

May 18, 1954

H. LORENZ
PROCESS FOR THE PRODUCTION AND SINKING
OF CAISSONS OF ANY DESIRED SHAPE

2,678,540

Filed March 8, 1951

4 Sheets-Sheet 1

Fig. 1

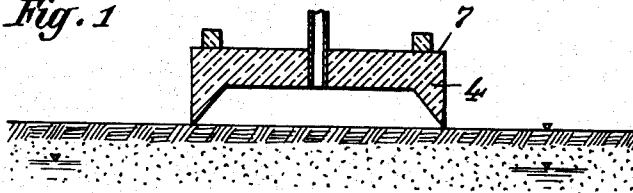


Fig. 2

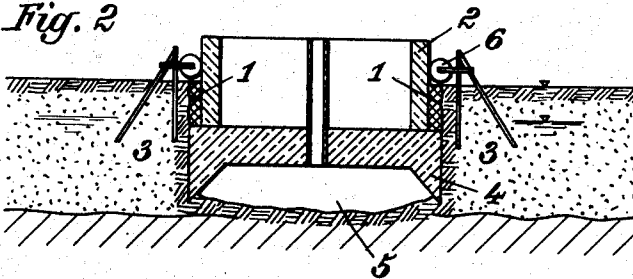


Fig. 3

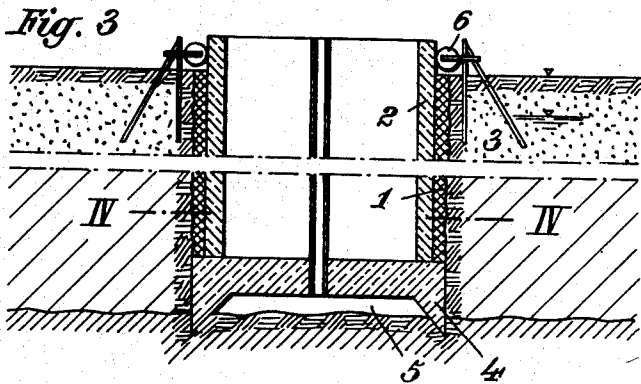
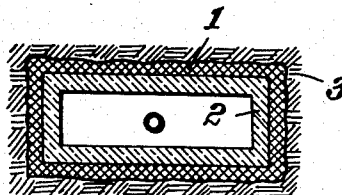


Fig. 4



Inventor
HANS LORENZ

by
Hauert & Lohr G.
AGENTS

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4 Sheets-Sheet 2

Fig. 5

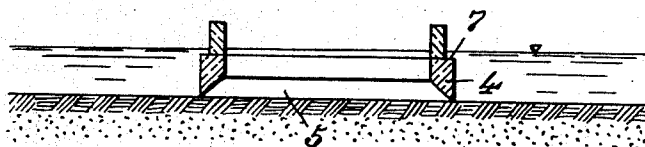


Fig. 6

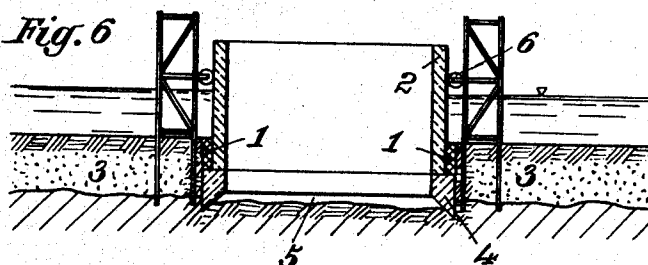


Fig. 7

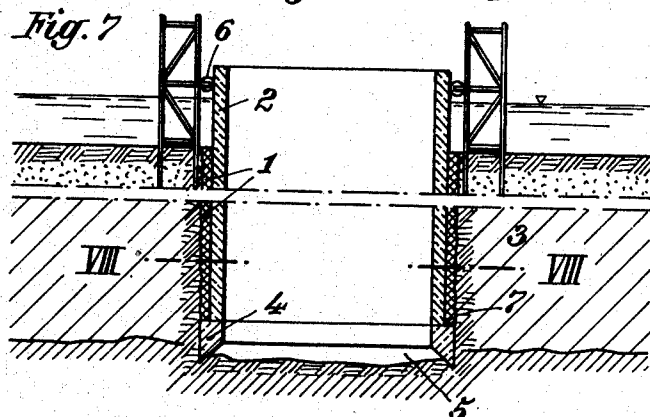
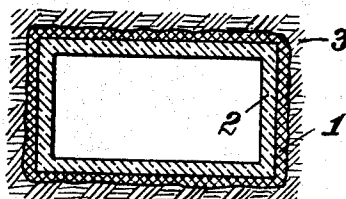


Fig. 8



Inventor
HANS LORENZ

by
Hauert, Lake & Co.
AGENTS

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4 Sheets-Sheet 3

Fig. 9

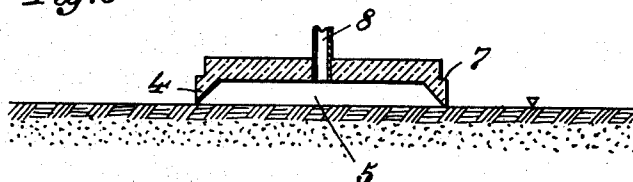


Fig. 10

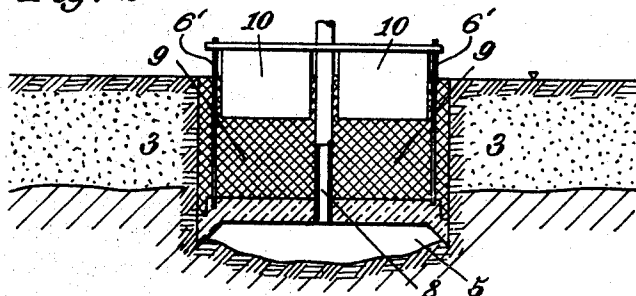


Fig. 12

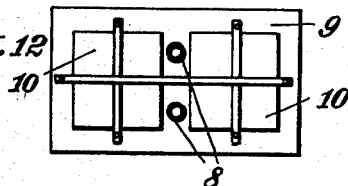
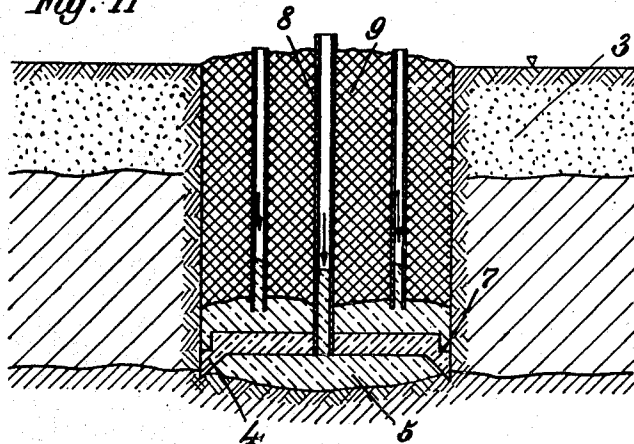


Fig. 11



Inventor

HANS LORENZ

by

Naeltine, Lake & Co.

AGENTS

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2,678,540

Filed March 8, 1951

4 Sheets-Sheet 4

Fig. 13

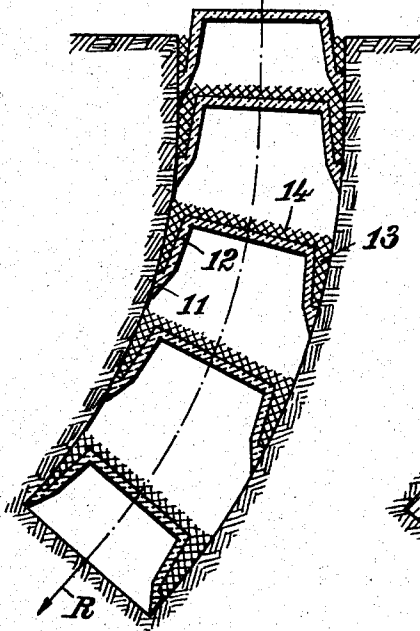


Fig. 14

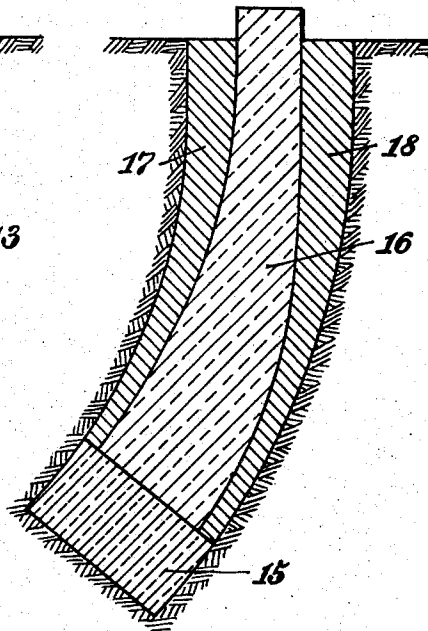
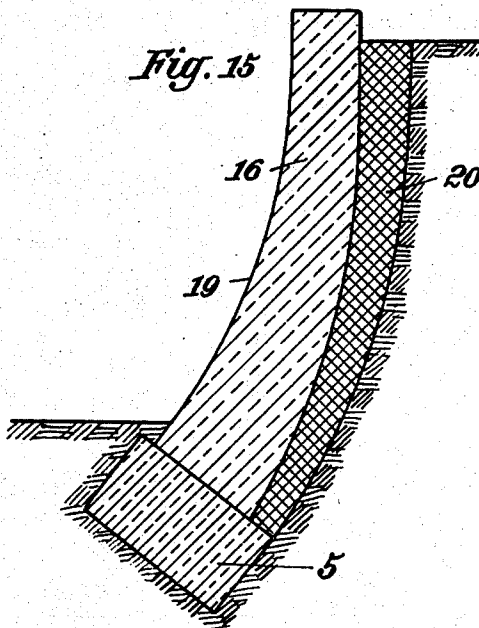


Fig. 15



Inventor

HANS LORENZ

by

Vaseltine, Lake & Co.
AGENTS

UNITED STATES PATENT OFFICE

2,678,540

PROCESS FOR THE PRODUCTION AND
SINKING OF CAISSONS OF ANY DE-
SIRED SHAPE

Hans Lorenz, Berlin-Tempelhof, Germany

Application March 8, 1951, Serial No. 214,496

Claims priority, application Germany
March 11, 1950

11 Claims. (Cl. 61—81)

1

This invention relates to a process for the production and sinking of caissons of any desired shape and has for its object to permit the production of such caissons with minimum dimensions, weights and reinforcement.

The penetration of a caisson into the soil is based upon a slide phenomenon and the loading of the cutting edges of the caisson must therefore be sufficient to overcome both the stability of the soil within the working chamber from which the soil is removed, and also effect a breech therein, that is to say arching of the material. This process is unfavourably influenced by the friction of the soil against the outer surfaces of the caisson since this friction acts in opposition to, and therefore has the effect of reducing, the weight acting on the cutting edges.

It has been proposed to avoid this disadvantage by giving the caisson an upwardly tapered form. However, this expedient was abandoned since it caused considerable disturbances in the structure of the soil outside the caisson.

It has furthermore been proposed that the caisson should have, at the level of the cutting edge, somewhat larger dimensions than its side walls to reduce the friction against the side walls. Neither does this expedient produce the required results since, more especially at great depths, the cavity around the side walls and above the knife edge, becomes filled with soil forced therein.

Filling the cavity with certain materials, such as slag, has also been attempted without any appreciable success.

Therefore, in all known caisson foundations sticking of the caisson is frequently unavoidable especially in the case of different soil strata, and it is necessary to provide, in addition to the caisson weight necessary for the final structure, ballast by means of which it can be further sunk.

Even more undesirable results are produced by unequal friction at the same level, which unequal friction occurs more especially in the case of caissons of rectangular cross-section. In order to allow for bonding stresses thus produced, the wall of the caisson must be heavily reinforced. The same applies to tensile reinforcement required when danger exists of the caisson sticking far above its cutting edge and of a great weight acting on this cross-section.

Consequently, the presence of the side wall friction unavoidable in caisson foundations results in a considerable over-dimensioning, additional reinforcement and consequently excessive cost, the expenditure of which is unwarranted by the final structure.

2

According to the invention, the aforesaid disadvantages in the sinking of caissons of any desired form are completely avoided if there is introduced between the side wall of the caisson and the soil, a liquid having thixotropic properties which does not penetrate into the voids of the soil but, by forming a fluid-tight film, sets up a liquid resistance to the soil pressure, which resistance may, in accordance with the concentration of the liquid, be greater than the hydrostatic pressure, so that on the one hand it protects the earth wall against collapse and on the other hand exerts on the side wall of the caisson purely horizontal readily determinable forces and does not exert on the side wall of the caisson any vertical components produced by friction.

By "thixotropy" is understood the property of certain colloidal suspensions which enables them to pass suddenly from the liquid aggregate condition into the solid aggregate condition. Such liquids do not penetrate into porous structure, such as coarse grained soil, even under high external pressures. There is formed on the surface of contact of the liquid with the soil, a water-impermeable film which prevents further penetration of material similarly to a rubber membrane. Experiments have shown that even with soil, such as gravel and rubble, having large voids between particles, this property is fully maintained.

Such a liquid may be produced, for example, by a suspension of pure bentonite in water. Experiments have shown that the thixotropic action of such a suspension collapses at a concentration of about 100 grammes of bentonite per litre of water. The specific gravity of this suspension is at first only slightly greater than 1 gramme per cubic centimetre. If, for example, it is necessary in view of the existing soil conditions to increase the specific gravity, it is possible to add finely ground heavy spa, which does not separate from the suspension in the form of a sediment, since it is prevented from sinking by the thixotropic properties of the liquid even when left to stand for a long time. The specific weight of the suspension mixed with heavy spa is consequently maintained for a long time and can be increased to about 3 grammes per cubic centimetre.

The employment in deep boring and shaft sinking industries of thick washes or drilling muds for retaining open bore holes and circular shafts is already known. These drilling muds, which consist generally of emulsions of argillaceous material present in situ, utilize the possibilities of thixotropic liquids consisting of bentonite, only

to a small extent. Neither is this necessary for retaining open the bore holes and circular shafts with the existing circular cross-sections, since owing to the arching effect a small counter-pressure is sufficient to ensure stability of the earth wall. However, the static conditions are far less favourable in the case of overhanging walls of plane or any other form such as exist in the case of caissons of rectangular cross-section or upwardly tapered caissons. In such cases, stability of the earth walls can only be obtained if all properties of thixotropic liquids which do not act hydrostatically in the same way as water, are intentionally utilized. Again, in the case of caissons of round cross-section, the object of the invention, that is to reduce the dimensions and reinforcement to the extent statically necessary for the permanent structure, is only achieved if all the properties of the thixotropic liquid are intentionally utilized.

However, by introduction of a liquid having thixotropic properties between the side walls of the caisson and the soil, not only is collapsing of the soil into the cavity between the side walls of the caisson and the soil avoided, but in addition no friction is set up on the surface of the side walls so that the said surface has only to take up the hydrostatic pressure of the liquid introduced. This pressure can be readily calculated at any depth so that over-dimensioning of the caisson which has hitherto been necessary and usual both to overcome the frictional resistances and also to allow for the uncertainty in the estimates of the pressure of the soil, is eliminated. Moreover, the liquid pressure has equal values under all circumstances, as measured in horizontal section. The stresses on the side walls of the caisson are consequently annular stresses which can readily be taken up with minimum cross-sections. The lack of guiding of the caissons by the soil can be simply compensated by a roller guide system, for example, at ground level.

In the sinking of a caisson foundation in open water, the thixotropic liquid is not introduced until the horizontal curb above the cutting edge of the caisson has penetrated into the water bed, the higher specific gravity and the colloidal properties retaining the liquid in the space between the side walls of the caisson and the soil thus preventing it from rising and separating and from penetrating into the soil.

To reduce further the friction, the lateral surfaces of the structural unit containing the working chamber are arranged to project rearwardly above the knife edge, and the space between these backwardly projecting lateral surfaces and the soil may be filled with thixotropic liquid.

The new process according to the invention may also be applied to a caisson having no side walls. In this case, the structure unit provided with knife edges and enclosing a working chamber is sunk into the soil alone, the necessary pressure on the coiling of the working chamber being produced by the weight of the thixotropic liquid bearing thereon. Uniform sinking is ensured by an adjustable suspension of the structural unit on bearers or floats. After final sinking, the space above the ceiling of the working chamber is completely or partially filled with concrete from below or another structural unit of any desired form may be mounted on the foundation created.

If the structural unit provided with knife edges and embracing a working chamber has no side

walls or has side walls projecting rearwardly to a considerable extent, it is furthermore proposed to fill the liquid-filled space above the ceiling of the working chamber with a thixotropic liquid, the concentration of which decreases in stages from the soil side to the centre, if necessary to zero.

In applying this process, a considerable proportion of bentonite may be saved, which is particularly important if the caissons to be produced have fairly large cross-sections. The invention is based upon the discovery that thixotropic liquid columns of different concentrations do not mix with one another. If, for example, the caisson has a cross-section of 30 x 20 metres, it is quite sufficient in order to achieve the object aimed at, to provide, above the ceiling of the structural element, an annular liquid column of a thickness of about 0.5 metres and a concentration of 200 grammes per litre, in contact with the soil wall. The adjoining liquid column in the inward direction may also be annular and it preferably has a thickness of approximately 1 metre with a concentration of about 100 grammes per litre, while the innermost layer, which fills the entire free space, or which extends as far as the rearwardly projecting side wall of the caisson, may consist of pure water. In some cases it is sufficient to provide two liquid columns above the structural unit, in which case the outer liquid column in contact with the soil wall also has a high concentration. It will readily be seen that, especially in the case of caissons of large cross-section, considerable quantities of bentonite may be saved. It is merely necessary to provide on the soil side, a thin liquid column of highly concentrated bentonite suspension while the remaining liquid columns filling the large internal space, may consist of clay solution of lower concentration, the additions of which, for example clay or loam, may be produced in situ.

According to the invention, the liquid columns of different concentrations are preferably introduced through pipe lines and nozzles arranged in or on the top of the structural unit and fed through delivery tubes during the sinking, for example from above or, if the working chamber in the structural unit is of sufficient dimensions, from the working chamber itself.

Preferably, short partitions are provided on the ceiling of the structural unit to influence the direction of flow of the liquids of different concentrations in the required manner.

The new process for the production and sinking of the caissons of any desired shape may also advantageously be employed for inclined sinking, in which case the caisson is first sunk vertically to a certain depth and thereafter further sunk at a constant, or if desired, variable angle of rotation, for example by unequal excavation of soil in the working chamber.

Inclined sinking of a caisson is preferably effected when the structure to be built upon the caisson constantly undergoes considerable horizontal stresses, for example, due to the pressure of earth. By inclined sinking of a caisson it is possible to adapt the structural unit in an improved manner to the supporting line, that is to say to the line connecting the points of application of the resultants in the individual cross-section.

In a known process for inclined sinking, the longitudinal section of the working chamber is constructed in the form of a rhombus so that the caisson is guided obliquely downwards on one

5

lateral surface of the rhombus by the resistance of earth. In this process, the caisson travels, when sinking, through a horizontal distance which must be predetermined. This calculation, however, often causes difficulties since assumptions must be made for the purpose of simplification. Nevertheless soil constants necessary for this purpose cannot be ascertained with sufficient accuracy.

While in the known inclined sinking method the base of the working chamber always remains horizontal, in the new process the base can be adjusted to any angle of rotation in relation to the horizontal. This affords a great advantage in that at each sinking depth the resultant of the forces may be perpendicular to the base, so that if the sinking operation is correctly conducted, that is to say if the angle of rotation is correctly adjusted, the supporting line coincides with the centre axis of the structure, that is to say no moments are set up at any point, and the structure thus only undergoes a compressive stress. A further advantage resides in that no accurate calculation as regards the positioning of the caisson need be made in advance, but corrections in the position of the caisson can readily be made during the sinking process. Such corrections are often necessary also when caissons are sunk vertically. For this purpose, it is merely necessary to determine the momentary position of the caisson at ground level by means of a simple measuring device. The space above the working chamber remains filled with thixotropic liquid, so that collapse of overhanging soil walls is rendered impossible.

The excavation of varying depths of soil at the transverse walls of the working chamber may be effected manually, that is to say by workmen operating under compressed air, or mechanically by installing automatic flushing devices, for example with the aid of a mammoth pump. According to requirements, the caisson can be directed downwardly in the rotated position at a constant angle of rotation, or the angle of rotation may be constantly varied, so that the centre of gravity of the working chamber describes a descending curve. The angle of rotation for the caisson may be increased to 90° or more, so that from a certain sinking depth the caisson moves horizontally or even rises again. In this way, shafts or bores holes may be formed extending horizontally or at any desired angle.

Preferably, the space formed above the caisson is so filled with thixotropic liquids of different concentrations that liquids of higher concentration may be introduced in contact with the soil walls, more particularly at the overhanging soil walls than at the centre of the chamber.

When the caisson has reached the required depth, the chamber filled with thixotropic liquid is concreted from below, a reinforcing basket having been inserted in the liquid-filled open end beforehand. Since the thixotropic properties of the liquid prevent collapse of soil from the walls of the shaft even when these walls overhang, any disintegration of the wall or shuttering thereof for the purpose of concreting, is unnecessary.

If it is desired to give the foundation structure a particular economical form, it is also possible to provide in the space filled with thixotropic liquid forms or shuttering, the internal space of which is concreted, whereafter the shuttering is withdrawn and the remaining spaces filled with thixotropic liquid are filled with earth or thin concrete.

6

In contrast to the relatively limited field of application of the known inclined sinking method, the new inclined sinking process can also be employed to produce, for example, a supporting wall or quay wall if the soil on the air side or water side adjacent the supporting wall is not to be dredged away until later, as is the case, for example, in the production of new harbour basins or the like. In this case, the supporting wall or quay wall is lowered in the manner described and the harbour basis is dredged out after completion of the concrete work. With such a construction of the supporting or quay wall, all reinforcing and shuttering steps are unnecessary.

It is also possible to adapt the form of the quay wall on the air side and on the water side to the configuration of hulls of ships. In the production of such a supporting or quay wall, a layer of thixotropic liquid preferably remains in the bottom of the soil side of the supporting wall. The object of the said layer is to distribute uniformly over the supporting wall, a soil pressure composed of periodically occurring loads at individual points or along sections of the land with the aid of the hydrostatic action of this layer of liquid, so that it is unnecessary to dimension the supporting walls in accordance with the most unfavourable load which will occur, as is the case in normal practice.

For a better understanding of the invention and to show how it may be carried into effect, the same will now be described with reference to the accompanying drawings, in which:

Figures 1 to 3 show in vertical section, a caisson in various sinking stages and Figure 4 is a horizontal section in the line IV—IV of Figure 3.

Figures 5 to 7 show in vertical section, a caisson foundation in open water and in different sinking stages, and Figure 8 is a horizontal section on the line VIII—VIII of Figure 7.

Figures 9 to 11 show in vertical section, a caisson foundation in which the caisson has no side walls, again in different sinking stages, and Figure 12 is this caisson foundation in plan view.

Figure 13 is a caisson in horizontal section in different stages of an inclined sinking operation.

Figure 14 shows a supporting wall erected on an obliquely sunk caisson, and

Figure 15 shows the same supporting wall employed as a quay wall.

In the caisson foundation shown in Figures 1 to 4, a thixotropic liquid 1 of suitable concentration is introduced between the caisson side wall of jacket 2 and the soil 3. The cutting edge of the caisson 4 comes into contact with the soil and prevents penetration of the liquid 1 into the working chamber 5. By means of a roller guide system 6 at ground level, inclination of the caisson during sinking is prevented.

The cutting edge 4 is produced and sunk in the normal manner. As soon as the curb 7 provided above the cutting edge, sinks below ground level, the hollow space defined between the caisson jacket 2 and the soil 3 is filled with thixotropic liquid. This filling is supplemented during the further sinking to such an extent that the liquid always reaches ground level. When the caisson has been sunk to the required final depth, the thixotropic liquid introduced is no longer required. It is removed, and if desired recovered, by filling the space with concrete between the jacket and the soil through the medium of pipes introduced therein and simultaneously pumping off the liquid issuing at the top.

The same sinking method is also applicable, as

shown in Figures 5 to 8, to foundations in open water when required to sink a body produced elsewhere, for example a floating caisson, which is first deposited on the water bed. Since the specific gravity of the thixotropic liquid 1 is always greater than that of water, the thixotropic liquid introduced remains in the cavity between the jacket 2 and the soil 3 and is not washed out, nor does it penetrate into the soil, owing to its thixotropic properties.

The new sinking method is applicable to any caisson foundation irrespective of whether it is a question of open caissons or of compressed air foundations. Figures 1 to 4 show as an example a compressed air foundation, while Figures 5 to 8 show an open caisson.

The quantity of thixotropic liquid to be introduced is relatively small and since the cost of producing such a liquid is also low, considerable saving is effected by reducing the cross-section of the caisson side wall or jacket which only has to take up horizontal hydrostatic pressure. Furthermore the walls and ceiling of the working chamber are substantially lighter, since the vertical hydrostatic pressure required for sinking acts directly above the cutting edges.

A further development of the new process is illustrated in Figures 9 to 12. In this case the cutting edge 4 and the working chamber 5 are again produced at ground level. By dredging out the soil in the working chamber 5, the cutting edge 4 is lowered so far that the curb 7 of the cutting edge lies below ground level. In the further sinking operation, the thixotropic liquid 1 is again introduced into the cavity. In contrast to Figures 1 to 8, the foundations shown in Figures 9 to 12 have no jacket provided above the ceiling of the working chamber, the connection to the working chamber being established merely by an upwardly extended shaft tube 8. The entire space 9 above the ceiling of the working chamber is filled with thixotropic liquid 1, and the hydrostatic pressure of this liquid both secures the shaft wall against collapse and affords the necessary pressure on the ceiling of the working chamber for further sinking. To ensure uniform sinking of the caisson and to prevent a sudden penetration, for example when soft strata are encountered, the caisson is suspended on cables 6' which, in the case of smaller constructions are secured to bearers laid over the shaft openings, or in the case of larger constructions are suspended from containers 10 floating in the liquid. When the caisson has reached the required depth, first the working chamber 5 and then the entire liquid filled space 9 is filled with concrete from below. Experiments have shown that, in contrast to concreting under water, concreting in the thixotropic liquid is as easy as in the air. Above all, washing out and separation of the fresh concrete is avoided.

Figure 13 shows a caisson in different stages of an inclined sinking operation taking place along the curve R. The caisson is constructed in the form usually adopted for straight sinking and is provided at its lower end with cutting edges 11. Above the cutting edges 11, the lateral surfaces 12 of the caisson are arranged to project rearwardly, so that the space 13 between these rearwardly projecting lateral surfaces and the soil, and also the space 14 above the ceiling of the caisson, may be filled with thixotropic liquid. When the caisson has been vertically sunk to a predetermined depth, depending upon the loading conditions and the soil conditions, the caisson is inclined owing to the fact that a greater excava-

tion of soil takes place below the cutting edge shown to the right in the drawings than on the opposite side. According to requirements the caisson may be sunk to the required depth at a constant or variable angle of rotation. Preferably, the inclined sinking takes place in such a manner that the line connecting the center points of the individual cross-sections coincides with the supporting line R of the subsequent structure.

Figure 14 shows a finished supporting wall erected on the obliquely sunk caisson 15. This supporting wall 16, which has an upwardly tapering cross-section, is formed with the aid of forms or shuttering positioned inside the shaft filled with thixotropic liquid. After withdrawal of the shuttering, the remaining spaces 17 and 18 filled with thixotropic liquid are filled with soil or thin concrete.

Figure 15 shows a supporting wall 16 corresponding in its dimensions to the supporting wall shown in Figure 14. The supporting wall 16 here serves as a quay wall when the soil has been dredged out after completion of the wall. The form 19 of the quay wall on the air side and water side is adapted to the configuration of the hull skin of a ship. The space 20 on the soil side between the quay wall 16 and the soil is filled with thixotropic liquid.

I claim:

1. A process for producing a foundation by sinking a caisson which comprises the step of introducing into a cavity defined between the caisson and the surrounding soil a liquid having thixotropic properties capable of preventing the liquid from penetrating into the voids of the surrounding soil and of causing the liquid to form a fluid-tight film, whereby the liquid opposes hydraulic resistance to the pressure of the soil.

2. A process according to claim 1 wherein the resistance opposed by the liquid is so conditioned by the concentration thereof as to support the soil wall of the cavity against collapse by exerting purely horizontal forces thereon and as to lubricate the caisson and soil wall to eliminate vertical components due to friction as the caisson is lowered.

3. A process according to claim 1 for producing a foundation beneath a body of water which comprises first sinking the caisson into the soil bed underlying the water until the upper surface of the caisson has penetrated beyond the surface of the bed, providing a hollow shaft above the caisson having a lesser periphery than the caisson thereby to define a cavity between the shaft and the soil bed, and thereafter introducing into said cavity a thixotropic liquid having a higher specific gravity than water and colloidal properties sufficient to prevent said liquid from rising out of said cavity and separating off and from penetrating into the soil.

4. A process according to claim 1 wherein the concentration of the thixotropic liquid decreases from a maximum adjacent the surrounding soil to a minimum remote from the soil.

5. A process according to claim 4 wherein the thixotropic liquid of highest concentration comprises a thin layer of a highly concentrated bentonite suspension and the remainder comprises a clay solution of lower concentration.

6. A process according to claim 1 which comprises first lowering the caisson substantially vertically to a predetermined depth and thereafter excavating the soil unevenly below the caisson.

son to cause lowering thereof at an angle to the vertical.

7. A process according to claim 6 wherein a line connecting the center points of successive positions of the caisson as it is lowered at an angle to the vertical coincides with the pressure line of the foundation to be produced. 5

8. A process according to claim 6 wherein the angle to the vertical is progressively increased up to at least 90° as the caisson is lowered. 10

9. A process according to claim 6 for producing a supporting wall which comprises removing the soil from one side of the wall to expose said side.

10. A process according to claim 9 wherein a film of thixotropic liquid is retained between the 15

adjacent soil and the side of the wall opposite to said exposed side, thereby to distribute soil pressures evenly over the whole surface of said opposite side.

11. A process according to claim 9 wherein said exposed side is substantially complementary in configuration to the hull of a ship.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
961,788	Moran -----	June 21, 1910
2,213,169	Ouchi -----	Aug. 27, 1940