around the concrete.

21. The method of building piers and the like which consists in providing a shell and a suitable structure therein, excavating through said structure and applying the necessary vertical pressure thereto to sink said shell and removing said shell and replacing it by concrete.

22. The method of building piers and the like which consists in sinking a series of collapsible rings adapted to maintain the form of the excavation and a surrounding shell adapted to keep out water but not alone to withstand the pressure encountered, excavating through said rings and transmitting through said rings the necessary vertical pressure for sinking, withdrawing said rings progressively from the bottom upward and introducing progressively from the bottom upward as said rings are withdrawn a body of concrete, so as to leave only a short height of said shell unsupported at any time and to form finally the finished structure.

In witness whereof, I have hereunto signed my name in the presence of two subscribing witnesses.

DANIEL E. MORAN.

Witnesses:

W. W. CORLETT,

D. ANTHONY USINA.