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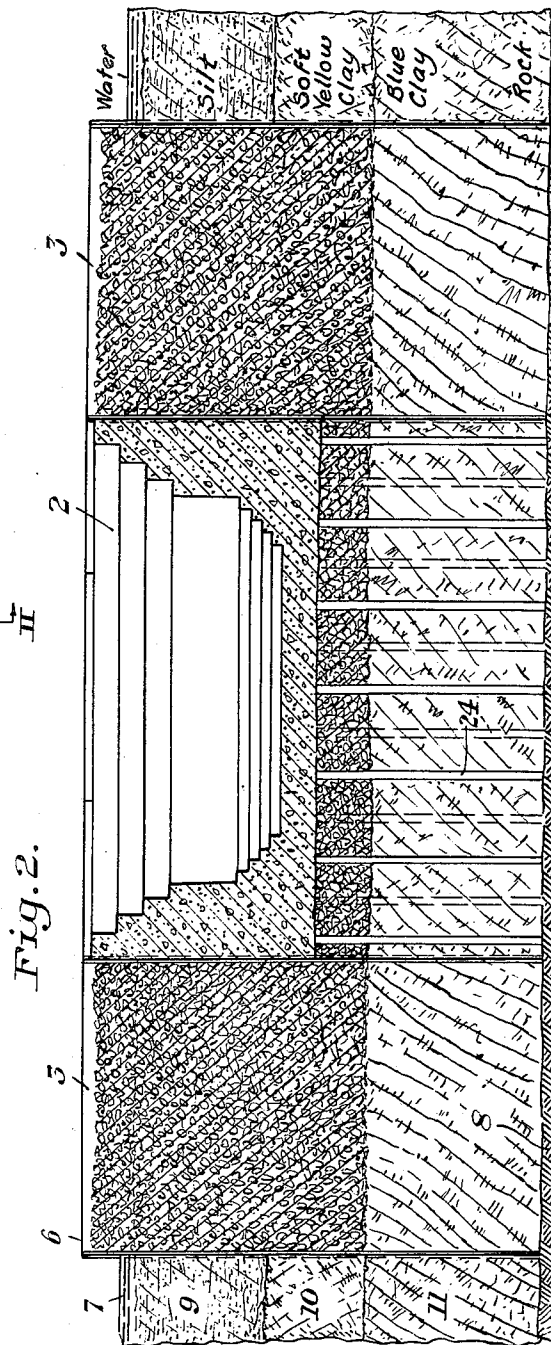
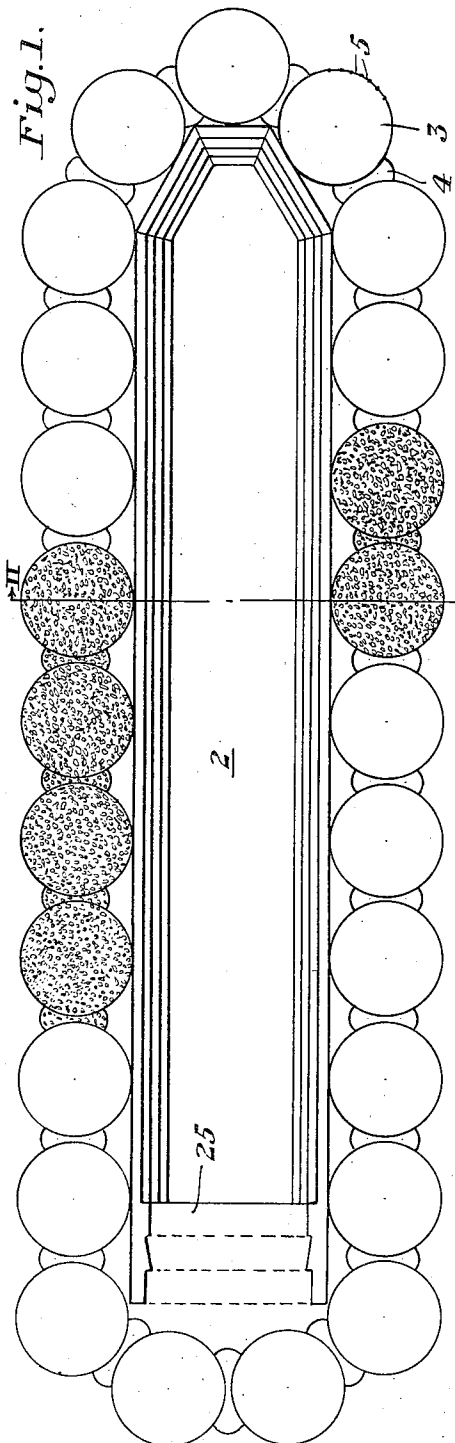
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2,101,358

METHOD OF MAKING LOAD SUSTAINING STRUCTURES

Filed May 28, 1937

3 Sheets-Sheet 1



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Fig. 3.

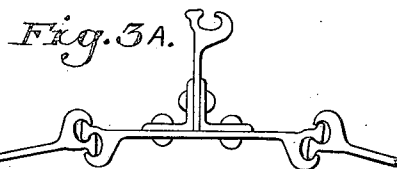
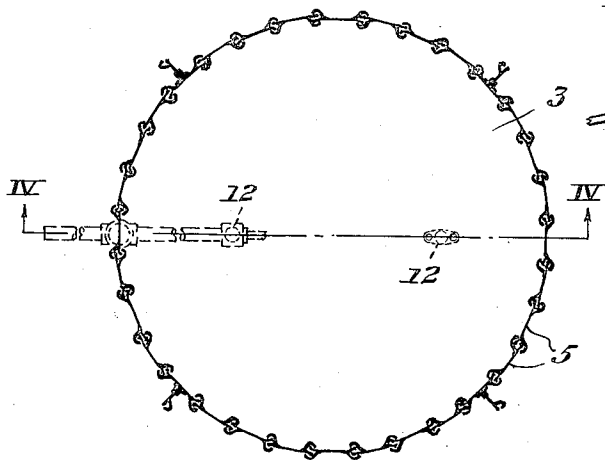


Fig. 5.

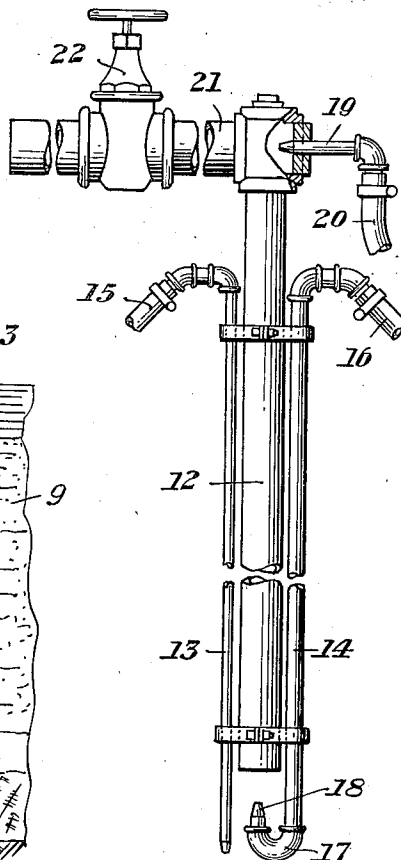
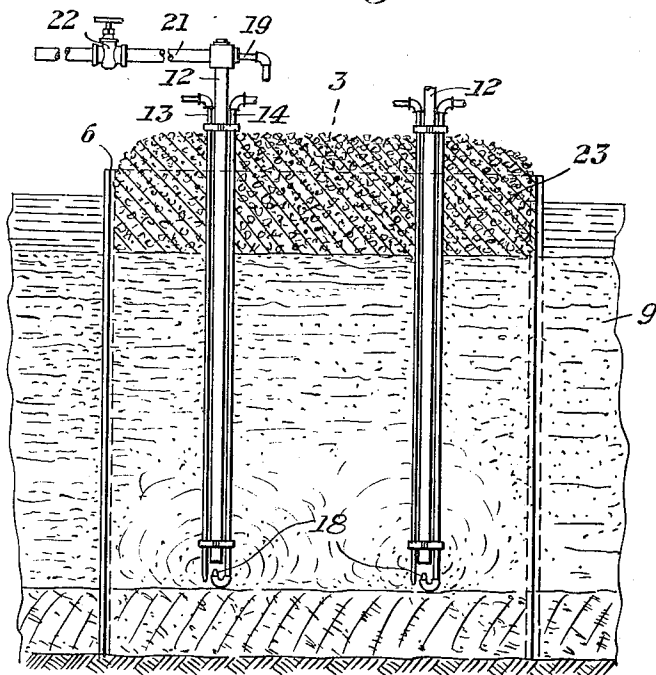


Fig. 4.



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Fig. 6.

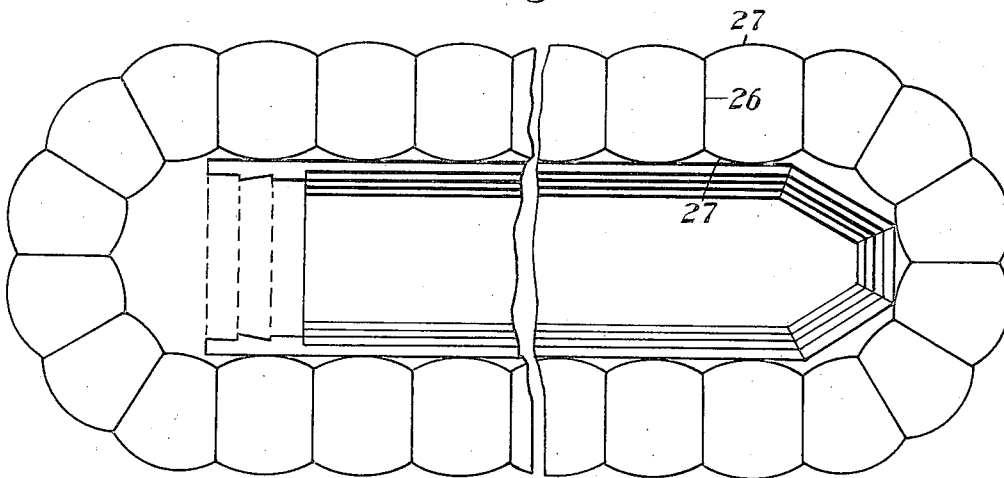


Fig. 7.

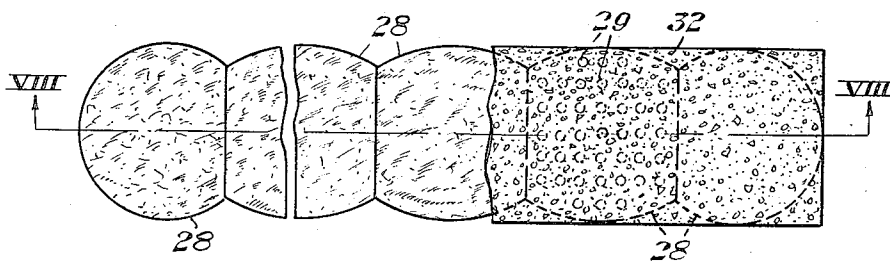
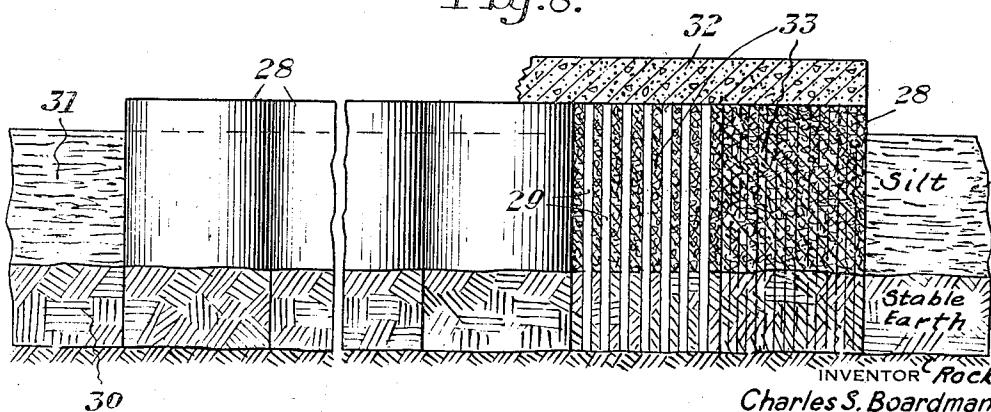


Fig. 8.



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UNITED STATES PATENT OFFICE

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METHOD OF MAKING LOAD SUSTAINING
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9 Claims. (Cl. 61—50)

This invention relates to load sustaining structures in earth and a method of making the same. It is of particular value in the making of piers, coffer-dams, docks, lockwall and other structures in places where there is a layer of unstable earth, for example, silt or quicksand, over the load-bearing substratum. When such conditions are encountered ordinary methods of construction require that the walls of the structure be extensively braced in order to withstand pressure of the silt, or other unstable material outside the walls while the work within the walls proceeds. This bracing is not only expensive in itself but seriously interferes with the work at hand and increases the cost of the whole operation. Another difficulty is encountered where it is attempted to support structures over earth of the character above mentioned on load bearing piles which are driven into the substratum. If the overlying unstable ground is of any substantial depth the piling finds but little lateral support therefrom and consequently the structure is weak in its resistance to lateral forces. These forces may be very great in the vicinity of tide water or if the superstructure is subjected to wind loads.

All of the foregoing difficulties are overcome by my improved structure and method of making it. Stated in brief terms, I provide for sinking a "cell" or cells from the surface into the substratum as for example by driving interlocking steel piling and removing the earth above the substratum from within the cell and substantially simultaneously charging material, such as broken stone, into the cell to replace the removed earth, thus balancing the pressure which the surrounding earth exerts upon the walls of the cell and preventing its collapse. As indicated, the cell may be made of sheet piling and internal bracing may be partially or entirely dispensed with. If desired, the cell may be surcharged with the material so that it exerts a pressure in excess of the pressure exerted by the surrounding earth. The effect of the surcharging is to lock the joints in the piling substantially to water-tightness. The unstable earth within the cell may be removed in various ways, but I prefer to use an hydraulic jet system employing jet excavators which extend downwardly into the cell and which may be withdrawn through the charged material.

In the making of a coffer-dam a series of cells will be employed, they being connected together to form a continuous structure. A series of cells so arranged in a closed loop will constitute a highly satisfactory coffer-dam and all structures

of the sort which I contemplate may be installed at a comparatively low cost.

In cases where it is desired to drive load bearing piles into the substratum a cell or cells of the character above described may be formed and the piles driven through them. A great advantage of this construction is that any lateral force exerted on the piles, as, for example, by reason of a wind load, will be distributed through the charged material in the cell to the cell wall, but instead of the pressure being concentrated against the silt or other unstable surrounding earth, it will be distributed over the wide expanse of area afforded by the submerged sides of the cell and can be successfully resisted by the surrounding earth.

If desired the divided material which is charged into a cell may be made substantially monolithic by forcing a binder, such as cement or sulphur, into the interstices.

In the accompanying drawings illustrating certain preferred embodiments of my invention,

Figure 1 is a top plan view of a coffer-dam;

Figure 2 is a transverse section on the line II—II of Figure 1;

Figure 3 is a top plan view to enlarged scale of one of the cells;

Figure 3-A is a top plan view to still further enlarged scale showing interlocking sections of the sheet piling;

Figure 4 is a vertical section on the line IV—IV of Figure 3 showing the preferred method of removing the unstable earth within the cell;

Figure 5 is a view to larger scale and partly broken away showing the hydraulic device employed for removing the earth;

Figure 6 is a view corresponding to Figure 1 but showing a modified cell structure;

Figure 7 is a top plan view showing a structure embodying load bearing piles; and

Figure 8 is a vertical section on the line VIII—VIII of Figure 7.

Figures 1 and 2 show a coffer-dam for a dry-dock indicated generally by the reference character 2. The coffer-dam consists of a series of 25 cylindrical cells 3, connected by bulwarks 4, thus to form a closed loop defining the space in which the dry-dock 2 is to be built.

In Figure 2 I have illustrated two of the cells in section. The cells 3, as well as the bulwarks 4, are made by driving interlocking sheet piling sections 5, as more clearly shown in Figure 3. One of the special piling sections used for connecting the bulwarks 4 to the cells 3 is shown in Figure 3-A. Figure 2 shows the cells extending from a top level 6 above the normal water 55

level 7 of the body of water adjacent which the dry-dock is to be built, and extending down to rock or hardpan 8. I have shown the cell extending through a layer of silt 9, a layer of soft yellow clay 10 and a layer of blue clay 11.

The problem, of course, is to provide a coffer-dam which will permit of excavating for building the dry-dock 2. If it is attempted to unwater the construction space defined by the coffer-dam and then digging out the undesirable material therewithin, while leaving the silt within the cells 3, the coffer-dam will lack the structural strength required to overcome the pressure of the surrounding water and silt. In order to overcome this difficulty I proceed in the manner indicated in Figures 3, 4, and 5. Figure 5 shows an hydraulic excavator consisting of a central discharge tube 12 carrying jet pipes 13 and 14 and adapted to be sunk into the earth which is to be removed. The jet pipe 13 is connected to a source 15 of water under pressure and the jet issuing from the pipe 13 is directed downwardly and serves to loosen the earth around the foot of the pipe 12 and to make it relatively easy to dig downwardly. The jet pipe 14 is connected to a source 16 of high pressure water and is provided with a U-joint 17 at the bottom so that its jet 18 is directed upwardly into the pipe 12. This jet entrains the loosened earth and carries it to the top of the pipe 12 where a third jet 19, connected to a source 20 of water under high pressure, directs it into a discharge pipe 21. A valve 22 is provided in the discharge pipe 21, which valve may be closed during the preliminary digging and placing of the tool, thereby to prevent ingress of material into the pipe 12 in amounts sufficient to plug it before the actual removal of earth begins.

In Figures 3 and 4 I have shown two digging tools of the type illustrated in Figure 5. The number used in any particular case will of course depend upon the size of the cell and the desired rate of removal of earth from therewithin.

When the digging commences a charge of divided material, preferably broken stone, as indicated at 23 in Figure 4, is placed in the cell and on top of the earth to be removed. As the digging tools of Figure 5 continue to function and remove the undesirable earth from the cell, the divided material 23 moves downwardly by gravity and replaces it, additional material being charged on top as required.

The divided material in the cell exerts an outward pressure sufficient to prevent the cell from collapsing. In Figure 4 I have shown the cell surcharged with such material so as to provide an internal pressure which exceeds the external pressure. This is desirable in that it places the sections of sheet piling in tension, thus insuring joints having a substantial degree of watertightness and eliminating the necessity for any substantial amount of caulking. It will be understood that the surcharge does not necessarily extend above the top level 6 of the cell so long as the material is present in a sufficient amount to provide a pressure which exceeds the external pressure.

The digging will be continued until the soft and unstable material in the cell has been removed. Indeed, the ability of the hydraulic excavators to remove material is a measure of the character of the earth remaining in the cell, and when the excavators no longer function to remove it the cell will generally be stable and if properly designed will resist the external forces

without danger of collapse. The excavating devices may be withdrawn through the charged material which will move down by gravity to fill the spaces thus left.

After all of the cells 3 and, if desired, the intermediate spaces defined by the cell walls and the bulwarks 4, have been treated as above described, the coffer-dam may be unwatered and the work within it carried through. In Figures 1 and 2 I have shown a concrete dry-dock within the coffer-dam and at 24 I have indicated load-bearing piles for supporting it. If desired, the cells may be left in place around the completed dry-dock except for the cells adjacent the gate end 25, which cells must be removed to permit the use of the dry-dock. If desired all of the cells may be removed after the work has been completed.

It will be noted that the cells are all free of internal bracing and that they may be constructed at low cost as compared with methods of construction ordinarily employed. I prefer to use cells of cylindrical cross section as illustrated in Figure 1, but in many cases it may be desirable to use another form of cell as indicated in Figure 6. In this view adjacent cells have a common wall 26 which will generally be straight. The outer walls 27 will be curved so as better to withstand the pressures encountered. The pressures on the wall 26 will be substantially equal and opposite if the digging and charging is carried out at approximately the same rate in the adjacent cells.

Figures 7 and 8 show a structure embodying load-bearing piles. As illustrated the structure consists of a series of cells 28 of much the same character as those illustrated in Figure 6. In the present case, however, the structure involved is not a coffer-dam but is intended to provide adequate lateral support for load-bearing piles 29. The difficulty of providing adequate lateral support is well illustrated in Figure 8 wherein the piles are shown driven into a substratum 30 of good bearing soil having an overlying stratum 31 of silt or the like. The piles are required to support a superstructure 32. If they were driven directly through the silt and were required to withstand whatever lateral forces may be encountered, as, for example, from tides or from wind pressures on the superstructure, they would sway unduly because the resistance of the silt is so low that the concentrated pressure exerted by piles bearing directly against the silt would not be successfully met. In Figures 7 and 8, however, this difficulty is overcome by first providing the cells 28, removing the silt therefrom and filling them with a more stable material 33, as, for example, broken stone, in the manner above described, then driving the piles 29, and then erecting the superstructure 32. The cells are allowed to remain in place beneath the superstructure. If there be any lateral forces tending to sway the piles this force is communicated to the material 33 and thence to the cell wall. While the lateral force must ultimately be resisted by the surrounding silt, the arrangement just described serves to distribute the lateral force over the projected area of the cell wall rather than over the projected area of the pile, and in consequence the unit pressure is lowered in an amount sufficient to permit of the silt successfully resisting it.

If desired, the piles may be driven through the silt and the charge of material formed in

a cell therearound, but for the ordinary case I prefer the sequence of steps as above described.

For reasons which will be clear from the above description I prefer that the stable material charged into the cell shall be divided, but it may be made monolithic if desired. In certain cases, especially where a permanent structure is to be made, the divided material may be bonded together by a suitable material. For example, cement grout may be forced into it under high pressure so as to fill the voids and form a substantial monolith, or sand, gravel or stone may be charged into the cells and after suitable heating by means of steam may be filled in with molten sulphur which upon cooling will firmly unite all of the particles.

The cells may be strengthened, if desired, by welding the piling sections together, generally above the water line. This is of particular value if they are to form part of a permanent structure.

The substratum is not necessarily of the character above described. In many cases it will be found entirely feasible to use a substratum of sharp sand for the foundation. Such sand, when confined as in my improved system, will afford adequate support for the structure to be built on it. The filling material need not be broken stone. Sand, gravel or hard slag, for example, may be used. It will be understood, therefore, that while I have illustrated and described certain present preferred embodiments of the invention, these are by way of illustration only and the invention may be otherwise embodied or practiced within the scope of the following claims.

I claim:

1. The method of making a load sustaining structure in earth which comprises sinking a cell from the surface into a substratum, removing earth above the substratum from within the cell, and substantially simultaneously charging divided material into the cell to replace the removed earth, the divided material being of a character to resist the pressure of the surrounding earth.

2. The method of making a load sustaining structure in earth which comprises driving interlocking steel piling to form a cell extending from the surface into a substratum, removing earth above the substratum from within the cell, and substantially simultaneously charging divided material into the cell to replace the removed earth, the divided material being of a character to resist the pressure of the surrounding earth.

3. The method of making a load sustaining structure in earth which comprises sinking a cell from the surface into a substratum, removing earth above the substratum from within the cell and substantially simultaneously charging material into the cell to replace the removed earth, the charged material being of a character to

resist the pressure exerted by the surrounding earth, the material being surcharged in the cell.

4. The method of making a load sustaining structure in earth which consists in sinking a cell from the surface into a substratum, removing earth above the substratum from within the cell by means of hydraulic jets, and substantially simultaneously charging material into the cell to replace the removed earth, the divided material being of a character to resist the pressure exerted by the surrounding earth.

5. The method of making a load sustaining structure in earth which consists in sinking a cell from the surface into a substratum, removing earth above the substratum from within the cell, maintaining a charge of replacement material on top of the earth in the cell and permitting it to sink as the earth is removed, thus maintaining a mass within the cell which is resistant to the force exerted by the surrounding earth.

6. The method of making a load sustaining structure in earth which comprises sinking a cell from the surface into a substratum, removing earth above the substratum from within the cell, substantially simultaneously charging divided material into the cell to replace the removed earth, the divided material being of a character to resist the pressure on the surrounding earth, and driving load-bearing piles within the area defined by the cell wall.

7. The method of making a load sustaining structure in earth which comprises sinking a cell from the surface into a substratum, removing earth above the substratum from within the cell, substantially simultaneously charging divided material into the cell to replace the removed earth, the divided material being of a character to resist the pressure on the surrounding earth, and binding the charged material into a monolithic mass.

8. The method of making a load sustaining structure in earth which comprises sinking a cell from the surface into a substratum, removing earth above the substratum from within the cell, substantially simultaneously charging divided material into the cell to replace the removed earth, the divided material being of a character to resist the pressure on the surrounding earth, and feeding cementitious material into the cell to bind the charged material into a monolithic mass.

9. The method of making a load sustaining structure in earth which comprises sinking a cell from the surface into a substratum, removing earth above the substratum from within the cell, substantially simultaneously charging divided material into the cell to replace the removed earth, the divided material being of a character to resist the pressure on the surrounding earth, and feeding molten sulphur into the cell to bind the charged material into a monolithic mass.

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