Sept. 8, 1931. J. H. THORNLEY 1,822,550

FOUNDATION FOR BUILDINGS, BRIDGES, AND THE LIKE

Filed Nov. 19, 1926 3 Sheets-Sheet 1

Fig. 1.

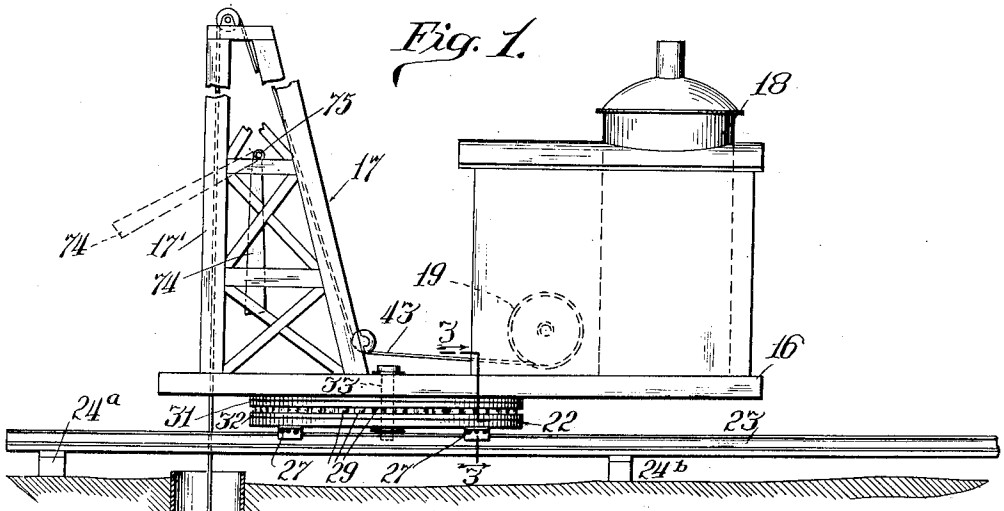


Fig. 5.

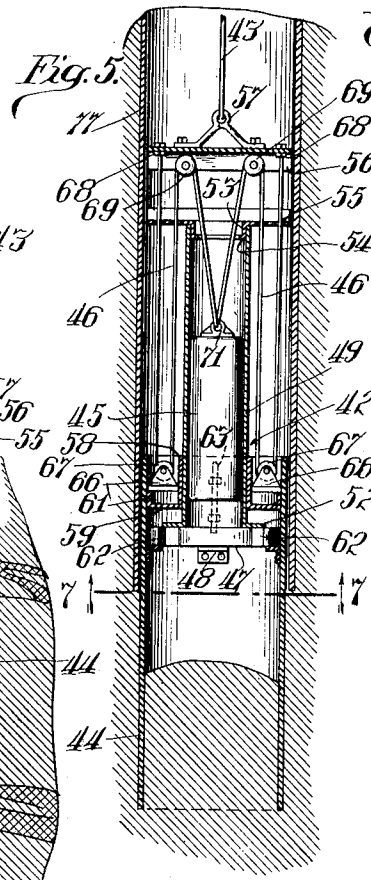
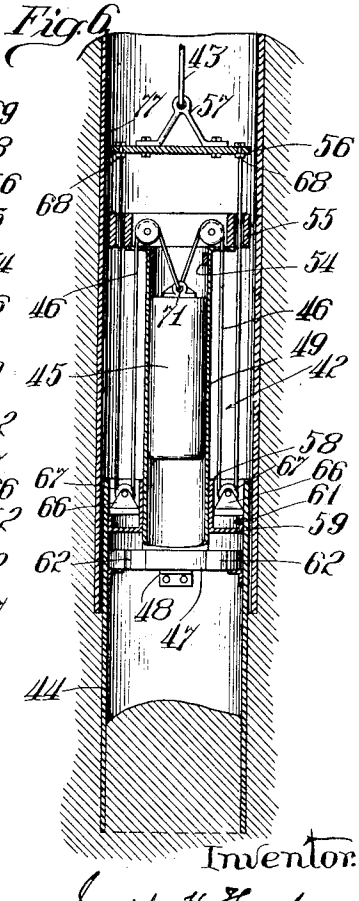


Fig. 6.



Inventor:
Joseph H. Thornley,
John L. Jameson.
By
Attorney

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FOUNDATION FOR BUILDINGS, BRIDGES, AND THE LIKE

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Fig. 2.

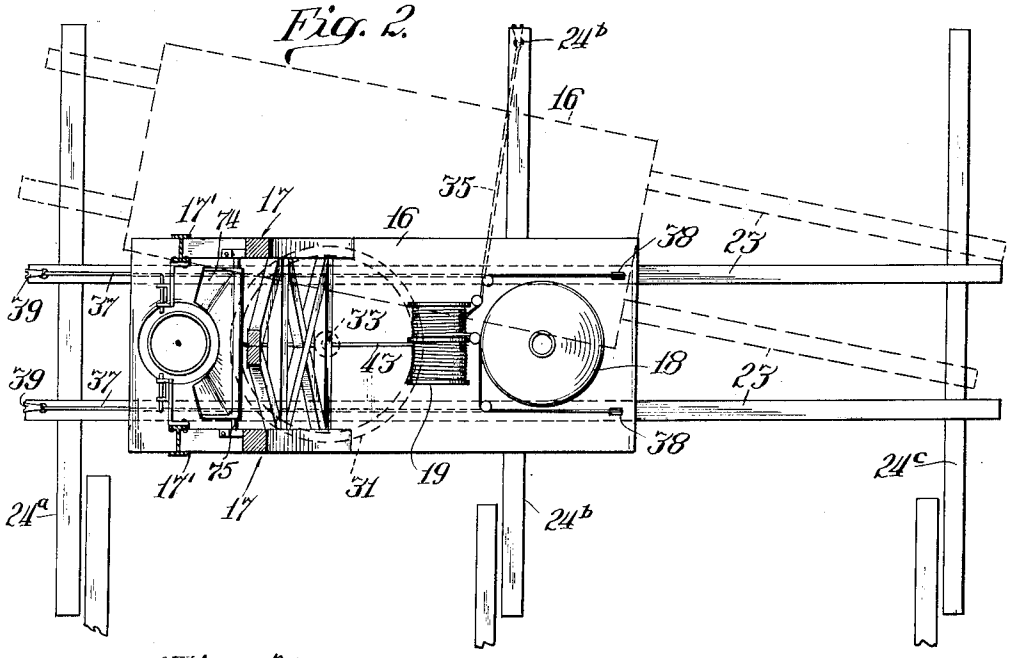


Fig. 3.

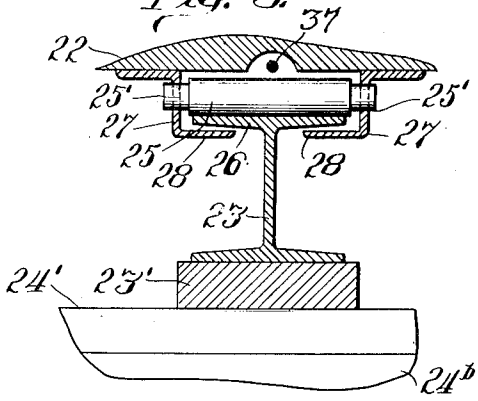


Fig. 4.

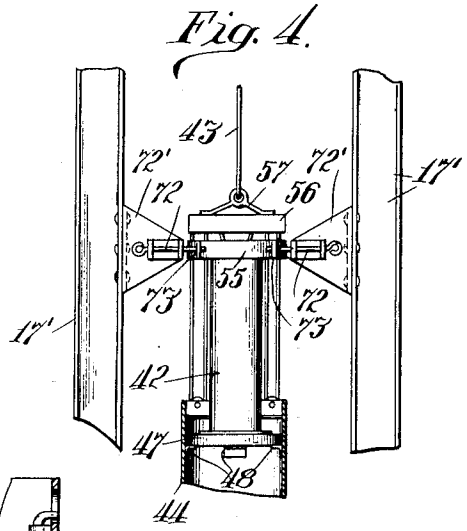


Fig. 7.

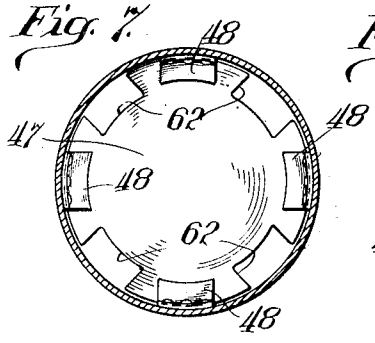
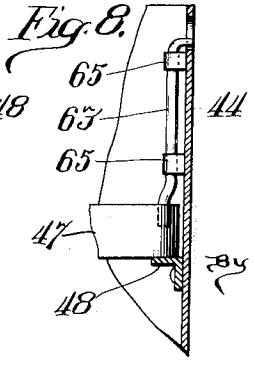


Fig. 8.



Inventor:
Joseph H. Thornley,
By John L. Jewson.
Attorney

Sept. 8, 1931. J. H. THORNLEY 1,822,550

FOUNDATION FOR BUILDINGS, BRIDGES, AND THE LIKE

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Fig. 9.

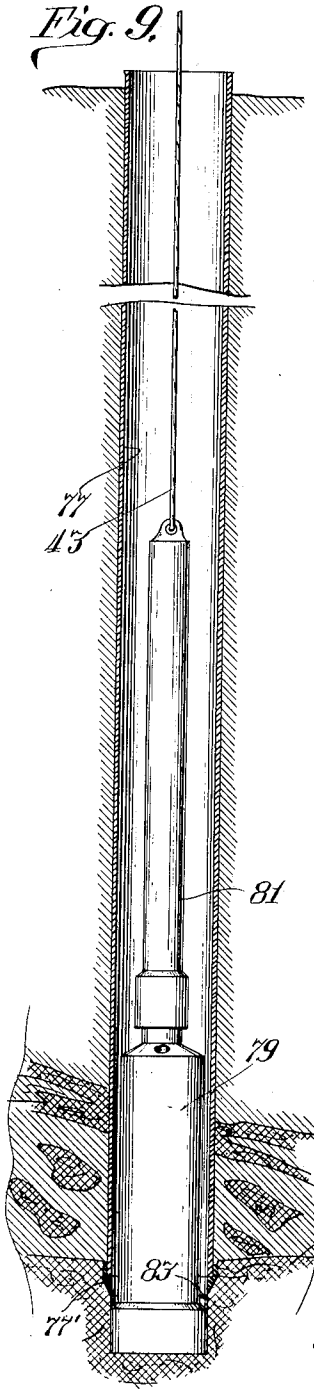


Fig. 10.

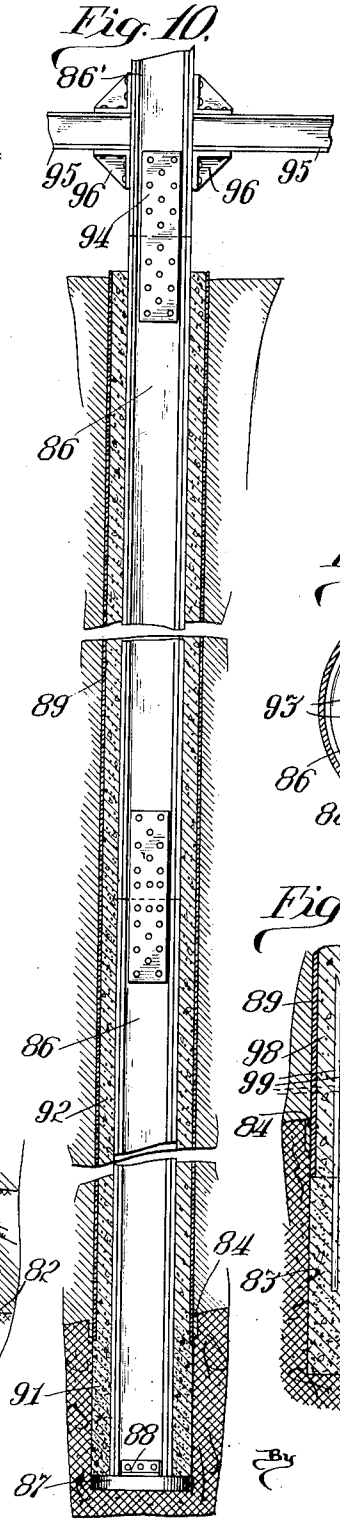


Fig. 11.

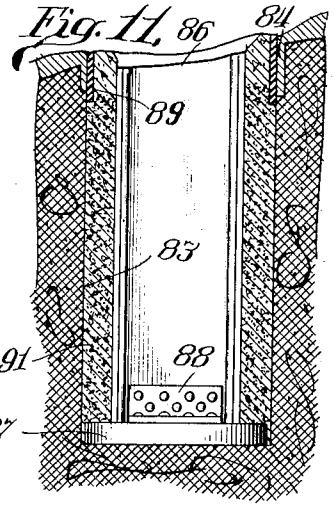


Fig. 12.

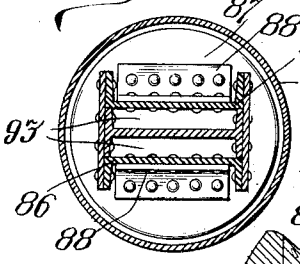


Fig. 13.

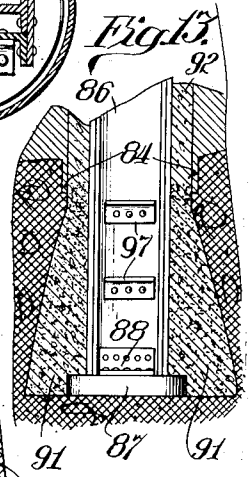
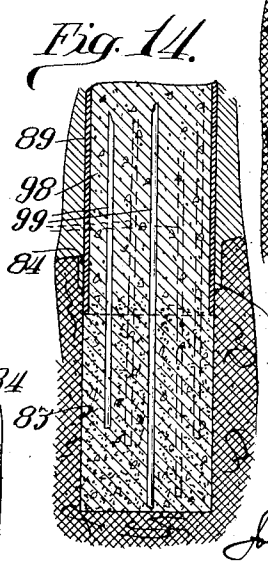


Fig. 14.



Inventor,
Joseph H. Thornley,
John L. Jameson.
By
Attorney

Patented Sept. 8, 1931

1,822,550

UNITED STATES PATENT OFFICE

JOSEPH H. THORNLEY, OF CHICAGO, ILLINOIS

FOUNDATION FOR BUILDINGS, BRIDGES, AND THE LIKE

Application filed November 19, 1926. Serial No. 149,285.

The present invention relates to foundations for buildings, bridges and the like, having particular reference to foundation columns or caissons which are extended down to bed rock or hardpan, or like firm bearing material.

Considered in its broadest aspect, the invention has two general objects: (1) to avoid the great expense and loss of time involved in digging out holes for these foundation columns by manual labor, such object being attained by employing certain new mechanical digging and drilling methods; and (2) to provide an improved foundation structure characterized by numerous advantages such as having the ability to carry tensile as well as compression loads, having a higher load bearing value, and having a load bearing value which can be definitely calculated with all elements of uncertainty removed. The mechanical digging and drilling method has a unique correlation to the improved foundation structure in that this mechanical digging and drilling method makes possible the construction of the improved foundation structure with all of its attendant advantages; and, on the other hand, the improved foundation structure with its attendant advantages makes the mechanical digging and drilling method a practicable and feasible operation.

Referring to the accompanying drawings illustrating the preferred manner of carrying my invention into effect:

Figure 1 is a fragmentary side elevational view of the digging and drilling machine, illustrating this machine engaged in the initial step of digging down through the softer soils lying above the rock strata.

Fig. 2 is a plan view of this digging and drilling machine, part of the tower being shown in section, illustrating the mounting of the machine on the skid timbers which constitute part of the novel supporting means designed to give the machine its ready mobility.

Fig. 3 is a detail sectional view taken on the plane of the line 3—3 of Fig. 1, illustrating the roller mounting of the bed of the machine on its attached track rails.

Fig. 4 is a fragmentary front elevational view of the guide leads of the tower, showing the latch means employed in the operation of dumping the mechanical digging unit.

Fig. 5 is a vertical sectional view through one embodiment of the improved digging unit which is employed in the initial step of digging through the softer soils.

Fig. 6 is a similar sectional view of another embodiment of this digging unit.

Fig. 7 is a transverse sectional view through one of these digging units, taken, for example, on the plane of the line 7—7 of Fig. 5.

Fig. 8 is a detail sectional view, illustrating the releasable locking means employed for holding the digging shell and the slug expelling core against relative rotation.

Fig. 9 is a vertical sectional view, somewhat similar to Figure 1, illustrating the next step of drilling through hard strata and into the bed rock or hardpan by the use of a drilling bit.

Fig. 10 is a vertical sectional view illustrating the completed foundation column.

Fig. 11 is a similar sectional view on a larger scale, illustrating in detail the bonded anchorage of the foundation caisson in the bed rock.

Fig. 12 is a transverse sectional view through the lower part of the column before the concrete has been poured in around the structural member.

Fig. 13 is a sectional view similar to Fig. 11, illustrating a modified construction of foundation caisson, and

Fig. 14 is a similar sectional view of another modified construction of caisson.

The several operations of digging, drilling, lowering the casing sections for casing-off the hole or well and lowering the structural steel column, (where such is employed) require a derrick rig or some equivalent form of tower over the hole for guiding the several operations and for supporting overhead sheave blocks for the hoisting cable and other tackle. Obviously, where a large number of holes are to be sunk at closely spaced points for a plurality of foundation caissons, as in the aver-

age building structure, it is impracticable to erect a stationary derrick for each caisson sinking operation and to then dismantle this derrick for transporting to and re-erecting over another point of digging. To avoid this difficulty I have devised an improved digging and drilling machine wherein all parts of the machine including the tower or derrick, the power plant, the winding drum, etc., are embodied in a single portable unit capable of ready mobility so that it can be quickly swung or shifted to different points on the site.

Referring to Figs. 1 and 2, which illustrate this portable derrick rig, it will be seen that it comprises an upper platform 16, on which is erected the tower 17, the power plant 18 and the hoisting drum and other operating parts 19. This platform has a turntable mounting on a lower frame or bed 22, which in turn has roller support on two parallel rails 23, such rails constituting attached parts of the movable unit. As shown in Fig. 2, the entire unit is supported on heavy timbers 24^a, 24^b, 24^c etc. laid on the ground at spaced points, such timbers serving as skidways on which the two rails 23—23 can be slid either laterally or longitudinally. Referring to Fig. 3, each of the skid timbers is "scabbed" or faced on its upper side with a plank 24′ of oak which is nailed thereto and which has its upper surface coated with grease. The two parallel rails 23 extend transversely of the skid timbers so as to be supported thereon, such rails being preferably constructed as heavy H-beam sections (Fig. 3), although these rails might also be constructed as heavy timbers. The undersides of these rails are likewise scabbed or faced with sections of oak planking 23′ which are suitably secured thereto and which are also greased. The transverse sliding motion of the two rails 23—23 across the skid timbers affords the main lateral adjustment of the machine.

One of the longitudinal adjusting movements of the machine is obtained by arranging the bed or frame 22 to roll lengthwise of the rails 23 on sets of rollers 25 disposed at each end of the frame and bearing on the upper flanges 26 of the rails. These rollers are boxed in between pairs of Z-shaped bars 27 which are bolted to the underside of the frame. The rollers have reduced journal ends 25′ which have bearing support in holes in the vertical web portions of the Z-bars, or in bearing sockets or blocks which may be mounted on the bars to receive these journal ends. The lower flanges 28 of the Z-bars extend under the upper horizontal flanges 26 of the rails, thereby affording a hooked or embracing engagement between the bed and the rails whereby upward or lateral separation of the bed from the rails is prevented. As will hereinafter appear, this embracing engagement between the Z-bars 27 and the rails 23 prevents any possibility of the platform or bed of the machine tipping forwardly relative to the rails under heavy hoisting stresses, which stresses would follow from pulling the driving casing out of the ground.

The platform 16 has any suitable turntable mounting on the bed or frame 22, such turntable mounting comprising, for example, a series of rollers 29 tracking between upper and lower circular rails 31 and 32 secured respectively to the platform and to the frame. A central king bolt 33 passes down from the platform through a suitable bearing secured to the frame bed, and this king bolt may have a collar or nuts engaging thereon below the central bearing to prevent upward movement of this king bolt relative to the bearing in any tipping tendency of the platform. Any suitable arrangement of segment gear and pinion may be employed for rotating the platform 16 on this turntable mounting through power operating mechanism, or cable means may be employed for swinging the platform.

By virtue of the foregoing construction, the machine has swinging movement around the turntable mounting, lateral movement across the skid timbers 24^a, 24^b etc., and a longitudinal movement along the parallel rails 23. Lateral movement of the machine across the skid timbers is effected by taking a hitch to the bed 22 or to one of the side rails 23 and pulling the machine laterally through an arrangement of tackle connected to any fixed point located to one side of the machine. The cable connections indicated at 35 in Fig. 2 are representative of such tackle connections for sliding the machine. The power for operating this tackle may be derived from the cable drum or winch 19 which is mounted on the platform 16. In this lateral movement both rails 23—23 of course move with the bed and platform as a result of the Z-shaped bars 27 embracing the upper flanges of these rails, the latter rails sliding readily over the skid timbers by reason of their greased contacting surfaces. When the desired lateral movement extends beyond the ends of the timbers 24, additional timbers indicated in Fig. 2 are laid alongside the first timbers in overlapping relation so that the movement of the machine may be continued on this second set of timbers. A wide range of lateral movement is also available by pivotally swinging the bed and rails. The dotted line position of the rails in Fig. 2 illustrates this lateral swinging movement, such being obtained by blocking the rails at one end against movement and swinging the other ends of the rails through a tackle hitch as above described.

The longitudinal movement of the bed 22 and platform 16 along the rails 23 may be similarly effected through a tackle hitch extended to any fixed point adjacent the ends of

the rails; or the bed or platform can be jacked along the rails. If a power drive is desired for movement in this direction, such may be obtained by providing toothed racks on the rails 23 in which engage pinions carried by the bed 22 and arranged to be driven from any suitable source of power carried by the machine. When the bed approaches the ends of the rails 23 in the progressive movement of the machine along the line of foundation locations, the rails are slid forwardly under the bed to continue the track structure in the desired direction of travel. This operation is effected by blocking the bed 22 to any stationary point, such as to one of the skid timbers 24, and thereafter applying sliding effort to the rails to cause them to slide endwise across the skid timbers, and relative to the bed. For example, assuming that the bed has been rolled to the right in Fig. 2 so that it is approaching the right hand ends of the rails, and it is desired to continue the drilling operations in this direction, the first step is to block the bed against movement to the left, as by interposing a suitable block or timber between the central skid timber 24^b and any suitable abutment point on the underside of the bed. Thereupon cables 37 are extended from the winch or winding drum 19 out over sheaves 38 at the right hand end of the platform, from whence they are doubled backwardly under the platform for connection to the left hand ends of the rails through hooks or any other suitable attaching devices 39. It will be evident that as the cables 37 are wound upon the drum 19 the rails 23 will be caused to slide longitudinally to the right by reason of the inability of the bed 22 to move to the left. Thus, the rails may be slid progressively across the tops of successive skid timbers laid one after another like the ties in a road bed. By properly timing the shifting movements of the rails 23 with the progressive movement of the machine, the latter may be moved along the drilling line by the use of only three skid timbers 24^a, 24^b and 24^c, the rearmost timber being removed and placed in front in each shifting movement as the rails are slid forwardly, the weight of the machine being carried during the greater part of the time on two of these skid timbers. Obviously, travel in the opposite direction is a mere reversal of these steps.

As before described, owing to the fact that Z bars 27 hook under the flanges 28 of the rails, there is no possibility of the bed tipping downwardly or forwardly at the front end relative to the rails. Thus any tendency for the tower 17 and platform 16 to tip forwardly under the stress of a heavy hoisting load would also require the tipping of the rails 23, which obviously would be impossible owing to the fact that the rails extend forwardly beyond the end of the machine and beyond the vertical line of the tipping load. There is little tendency to cause the tower and platform to tip laterally, but any such tipping tendency is resisted by the weight of one of the rails 23, which is very heavy and which would have to be lifted in such lateral tipping of the machine. Thus, stability of the relatively high tower 17 is assured at all times, even under the relatively heavy loads imposed in the operations of digging, of lowering the structural steel column, and of pulling the casing from the hole after the concrete has been poured. The pivotal turntable movement of the platform 16 relative to the bed 22 also enables the tower to be swung to either side, or to the opposite end of the bed. This enables digging and drilling operations to be carried on at either side of the machine or at either end thereof, which is of advantage for working into and out of corners and up into close proximity to other structures. Moreover, the turntable motion is frequently of great advantage for dumping the slug of soil from the mechanical digging unit into a truck. The several adjustments and movements just described produce a machine having great mobility for manœuvring quickly to different points on the site. The machine can be easily dismantled for transporting from one building location to another. The tower, which can be readily knocked down and re-erected, comprises in the main two vertical I beams 17′ forming the open front of the tower and serving as guide leads between which the several digging and drilling operations are supported and guided. Where the drilling operation is performed by a reciprocatory bit, a walking beam may be employed for raising and dropping the cable, or a tripping clutch mechanism may be associated with the winding drum 19 for this purpose. It will be observed that in the event that a rotary drilling bit is employed, the rig can be securely held through the long rails 23 against the torque of such bit.

The initial operation of digging through the upper strata of loose, soft soils is performed by a digging unit 42 which is preferably operated by a single cable line 43 extending up over a sheave block in the top of the tower 17. As previously described, the digging unit 42 comprises a cylindrical shell 44 having an open lower end which is driven into the soil by the impacting blows of a drop hammer 45 contained within the digging unit, see Figs. 5 and 6. When the unit is operating at the bottom of the hole, up and down movement of the cable line 43 through a limited stroke is operative to raise and drop the hammer. This up and down movement of the cable line may be effected through the walking beam previously referred to, or it may be effected through slip clutch mecha-

nism cooperating with the hoisting drum 19, the latter practice being illustrated.

The hammer is raised and dropped through a pair of cables 46—46 coacting with the single cable line 43 (although, if desired, the line 43 might be connected directly to the hammer 45), and the blows of the hammer on its down strokes are transmitted to the shell through impact means comprising a relatively heavy disk-like plate 47 which reposes within the shell and engages on ledges or shoulders formed by heavy brackets or lugs 48—48 which are secured at different angular points around the interior of the shell. The plate 47 also serves as the head of a ram or core which is adapted to have relative telescopic movement within the shell 44 for expelling the contained slug of soil from the lower end of the shell when the digging unit is hoisted up into the tower for its dumping operation. A cylindrical sleeve 49, of smaller diameter than the digging shell, is secured to the head 47 and serves as a stem for this core or ram, and also as a cylindrical guide within which the hammer 45 is reciprocated. The lower end of the sleeve 49 is secured to the plate 47 in any suitable manner, as by flanging the lower end of the sleeve outwardly and bolting this flange to the plate as indicated at 52. The hammer strikes the plate 47 directly, this plate being of relatively heavy construction to withstand these blows. The upper end of the sleeve 49 is secured to the outer side of a downwardly extending tubular neck portion 53, the lower end of which is flanged inwardly as indicated at 54 to form a limiting stop for limiting the upward movement of the hammer within the sleeve 49. The attaching portion 53 is secured to or forms a part of a transversely extending member 55, similar to a cross yoke or bar. Operating above this cross yoke 55 is a second cross yoke 56, to which is attached the line 43 through any suitable bracket or eye 57.

Secured within the upper end of the digging shell is an annular member 58, the central portion of which is formed as a relatively long tubular guide within which is guided the sleeve 49 of the dirt expelling core. A horizontal flange 59 extends outwardly from the lower end of this tubular guide portion, and an upwardly turned flange 61 extends around the perimeter of the bottom wall 59 and is riveted to the sides of the digging shell 44. The bottom wall 59 forms an upper stop against which the core head 47 engages when lifting the digging unit out of the well. Referring to Fig. 7, it will be seen that the circumference of the core head 47 is formed with a spaced series of notches 62, corresponding in number and size to the driving lugs or brackets 48. In one angular position of the digging shell 44 the solid portion of the core head 47 will engage with the lugs or shoulders 48, at which time the down strokes of the hammer 45 will be transmitted to the shell through these lugs. By rotating the shell to bring the lugs into registry with the notches 62 the digging shell and core can have relative telescopic movement whereby the core head will operate to expel the contained slug of soil from the lower end of the digging shell, such operation occurring when the unit is in its elevated dumping position between the leads of the tower. In order to maintain the notches 62 out of registry with the lugs 48 when the shell is being driven into the ground, a releasable locking pin 63 is mounted in the upper part of the shell for reception at its lower end in a socket or hole in the top of the plate 47, see Fig. 8. This locking pin is guided for vertical movement in brackets 65 carried on the inner side of the shell, and by lifting this pin the lugs 48 may be revolved into registry with the notches 62 for a discharging operation of the core.

Mounted in the upper end of the digging shell, in brackets 66 bolted to the bottom wall 59 of the member 58, are pulleys 67 around which pass the cables 46. The outer ends of these cables are anchored at their upper ends to the cross yoke 56 by any suitable attaching means 68. After passing down around the pulleys 67, the cables are extended up over pulleys 69 which are pivoted to the upper cross yoke 56. This yoke may be of inverted channel formation with the pulleys 69 pivotally supported between the side flanges of such channel. From these pulleys the cables pass down through a central opening in the lower cross yoke 55 and into the core sleeve 49 where they connect to an eye 71 bolted to the upper end of the hammer 45. While I have referred to two cables 46—46, these cables may be sections of a single cable having its intermediate portion passed through the eye 71 or through a sheave connected to this eye. In the construction shown, the two lower pulleys or sheaves 67 are placed at diametrically opposite points relative to the circular form of the digging shell and similarly the two upper pulleys 69 are also placed diametrically opposite for exerting hoisting power on the shell at two diametrically opposite points, but it will be obvious that three or more lower pulleys 67 and a corresponding number of upper pulleys 69 may be grouped at different points relative to the circular form of the digging shell for receiving a corresponding number of cable sections, so as to apply the lifting effort to the digging shell at three or more distributed points.

After the digging and drilling machine has been located with the tower leads 17' over the desired spot the digging unit is started into the soil by making a shallow excavation therein, and thereafter by raising and slacking the cable line 43 the hammer 45 is caused to reciprocate for driving the shell

44 down into the ground. This driving action will occur owing to the fact that the combined weight of the shell 44 and core 47—49 is greater than the weight of the hammer 45. In consequence of this, the upward hoisting movement of the cross yoke 56 will, through the cables 46, transmit a hoisting movement to the hammer 45, the shell 44 remaining in its lower position in contact with the ground. Upon quickly slacking the cable line the upper cross yoke 56 will be dropped, and with it the hammer 45, the lower end of the latter striking the impact plate 47 which delivers the hammer blow to the digging shell 44. As the shell descends into the ground the cable 43 must of course be gradually paid out to properly regulate the stroke of the hammer 45. This stroke is proportioned so that the upper end of the hammer will never strike the upper limiting stop 54 on the up stroke, but on the down stroke the full dropping inertia of the hammer will be effective on the plate 47. After the shell has been driven down into the soil to a depth where substantially the entire interior of the shell is filled by a slug of soil, the cable line 43 is wound up on the hoisting drum 19 for hoisting the digging unit up into the tower leads. Owing to the densely packed condition of the slug of soil within the shell and the frictional contact of this slug with the side walls of the shell, practically the entire slug will be raised with the digging unit. In the hoisting of the cable 43 the hammer 45 of course first moves upwardly into engagement with the upper limiting stop 54, and thereafter the cables 46 establish a direct hoisting connection between the upper cross yoke 56 and the shell 44.

The digging unit is hoisted up to a considerable height in the tower leads, to a point where the lower cross yoke 55 is brought into alignment with two latching bolts 72 mounted on plates 72′ secured to the side surfaces of the tower leads, see Fig. 4. With the cross yoke in proper position the bolts are thrust inwardly by the lead man to engage in eyes or keepers 73 carried on the side of the cross yoke 55. This rigidly locks the yoke against raising, lowering or swinging movements. The locking pin 63 is then raised to releasing position, which frees the shell 44 so that it can be rotated to bring the lugs 48 into registry with the notches 62, the locking bolts 71 operating to hold the yoke 55 and head 47 against rotation in this releasing movement of the shell. By now applying further hoisting movement to the cable 43 the shell 44 is pulled up over the core head 47 in an upward telescopic movement, this naturally following owing to the fact that the cross yoke and core are held against vertical movement by the bolts 71 and hence the tension acting on the cables 46 must pull the shell up over the core. Preliminary to this last hoisting movement of the main cable lead, a chute 74 is swung out of the tower through the open front space between the leads 17′. It will be observed from Figs. 1 and 2 that this chute is pivotally supported at its upper end within the tower on a pivot shaft 75, so arranged that the chute in its normal vertical position will not interfere with the movement of tools, casing etc. between the tower leads. By the operation of any suitable hoisting tackle or other operating means the chute is caused to swing forwardly and outwardly between the derrick leads so that it will extend at a sloping angle below the lower end of the digging unit. Thus the slug of soil expelled from the digging unit will drop into the chute and be deflected forwardly into a truck at the front end of the machine. The swinging turntable movement of the machine also enables the tower to be swung to any angle for dumping into a truck to either side of the machine.

After the dumping operation has been completed and the chute returned to its normal position slack is gradually paid out to the cable 43 with the result that the shell 44 descends down over the core head 47 to bring the latter into its normal position against the stop shoulder 59. This descending movement of the shell will naturally follow as the cable line 43 is paid out owing to the fact that the shell 44 is heavier than the hammer 45. After the head 47 engages the stop shoulder 59 the shell is revolved to bring its lugs 48 under solid peripheral portions of the head 47, whereupon the locking pin 63 is dropped down to locking position to retain this angular relation between the core and shell. Thereafter the bolts 71 are released and the digging unit is again lowered into the hole for a continuation of the previously described digging operation.

Fig. 6 illustrates a modified form of digging unit of the same general construction as the one just described. In this modified form, however, the pulleys 69 are mounted on the lower cross yoke 55 instead of on the upper cross yoke 56. The hammer is reciprocated by alternately hoisting and dropping the cable 43, and the lower cross yoke is held in the tower leads by the bolts 71 during the dumping operation, substantially as described of the preceding embodiment. It will be observed that in these two embodiments all of the operations are performed by a single cable line 43, and such construction is preferable. However, it is also within the purview of the invention to employ two cables, one for reciprocating the hammer and one for raising and lowering the shell.

As the digging of the hole progresses, it is desirable to "case-in" the hole by sections of casing 77, this casing being of larger diameter than the digging unit 42 to permit the latter to pass therethrough. The provision of the tower and tower leads 17′ is of par-

ticular advantage for performing this casing-in operation, as the casing sections can be supported and accurately guided between the tower leads as the casing is being extended down into the hole. It is preferable that the lower end of the casing follow the descent of the digging unit 42 quite closely so that the digging shell in its gradual descent will always be within the guiding confines of the casing. Any excess sub-surface water accumulating in the bottom of the hole during the aforesaid digging operation can be bailed out by a standard bailer, such as is used in well drilling practice, or can be exhausted by a sand pump, as is well known in the art. The presence of the casing 77 will in most instances case off the hole against excess water.

When stony and other hard strata are encountered the operation of the digging unit 42 is discontinued and a drilling bit is employed to continue the operation down through these harder strata. This drilling operation may be performed either by a rotary bit or by a reciprocating bit, the latter practice being preferable, however, in view of the fact that the mechanism embodied in the digging and drilling machine for raising and slacking the cable for the digging unit 42 is also admirably suited to the operation of a reciprocating bit. In Fig. 9, illustrating this next drilling step, I have accordingly shown a reciprocating bit 79 connected to a stem 81 which in turn is hitched to the cable line 43. The bit is preferably of the same cutting diameter as the digging unit 42, and may be of any desired type.

When actual bed rock is encountered, such bed rock being indicated at 82 in Fig. 9, the drilling operation is continued down therein to a considerable depth to form a deep socket or recess 83. The broken up rock materials resulting from this drilling operation can be readily removed by bailing practice, or possibly by a sand pump, and it will be evident that this spoils material can be loaded into a truck and dumped therefrom without difficulty because there is practically no tendency for this material to agglomerate into a solid mass. After the socket has been cut out to the desired depth, the heavy casing 77 is driven down into the rock around the upper marginal edge of the socket. The casing is usually provided at its lower edge with a heavy annular shoe 77′ which is capable of being driven into the rock. As an alternative practice, the relatively shallow marginal recess for receiving the casing may be formed by an undercutting or reaming bit. This recess is indicated at 84 and it will be observed that it need only be sufficiently deep to effect a seal with the casing 77 for sealing off the subsurface water which almost invariably prevails just on top of the rock stratum. After this seal has been completed the hole and the socket 83 are pumped substantially dry. The socket is then prepared for receiving the lower end of the structural steel column by pouring in a small quantity of grout or a rich mixture of concrete which will form a uniform footing for the column across the bottom wall of the socket. The steel column indicated at 86, is then lowered into the hole, before this grout has had an opportunity to set so that the latter will distribute itself under the base of the column.

The steel column is intended to carry practically all of the load sustained by the foundation caisson and hence is of very heavy construction. As shown in Fig. 12, the column consists of any standard built-up structural shape. The considerable depth of the foundation hole will, in most instances, preclude the handling and setting of a steel column that has been previously constructed in its entirety. Hence, it will be necessary to lower the column in successive lengths or sections, and to bolt or rivet the adjoining ends of these sections together as they are being lowered into the hole. For this operation the presence of the digging and drilling machine with its tower leads 17′ is of great advantage, the successive sections being held in accurate alinement between the leads for the bolting or riveting operations and being gradually lowered as successive sections are joined.

Referring to Fig. 11, the lower end of the bottom section has secured thereto a relatively wide, circular base plate 87 through which the pressure imposed on the steel column is distributed across the entire bottom wall of the socket 83. The several structural shapes of the column are cut off flush so that they will all bear directly on this pressure plate, the latter being attached to the column by angle brackets 88 riveted to the column and to the plate. The small quantity of grouting which has been previously poured into the bottom of the rock socket 83 will fill all crevices in the bottom wall of the socket as the column comes to rest therein, thereby providing a firm footing distributed across the entire bottom surface of the plate.

When the entire column has been placed in the hole a light shell or casing 89 is lowered within the heavy outer casing, such inner shell being of inexpensive light gage metal. The several sections of this inner shell are also riveted or otherwise joined together between the tower leads as they are being lowered into the hole. This inner shell is supported in the hole with its lower end terminating just within the top of the socket 83 or in proximity thereto, so that it does not cover or line the side walls of the socket.

Thereupon a quantity of concrete 91 of a relatively rich mix is poured into the socket completely to fill the intervening space between the lower part of the steel column and the side walls of the socket. If desired this

batch of concrete can be poured into the socket before the inner shell has been lowered so that when the latter is lowered the bottom edge thereof will be partly supported on this filling of concrete.

The inner shell having been lowered and the mass of bonding concrete 91 having been poured to fill the socket, a large quantity of concrete 92 is then poured into the inner shell to fill the entire length of the shell in the space intervening between the shell and the column. This latter mass of concrete may be of relatively lean mix, as its principal purpose is to form a waterproof, protective sheath around the upper portion of the steel column and to reinforce the inner shell against the lateral pressure of the earth walls. The presence of the heavy drive casing 77 around the inner shell or casing amply protects the latter against the outward pressure of the mass of concrete being poured therein and against the inward pressure of the earth walls. After the inner shell has been completely filled, the outer casing is withdrawn by pulling the same upwardly through the use of hydraulic jacks or through hoisting tackle supported in the tower. The presence of subsurface water will be of no deleterious effect at this stage because the entire socket and hole is filled with concrete. Before this concrete has set the projecting upper end of the steel column is accurately spotted with reference to certain datum points, the plastic condition of the concrete permitting the steel column to be tilted slightly, if need be, for such positioning of the upper end. The spaces 93 between the structural shapes of the steel column (Fig. 12) may be completely filled with concrete, if desired, during the pouring of the outer sheathing 92, but I deem it preferable to leave these spaces open and to merely close the upper ends thereof by suitable plugs cemented therein, such plugs preventing the entrance of moisture into the spaces from the upper end of the column.

After the several structural columns have been set in the manner above described, their projecting upper ends are joined to the above-ground steel structure of the building, bridge or the like to be supported thereon. For example, in Fig. 10 I have shown the steel column 86 continued upwardly as a part of the above-ground superstructure, the latter being typified by the superposed column section 86′ secured to the foundation column 86 by splicing plates 94, and by the horizontally extending beams 95 which are secured to the column section by gusset plates 96. Thus the structural steel columns of the foundation become a unitary part of the steel framework of the building, whereby the superstructure above ground and the foundation structure below ground are directly joined in a unitary all-metal construction. This all-metal construction from bed-rock up avoids differential expansion and contraction of different materials; and the same modulus of compression and tension exists throughout the entire structure. In lieu of the splicing plates 94, horizontally extending attaching plates may be secured to the ends of the column sections 86 and 86′ for connecting these column sections together.

The light shell 89 may be dispensed with if desired, leaving the protective sheathing of concrete 92 in direct contact with the earth walls of the hole. Fig. 13 illustrates such a construction. This sheath of concrete is poured while the heavy outer casing 77 is in place, the latter holding the side walls of the hole against collapse during the pouring operation and being withdrawn before the concrete has set. It is opportune to remark at this point that while the protective sheathing of concrete 92 is perhaps the preferred method of waterproofing the outer surface of the structural steel column, other methods may be employed if desired. For example, that portion of the steel column extending upwardly above the socket 83 in the bed rock may be coated with pitch, tar or like protective material, in which event the concrete sheathing 92 may be omitted. That portion of the column extending down into the socket is not coated with such material, however, in order that the concrete 91 in the socket may effect a cementitious bond directly with the steel of the column.

Fig. 13 also illustrates another modification in the finished foundation. If desired, the socket 83 may be drilled out with a downwardly and outwardly flaring taper, which increases the effective wall area of the socket for cementitious bonding, and also increases the tensile strength of the caisson by reason of the wedge shaped end of the footing. This tapered form of socket may be obtained through the use of a reaming or undercutting bit; or, where the hole is of sufficiently large diameter to permit lowering a man it may be chipped out after the drilling of the cylindrical socket. The formation of this tapered socket is best adapted to hardpan and like firm bearing materials. The top surface of the base plate 87 and the heads of the rivets which join the structural shapes of the column, form a plurality of projecting ledge surfaces against which the bonding concrete 91 can bear in compression and tension. If desired, angle brackets 97 or like projecting members may be riveted to the steel column just above the base plate 87, the upper and lower surfaces of these brackets forming additional shoulders or ledge areas against which the bonding concrete 91 bears in tension and compression.

In some instances it may be desired to obtain the advantages of the socketed anchorage of the foundation in a less expensive construction of caisson where the structural steel

column 86 is omitted. Fig. 14 illustrates such a construction. The caisson is then formed as a solid concrete column 98 reinforced by rods or bars 99. These rods or bars are extended down into the socket 83, preferably to varying depths therein substantially as shown. The concrete in this instance is a load bearing medium and also a bonding medium for transmitting tension and compression loads from the reinforcing bars to the walls of the socket. This construction of caisson may include the light inner shell 89, as shown in Fig. 14, or such shell may be omitted as shown in Fig. 13.

As previously remarked, in each of the foregoing constructions the load bearing value of the caisson can be increased to any desired degree by merely extending the socket down to greater depths in the rock; which increases the area over which the load in bond is transmitted. The anchorage of the caisson in rock results in the rock serving as a pedestal base of indefinitely large area for the lower end of the caisson. The drilling of the socket in the bed rock also uniquely cooperates with the use of the structural steel column 86 in that it avoids the necessity of special make-up sections etc. If the lower end of the column had to rest on the top of the rock stratum, the surface of which is generally uneven and which is formed at varying depths, the several sections of the steel columns could not be ordered in advance and it would be necessary to have on hand a wide variety of make-up sections of varying lengths to take care of varying lengths of columns. In the present instance the socket in the rock can be drilled slightly deeper to bring the upper end of the topmost section to an exactly predetermined height for joining to the above-ground superstructure.

It will be seen from the foregoing that the present method of mechanically digging and then drilling into the bed rock makes possible the socketed anchorage of the end of the foundation caisson in the bed rock, which in turn, by virtue of the greater load bearing value which is thus given the caisson, enables a caisson of smaller cross sectional area to be employed without diminishing the total load bearing value of the foundation. The ability to employ caissons of comparatively small diameter reduces the required size of the drilling bit and other drilling equipment so that, considered conversely, this ability to carry the same or even greater loads on a foundation caisson of smaller diameter makes the use of the present mechanical digging and drilling method practicable. That is to say, in order to avoid the necessity of special drilling equipment of extremely large and cumbersome sizes it is desirable that the hole be kept within diameters such as are drilled in standard oil and water well drilling practice. In this latter field, standard equipment can be obtained for drilling holes up to approximately 24 inches in diameter. Tool equipment for diameters much in excess of this must be made special and the drilling rig and all associated parts become very large and cumbersome, which is particularly objectionable in the present field of operations where ready mobility of the drilling rig and the ability to maneuver into and out of corners etc., are essential characteristics. By reason of a greater load bearing values of the present foundation caissons, resulting from their bonded anchorage in the bed rock, I am enabled to confine these caissons to diameters approximating 24 inches, thereby permitting the use of standard bits, bailers and other well known drilling equipment. While the performance of a reciprocating drilling operation is preferable because it lends itself more readily to use with pile driver derricks generally used in these foundation operations, it will be understood that a rotary drilling operation may be performed.

Heretofore, the practice of cutting into a rock surface by manually operated tools and by manual labor within the cramped space at the bottom of a caisson hole involves such difficulties that the sinking operation is usually discontinued at the surface of the rock. Furthermore, the difficulty of cutting into the rock surface by manual labor is almost always aggravated by the presence of subsurface water directly above the rock surface, frequently in quantities which it is practically impossible to exhaust.

The present drilling operation is intended primarily for drilling into the bed rock but obviously it can be employed at any stage in the initial operation of digging with the mechanical digging unit, as when certain strata and soil conditions are encountered which are difficult to penetrate or handle in the mechanical digging unit. While the entire hole might be sunk by a drilling operation such as has been described, the difficulties incident to handling the spoils or waste material from such drilling practice makes the adoption of this latter practice objectionable for penetrating through the softer soils, as I have briefly referred to before. That is to say, the removal of the drilled and churned up material in a drilling operation is effected by the well known bailing method, which necessarily requires the presence of a large quantity of water for sweeping the material into the bailer at the bottom of the hole. In constructing foundations for buildings and other structures in congested localities, it is necessary that the excavated material be transported away from the site in dumping trucks or wagons. It will be evident that great difficulties would arise in transporting in such manner the churned up material ex-

cavated by the drilling operation, particularly when drilling through clays, etc. The dumping of a bailer of churned up clay and water into a truck would result in the clay settling into a relatively solid mass which would be extremely difficult to discharge from the truck. It will furthermore be evident that the use of a settling basin on the site of a building structure would be impracticable. These difficulties are avoided by the present mechanical digging method, which removes the material in a comparatively dry state, in which condition it can be readily handled in a truck and discharged therefrom. The sub-surface moisture of these soils will be sufficient to enable the soil to pack firmly in the digging shell for hoisting the soil therein in slug formation, but will not be present in the excavated material in quantities which would render difficult the handling of the material in the dumping trucks, etc. As above stated, the drilling bit will be used primarily for cutting through stones, boulders, and down into the bed rock, and the spoils materials resulting from these operations can be dumped from the bailer into the dumping truck without such materials tending to agglomerate into a solid mass in the truck.

The principal object in drilling the socket down to a considerable depth in the bed rock or hardpan is to afford a cemented bond between the caisson and bed rock which will carry a much higher compression load and also a very high tensile load. Moreover the drilling of this socket to a considerable depth also serves the useful purpose of conclusively indicating when bed rock is encountered. For example, in some instances a rock surface may be encountered which may be the surface of a large boulder or a thin stratum of rock located considerably above bed rock. With the prior hand digging methods there is no way of determining conclusively whether this is bed rock or a mere upper stratum or boulder and even where this is known the expense of continuing the excavating operation down through the rock stratum or boulder is generally prohibitive. As a result the finished foundation rests on a stratum of uncertain load bearing value. By the present practice, however, the drilling of a socket several feet deep into the rock surface will conclusively indicate if this rock surface is a mere superimposed stratum or is actual bed rock or hardpan.

The bonded anchorage of the steel column in the bed rock enables the inherently high modulus of compression and tension of the structural steel column to be utilized to the utmost. The first load bearing factor is the very heavy pressure which can be transmitted directly from the lower end of the steel column to the bottom wall of the socket in the rock. The second load bearing factor is the considerable pressure which can be transmitted laterally from the sides of the steel column to the sides of the socket through the adhesive bond of the concrete uniting these surfaces. It will be evident that this latter load bearing factor can be increased to any desired value by merely drilling the socket sufficiently deep, which will increase the areas over which the concrete bond is effective. This concrete bond also serves the very important function of reenforcing the bed rock against failure in an upward direction. Such failure may occur by an upheaval or upward spalling of the rock, when subjected to extremely high compression stresses. Obviously, the concrete bond with the side walls of the socket will react against stresses in the rock tending to cause failure in this direction. Tensile strength, something which has heretofore been practically non-existent in the caisson type of foundation, is also realized to a high degree in the present foundation, owing to the bonded anchorage of the caisson in the bed rock and to the very high modulus of tension of the structural steel column. This tensile strength is of considerable importance in high building structures where the windage stresses are considerable.

It will be evident that because there is no necessity of lowering a man to the bottom of the hole, and therefore no necessity for employing compressed air caisson practice, the present invention is admirably adapted to marine work.

While I have shown what I consider to be the preferred manner of carrying out my invention I do not consider the invention limited to the details of this specific disclosure, but on the contrary, through wide acquaintanceship with existing methods of constructing foundations, I regard the invention, or certain aspects thereof, as a pioneer step in the art.

What I claim as my invention and desire to secure by Letters Patent, is:—

1. A building construction comprising the combination with the steel framework of a building of a load sustaining column forming an extension of the frame to bed rock, the rock having a socket in which the lower end of the column is seated, and a cement filling in the socket, the cement filling engaging the column and the sides of the socket to anchor the column in the rock against tension.

2. A building construction comprising the combination with the steel framework of a building of a tubular casing extending from the surface to bed rock, there being a socket in the rock of a diameter substantially equal to that of the casing and communicating directly with the lower end of the tubular casing, and a load bearing column of substantially uniform section throughout forming an extension of said steel framework dis-

posed in said casing and socket and being anchored by cement to said socket to sustain either tension or compression on the column.

3. A building construction comprising the combination with the steel framework of a building, of a load bearing column forming an extension of the said framework, there being supporting bed rock having a socket therein, a tubular casing extending from the socket to the top of the ground, said column extending through said tubular casing and having a pedestal on its lower end resting in the socket and forming an extended footing for supporting compression on the column, and a cementitious filling for the socket and the casing, the cement filling in the socket engaging the column and the sides of the socket to anchor the column in the rock, said pedestal increasing the anchorage of the column in the rock for tension on the column.

JOSEPH H. THORNLEY.