July 6, 1954 H. LORENZ 2,682,750

PROCESS FOR INCREASING THE STABILITY OF FOUNDATIONS OF ALL TYPES

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Fig. 1

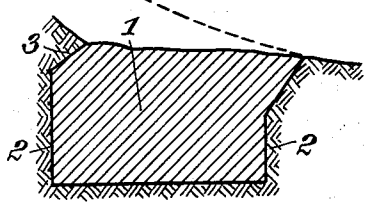


Fig. 2

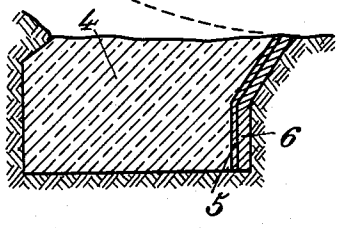


Fig. 3

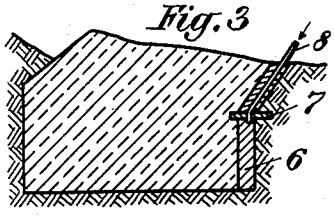


Fig. 4

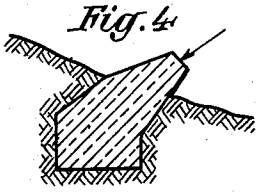


Fig. 5

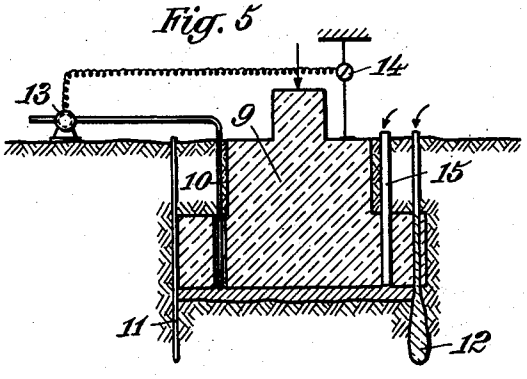


Fig. 6

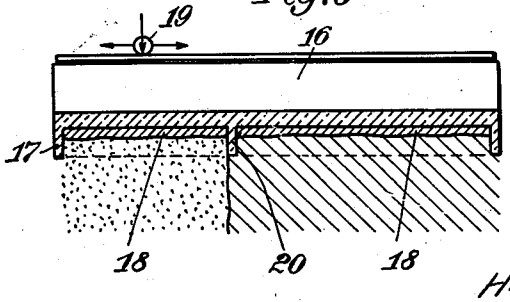
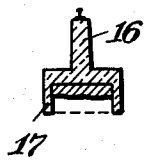


Fig. 7



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Fig. 9

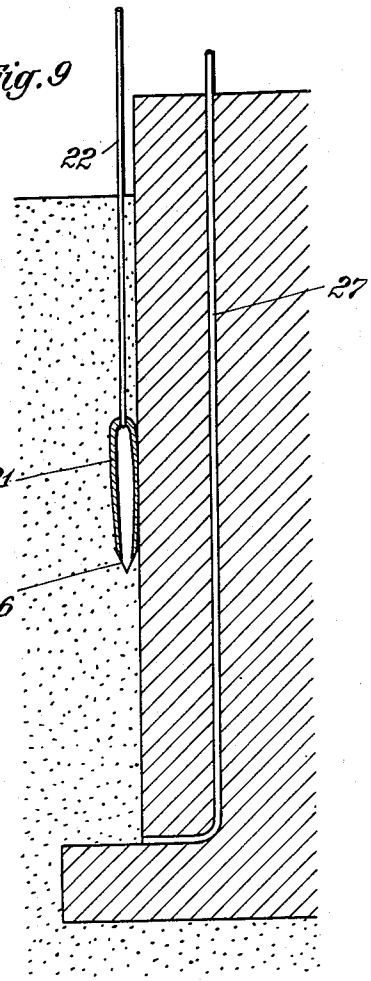
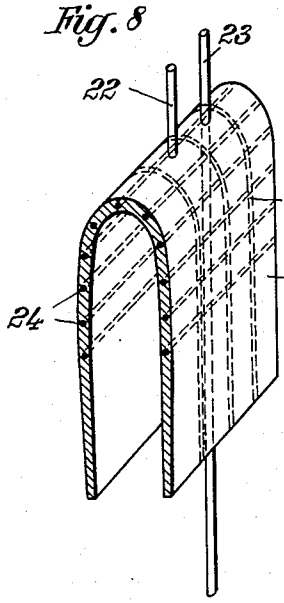


Fig. 8



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PROCESS FOR INCREASING THE STABILITY OF FOUNDATIONS OF ALL TYPES

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Fig. 10

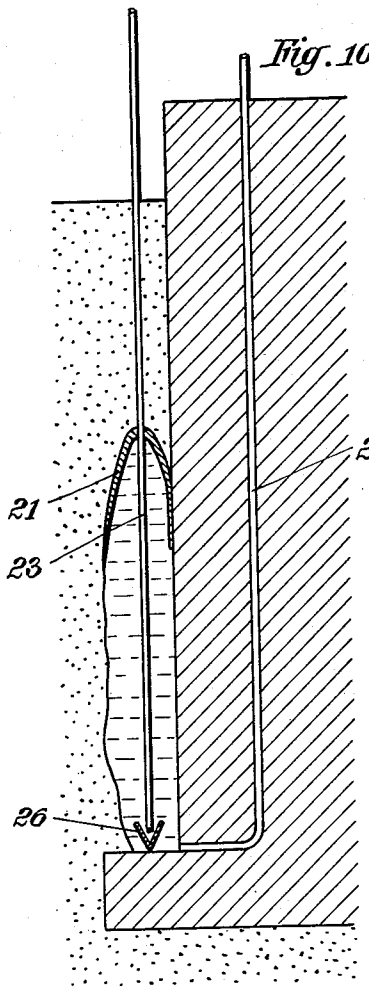
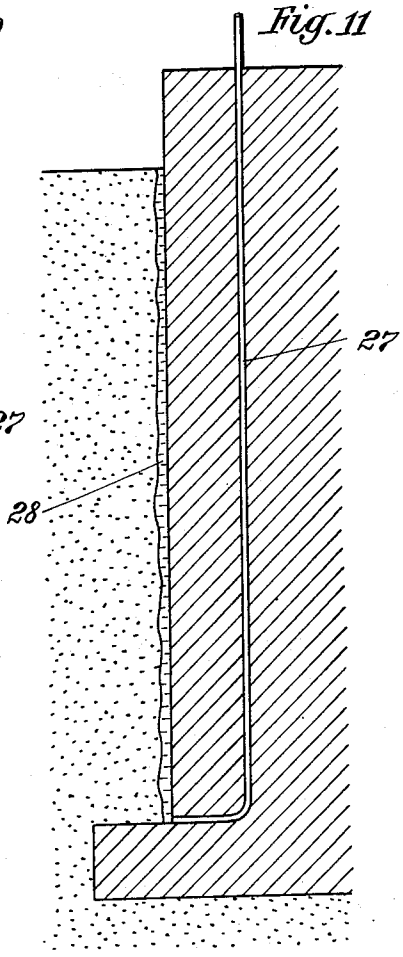


Fig. 11



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PROCESS FOR INCREASING THE STABILITY OF FOUNDATIONS OF ALL TYPES

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Fig. 12

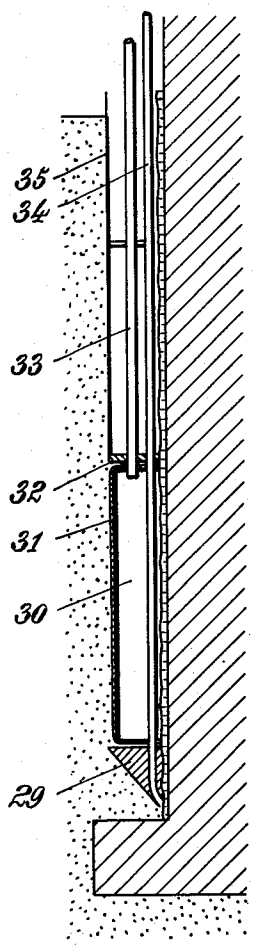


Fig. 13

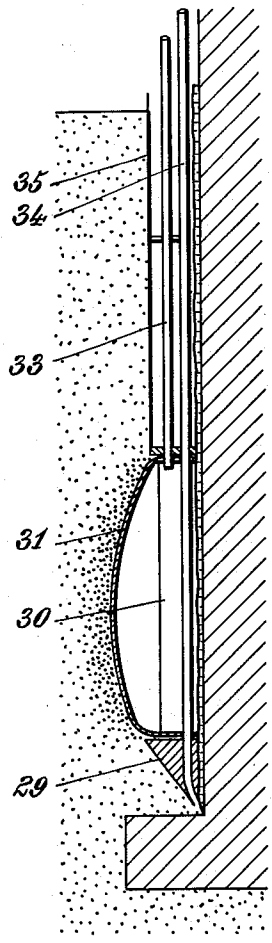
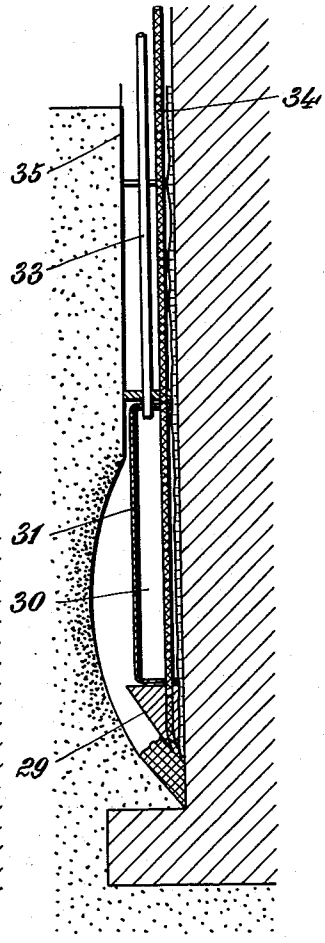


Fig. 14



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PROCESS FOR INCREASING THE STABILITY OF FOUNDATIONS OF ALL TYPES

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Fig. 15

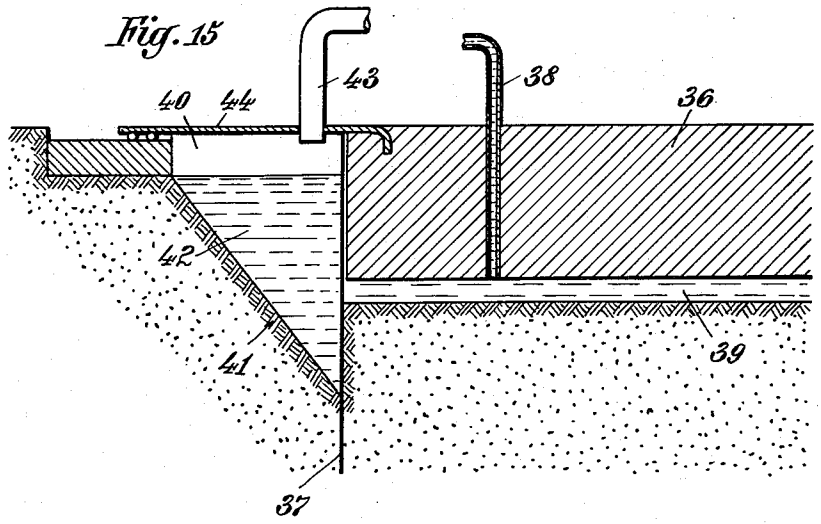
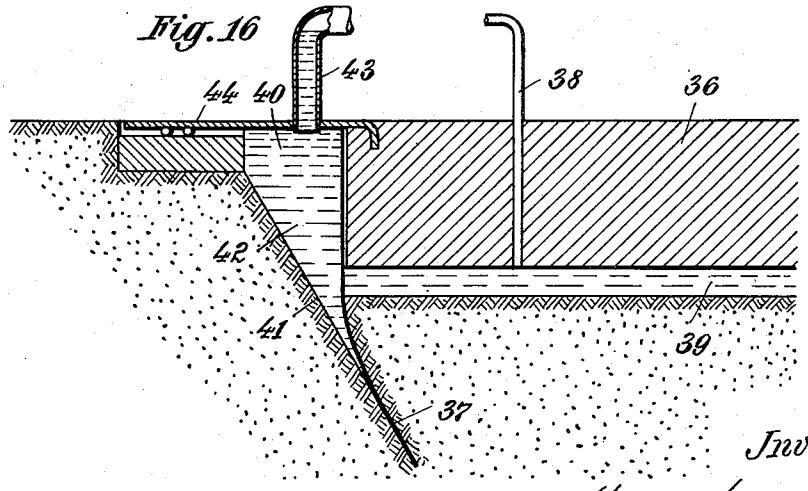


Fig. 16



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UNITED STATES PATENT OFFICE

2,682,750

PROCESS FOR INCREASING THE STABILITY OF FOUNDATIONS OF ALL TYPES

Hans Lorenz, Berlin-Tempelhof, Germany

Application April 3, 1951, Serial No. 218,975

Claims priority, application Germany April 6, 1950

17 Claims. (Cl. 61—35)

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This invention relates to a method of increasing the stability of foundations of all kinds.

Exhaustive experiments with thixotropic liquids, which for example are made by dissolving bentonite in tap water, have shown that such liquids do not penetrate into either fine grained or coarse grained soils, not even when the liquid is under a substantially higher pressure than the earth pressure. There is formed, in fact, at the surface of contact between liquid and soil a membrane of high surface tension, which prevents the penetration of the liquid into the soil and permits a pressure to be exerted on the soil at any desired depth and in any desired direction.

The invention is concerned with the application of this new knowledge to foundation engineering, in particular for increasing the stability of foundations of all kinds.

According to the invention, a liquid having thixotropic properties is introduced under pressure, or a similar liquid introduced in some other way is placed under pressure, the liquid being inherently incapable of penetrating the voids in the soil by virtue of its thixotropic properties but capable of exerting over the entire surface of contact between soil and liquid considerable forces equivalent to the hydrostatic pressure of the liquid on the principle of the hydraulic press, thereby leading to a considerable compression of the soil, which anticipates the extent of the subsequent compression, that is to say, it effects a preconsolidation of the soil and opposes the maximum earth resistance to the external forces acting on the foundation.

The liquid pressure acting between foundation and soil may be used for forcing back a displaced foundation occurring as a result of the yielding nature of the soil, the quantity of liquid forced being regulated, by means of a specially controlled apparatus, in accordance with the amount by which the foundation has shifted relatively to its proper position.

Heretofore, it has merely been proposed to pre-load or pre-consolidate a body of soil in the vertical direction by means of, for example, hydraulic presses introduced between the foundation and the footing. It is not possible, however, by means of these special presses, the use of which in foundation engineering is expensive, to preconsolidate the soil in any desired direction, and hence attain a deformation which is always necessary for attaining maximum earth resistance.

It has furthermore been proposed, particularly for raising buildings which have been subjected to

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considerable settlement through mining subsidence, to force beneath the foundation a sand-water mixture into the soil situated thereunder. Apart from the fact that the foundation has to include a special concrete plate of considerable dimensions and must be reinforced so as to prevent loss of water through cracks due to uneven settlement, whereby the lifting effect becomes doubtful, it is only possible to raise the foundation if the said special concrete plate has been made before erection of the building foundation.

Even though experiments have shown that the risk of lateral escape of the injected thixotropic liquid no longer exists if a slight thickness of soil lies above the lower edge of the foundation, further security against escape of the liquid may be provided by disposing at the foundation edges short aprons adapted to the settling mass and formed either by rammed in metal sheets or injected materials, such as for example cement, chemicals or the like.

In the case of foundations which are loaded eccentrically or have settled obliquely, additional aprons may be provided beneath the foundation footing in such a manner as to provide spaces according to the point of application of the resultant of the external forces, into which spaces the liquids having thixotropic properties are introduced.

In new buildings, the foundations will preferably be provided beforehand with thin vertical walls, which can be made very weak, since they have not to support any load, but are merely to prevent the liquid from escaping from the space below the foundation or from passing from spaces of higher pressure to spaces of medium or low pressure.

Of course, the new method may be employed not only for raising a foundation, but also so that a foundation, which has shifted in the horizontal or other direction may be forced back into its proper position by the injection of liquid under pressure between foundation and soil.

After the thixotropic liquids introduced have fulfilled their purpose, the spaces filled with these liquids may be concreted under suitable pressure, the thixotropic liquids being displaced at the same time. In this way, after the concreting of these spaces, the foundation is consolidated in the soil whereby due to friction between concrete and ground, the external forces are partly dispersed along the side walls of the foundation into the ground, thereby reducing the load on the foundation to a considerable extent.

In order to distribute concentrated individual loads as uniformly as possible over the soil, strongly reinforced footings have usually been employed heretofore in foundation engineering. Nevertheless, it is not always possible to produce the desired pressure, namely a rectangular stress distribution, below the foundation. By injecting under pressure a thioxotropic liquid below a foundation, a uniform liquid pressure is attained, and hence a uniform stressing of the soil, irrespective of whether the external loading of the structure is applied centrally or eccentrically, or even whether the external load is a moving traffic load. Thus, for example, a crane track beam, which is subjected to heavy moving individual loads, can be substantially weaker than heretofore by forcing a thixotropic liquid under said crane track beam, and a purely rectangular stress course may be attained in both directions below the foundation.

In a further development of the idea underlying the invention, it is proposed to lower along the sides of the foundation to a certain depth a folded rubber skin, if desired provided with steel reinforcement under the protection of a metal sheet preferably bent into the shape of a wedge and embracing one of the free lower ends of said rubber skin, then to introduce between the folded rubber skin, with distension of the sides of the rubber skin and with corresponding preconsolidation of the soil, thixotropic liquid under pressure, and thereupon to force concrete into the space filled with thixotropic liquid with simultaneous displacement of the liquid from said space. The rubber skin is now withdrawn for a certain distance and if desired the method is repeated in a number of successive operations.

The pipe lines serving for the supply and discharge of the thixotropic liquid and for the supply of concrete preferably extend upwardly from the fold of the rubber skin. In addition, thixotropic liquid may also be forced into the space below the rubber skin through pipe lines disposed in the foundation.

Instead of concreting the space between the foundation and the preconsolidated soil before each withdrawal of the rubber, the concreting operation may also be carried out after the soil has been preconsolidated to the desired height after repeated withdrawal of the rubber skin.

To facilitate the lowering of the rubber skin, thixotropic liquid may be injected, before the lowering operation, through pipe lines disposed in the foundation, into the boundary surface between foundation and soil, so as to form at the boundary surface a gap facilitating the lowering of the rubber skin.

According to a modified method, it is also possible, instead of the folded rubber skin, to lower along the sides of the foundation, a totally enclosed, oblong box, for example of steel sheet, provided with a cutter on its lower edge, the perforated side of the box turned away from the foundation being provided with a rubber skin on the outside, which, after the box has been lowered, is distended by means of liquid supplied under pressure to the inside of the box, the soil being thereby preconsolidated. After preconsolidation of the soil, the pressure liquid is shut off and concrete is introduced into the widened cavity during the withdrawal of the box. Finally, if desired, the method is repeated in a number of sequences. In the subsequent repetitions, of the method, the pressure of the liquid may be reduced in stages in view of the upwardly diminishing earth pressure. In this method also, thixotropic liquid may be supplied to the box cutter and to the outer surface of the foundation, preferably through pipe lines disposed in the foundation to facilitate lowering of the box.

If it is necessary not only to preconsolidate the soil in order to produce an earth resistance against horizontal external forces, but also through the earth resistance produced to bring about a considerable friction on the sides of the foundation, in order to increase the anchoring moment or by frictional effect on the sides, to reduce the pressure on the foot, the film of thixotropic liquid present according to the above method and remaining on the side of the soil or on the side of the foundation, may be troublesome. In this case, it is necessary to eliminate the originally desired lubricating properties of the thixotropic liquid. This may be effected, according to the invention, by adding chemicals to the residual thixotropic liquid, at the latest at the instant of introduction of the concrete, for example waterglass, which causes the liquid to precipitate and hence considerably reduce the lubricating properties.

The new method may also be used for correcting a foundation displacement which has occurred on account of the yielding nature of the soil, the method being applied solely to the side of the foundation away from which the foundation is to be returned to its original position.

The new method may also be employed advantageously for the protection of a foundation against the effect of dragging and pressing occurring in regions of mining subsidence, layers of thixotropic liquid being introduced below the foundation bottom or around the side surfaces of the foundations extending into the ground, in a predetermined amount with respect to the surmised dragging or pressing.

By the provision of a thixotropic liquid layer beneath the foundation bottom, which liquid does not enter the voids of the soil even under the pressure of the foundation bottom, the friction between the foundation bottom and the layer of thixotropic liquid is practically zero. Thus, in the event of dragging and pressing in the soil, the latter can move relatively to the foundation, which remains at rest, without exerting any appreciable forces on the foundation through friction. The lateral escape of thixotropic liquid beyond the edges of the foundation may be prevented by suitable means, for example by aprons provided on the edges of the foundation and extending downwardly into the ground.

If, in consequence of ageing phenomena, which it has not been possible to observe in the trial periods so far, the thixotropic liquid alters its properties in the course of time, so that it can no longer satisfy the requirements made of it, this disadvantage could be easily overcome by renewal of the thixotropic liquid at certain intervals by means of a simple pumping device. This may be effected, for example, by providing in the foundation, openings or pipe lines through which fresh thixotropic liquid is forced, while at the same time the spent liquid will be displaced through other openings. By means of the pumping device and pipe lines it is also possible to introduce the thixotropic liquid only shortly before the occurrence of the mine damage.

The thixotropic liquid layer serves for extensively reducing the effects of dragging and pressing on the sides of the foundations, such layer being introduced into the trenches sur-

rounding the sides of the foundation and the width of said trenches being adapted to the maximum amount of dragging and pressing to be expected. In this way, the hydrostatic pressure of the liquid acts against the foundation and also prevents the preferably unlined earth sides of the trenches from falling in. The aprons arranged around the edges of the foundation extend from the edges of the foundation downwards into the earth to a greater distance than the conjectured amount of subsidence to prevent lateral escape of the thixotropic liquid situated beneath the foundation footing or its communication with the thixotropic liquid situated at the sides. The bottom of the trenches surrounds the sides of the foundation to a greater depth than the bottom of the thixotropic liquid below the footing but is arranged above the lower edge of the aprons.

In the event of displacements of the unlined trench side towards the footing, the thixotropic liquid will be forced out upwardly. In the event of dragging, that is to say displacements away from the foundation, the liquid descends in the trenches and is refilled to the necessary height.

The trenches are provided with horizontally displaceable covers connected to the footing. According to whether compression or dragging occurs, the discharge of thixotropic liquid from the trenches or its replenishment may be effected through holes provided in the trench covers or through pipe lines opening into the latter from above.

It will depend upon the prevailing building conditions whether it is sufficient to provide the layer of thixotropic liquid only below the foundation bottom, only around the sides of the footing or in both places. If the foundation bottom is in the vicinity of the surface of the ground, the provision of thixotropic liquid below the foundation bottom will suffice. In the case of foundations of smaller cross-section, the bottom of which lies at a greater distance below the surface of the ground, it may be sufficient to provide the thixotropic liquid in trenches round the sides of the foundation. In all other cases, however, thixotropic liquid will be provided both below the bottom of the foundation and round the sides of the foundation.

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, wherein:

Figures 1 to 4 show the construction of an abutment for an arched bridge in various stages of production and in vertical section,

Figure 5 shows the raising of a foundation in vertical section,

Figures 6 and 7 show a crane track beam with the thixotropic liquid introduced below the foundation edges, in vertical longitudinal section and in cross-section.

Figure 8 shows diagrammatically a compacting device for introducing thixotropic liquid,

Figure 9 shows the compacting device lowered along the side of the foundation,

Figure 10 shows the compacting device distended under the pressure of the thixotropic liquid with preconsolidation of the soil,

Figure 11 shows the foundation and soil with a gap at the boundary face between foundation and soil produced by injecting thixotropic liquid before the introduction of the compacting device,

Figure 12 shows a box-like compacting device

introduced between foundation and soil before the preconsolidation of the soil,

Figure 13 shows the compacting device according to Figure 12 in the same position after the preconsolidation of the soil,

Figure 14 shows commencement of the concreting of the cavity formed after the preconsolidation of the soil,

Figure 15 shows a foundation footing with the layers of thixotropic liquid before the occurrence of dragging and pressing of the soil in vertical section, and

Figure 16 shows the footing according to Figure 15 with the layers of thixotropic liquid after the occurrence of pressing, in vertical section.

For the production of an abutment for an arched bridge according to Figures 1 to 4, which has to take the horizontal thrust of the bridge, the trench corresponding to the form of the abutment to be erected is first removed in wet excavator operation under the protection of a thixotropic liquid. As is shown in Figure 1, the thixotropic liquid 1, which fills the trench, prevents a fall of soil from the sides 2 even if said walls overhang, as is indicated at 3. After excavating the trench, the abutment 4 is concreted in accordance with Figure 2, after placing in position a form 5, the concrete being forced into the thixotropic liquid through pressure pipes. It has been found that separation into the component parts, as is the case with concreting under water, does not take place, and that even the setting of the concrete under liquid pressure results in considerably higher strength values than in the case of setting in the air. The boarding 5, the purpose of which is merely to keep open a narrow gap 6 filled with thixotropic liquid, is withdrawn after the concrete has set.

Now, as shown in Figure 3, a sealing 7, for example of concrete, metal foil or rubber, is introduced at a depth found by geostatic investigations, through which sealing a pressure pipe 8 is passed from above. Thixotropic liquid is forced through this pipe 8 and exerts powerful forces both on the back of the foundation as well as on the right hand wall of the trench, resulting in a shifting of the abutment to the left and hence to a compression of both trench sides. The pressure of the thixotropic liquid is proportioned so as not to exceed the limit of the earth resistance since otherwise plastic failure would occur. The gap 6 filled with thixotropic liquid is concreted under pressure after adequate shifting of the abutment and resulting preconsolidation of the soil. Figure 4 shows the finally concreted abutment. An external force acting on an abutment erected in this way comes against the maximum possible earth resistance without the abutment having first to be displaced under said force.

Similarly, with appropriate modification of the method, it is possible to solve all foundation problems in which it is a question of the preconsolidation of the soil, i. e. the utilisation of the maximum possible earth resistance. The application of the idea underlying the invention always results in a considerable reduction in the costs of foundation, the safety of the building being increased at the same time.

According to Figure 5, thixotropic liquid is injected under pressure below an existing foundation 9, for example through openings 10 driven vertically in the foundation, so that the foundation is lifted as soon as the pressure of the liquid is greater than that of the soil pressure. Pre-

vention against lateral escape of the thixotropic liquid may be obtained by driving in a short stopper wall 11 or by driving in short concrete aprons 12. The foundation may be lifted vertically by any desired amount by forcing in the thixotropic liquid if the length of the stop wall or apron is greater than that of the amount of lift. It is thereby possible to compensate settling which occurs on the loading of yielding soil. Since such settling proceeds very slowly, it is possible to keep the foundation at the desired level, even in the case of most unfavourable soil, by means of an automatic control between the pump 13 which forces the liquid below the foundation, and a measuring device 14 which indicates the settlement of the foundation. For example, the automatic control may be so adjusted that the pump is started when the foundation has settled 1 mm. below the intended position. The pump then forces so much liquid under the foundation necessary for bringing the foundation into its original position. After attaining this position, the pump is automatically stopped. When settling ceases, concrete is forced in through the pipe 15 which up to then has remained shut and the thixotropic liquid is displaced through the pipe 16. In this way, it is possible to erect a building, no matter how fragile on any desired soil, that is to say, however unfavourable, without incurring special costs for laying foundations or deep foundations.

In the embodiment according to Figure 5, the pressure of the liquid is equal in mangitude over the entire underneath surface of the foundation. If the foundation is subjected to an external eccentric loading, it is necessary to keep the pressure of the liquid greater at the more strongly loaded edges than at the opposite edges which, for example, may be attained by making partitions under the foundation which form on the periphery three chambers with the walls and five chambers in the case of three-dimensional eccentricity.

In the crane track beam according to Figures 6 and 7, its foundation 16 is provided with short aprons 17, which may be made either of concrete or of thin metal sheets. Thixotropic liquid 18 is forced in below the footing 16. If a heavy individual load 19 travels over a foundation constructed in this way, the wheel pressure is distributed over the entire surface under the foundation and produces only slight deformations of the soil, however, yielding the latter may be. The settling caused by such slight soil pressure is compensated by pressing up and lifting the foundation, as described in connection with Figure 5.

If the crane track beam extends over unequal kinds of soil, short transverse aprons 20 will be provided at the stratification boundaries, thereby providing a possibility of compensating settling in the more yielding soil stratum by forcing in liquid from below.

Figure 8 shows a compacting device for introduction of thixotropic liquid under pressure. This compacting device consists of a double rubber skin 21, folded at the upper end, a pipe line 22 passing directly through the fold for the introduction and removal of thixotropic liquid and a further pipe line 23 passing through the fold to the lower end of the rubber skin for the injection of concrete.

If it is a question of using higher pressures, the rubber skin will be provided in the vulcanising process with a transverse reinforcement 24 and a longitudinal reinforcement 25 of steel wire. When lowering the compacting device, the lower ends of the rubber skin 21 will be held by a metal sheet 26 bent in the form of a wedge.

As will be seen from Figures 9 and 10, a pipe line 27 may also be provided in the foundation body, through which thixotropic liquid can be supplied to the lower end of the foundation side.

After the rubber skin 21, under the protection of the wedge-shaped metal sheet 26, has been lowered to the desired depth, for example to the lower end of the foundation side face, the rubber skin is distended into the position shown in Figure 10 by means of thixotropic liquid introduced under pressure through the pipe lines 22 and possibly 27, the soil being thereby given the desired preconsolidation. Then, after releasing the pressure, the rubber skin is drawn upwardly by an amount corresponding to its length, and at the same time concrete is forced in through the pipe line 23 with simultaneous displacement of the thixotropic liquid through the pipes 22 and 27. By supplying thixotropic liquid through the pipe line 22, distension of the sides of the rubber skin 21 again takes place with preconsolidation of the soil. This process is repeated until the soil has been preconsolidated to the desired level.

It will be apparent that concreting the space between the foundation and the preconsolidated soil may also take place after the soil has been preconsolidated to the desired height after repeated drawing of the rubber skin.

In many cases, it may be expedient to close the narrow sides of the folded rubber skin, so that the injected thixotropic liquid cannot escape upwardly through these sides.

To facilitate the lowering of the compactor, for example in the form of the folded rubber skin 21, it is possible, as shown in Figure 11, to inject thixotropic liquid through a pipe line 27 provided in the foundation and open at the lower end of the foundation sides, before introduction of the compacting device, said liquid distributing itself on the boundary surface between foundation and soil and forming a gap 28 filled with liquid, in which the lowering of the compactor can be effected more conveniently.

In Figures 12 to 14, a compacting device is made in the form of an oblong entirely enclosed sheet steel box, which is provided on the lower face with a cutter 29 for facilitating the lowering of the box. The side 30 of the box adjacent the soil is perforated and is covered throughout its entire extent with a rubber skin 31. Through the top 32 of the box is passed a pipe line 33, serving to supply liquid under pressure to the interior of the box. A further pipe line 34 passes through the inside of the box and through the cutter 29 situated on the lower end of the box. This pipe line 34 serves to supply concrete. Mounted on the top of the box 32 is a headplate 35 which prevents fall of soil after bringing the box into the higher zones. During the lowering of the box, thixotropic liquid may be supplied through the pipe line 34 to the cutter 29 and the outside of the foundation to facilitate lowering of the box.

After the box has been lowered into the position shown in Figure 12, liquid under pressure is supplied through the pipe line 33 into the inside of the box. The liquid passes through the perforations in the side 30 of the box and distends the rubber skin 31 situated on the outside into the position shown in Figure 13, with preconsolidation of the soil. The liquid under pressure is shut

off, so that the rubber skin 31 again lies against the box side 30, and the box is drawn upwardly. During the upward drawing of the box, concrete is simultaneously forced in through the pipe line 34 and fills the cavity between the preconsolidated soil and the side of the foundation. When the box has been drawn upwardly by the amount corresponding to its length, liquid under pressure is again supplied through the pipe line 33 into the inside of the box and the process described is repeated.

Figures 15 and 16 show the application of the new method to a foundation footing in a region of mining subsidence.

As will be seen from the figures, vertical thin aprons 37, for example of sheet steel, are arranged round the periphery of the footing 36 on its side faces and extend downwardly into the soil. Passing through the foundation footing 36 are pipe lines 38, through which thixotropic liquid 39 is forced under the bottom of the foundation. Lateral escape of this thixotropic liquid beyond the foundation edges is prevented by the apron 37. Outside the foundation edges of the footing 36 is a trench 40, the width of which is to be proportioned in accordance with the dragging or pressing to be expected. Such dragging or pressing, according to figures previously obtained, amounts to about 0.5% to 1% of the length and width dimensions of the footing. The bottom of the trench 40 extends below the bottom of the thixotropic liquid 39 beneath the foundation bottom, but lies above the top edge of the apron 37. On the earth side 41, the trench 40 does not require revetment, since it is filled with thixotropic liquid 42 which prevents any falling from the side of the trench, and exerts in all directions a hydrostatic pressure, which does not substantially increase even if the wall of soil 41 approaches the footing 36 under the action of pressure. In such a case, a corresponding amount of thixotropic liquid 42 will be forced up out of the trench 40. The maximum force acting on the side faces of the foundation can never exceed the pressure of the liquid, however large may be the displacement through dragging and pressing. The force of pressure on the foundation can be reduced to about $\frac{1}{10}$ of the total earth resistance.

Preferably, the trench 40 surrounding the sides of the foundation is provided with a cover 44 and the thixotropic liquid forced out of the trench is discharged through pipe lines 43 opening into the cover. The cover 44 is connected to the footing 36 only by one side but is arranged for horizontal movement relatively to the soil surrounding the footing, as will be seen from the figures.

Displacements of the soil occurring below the bottom of the foundation are likewise unable to result in any action on the footing, since the thixotropic liquid 39 injected below the foundation bottom is practically free from friction, that is to say it does not transmit any horizontal forces.

I claim:

1. Method of improving the stability of foundations, footings and the like, which comprises introducing a body of liquid having thixotropic properties into a zone defined by the two contacting surfaces respectively of the soil surrounding the foundation and of at least one face of the foundation, said liquid being inherently incapable of penetrating into the voids in the surrounding soil due to its thixotropic properties but capable of exerting considerable forces over the entire surface of contact between the body of liquid and the soil equivalent to the hydrostatic pressure of the liquid and uniformly distributed over said entire surface on the principle of the hydraulic press, and establishing the hydrostatic pressure of said body of liquid at a value sufficient to harness the natural resistance of the soil to external forces acting on the foundation.

2. Method of improving the stability of foundations, footings and the like, having laterally directed forces exerted thereon, which comprises introducing a body of liquid having thixotropic properties into a zone defined by the two contacting surfaces respectively of the soil surrounding the foundation and of the side face of the foundation at which the forces are directed, said liquid being inherently incapable of penetrating into the voids of the surrounding soil due to its thixotropic properties but capable of exerting considerable forces over the entire surface of contact between the body of liquid and the soil equivalent to the hydrostatic pressure of the liquid and uniformly distributed over said entire surface on the principle of the hydraulic press, and establishing the hydrostatic pressure of said body of liquid at a value sufficient to precompress the soil at the opposite side face of the foundation in anticipation of the subsequent laterally directed forces, thereby to preconsolidate the soil and harness the natural resistance thereof to the external forces acting on the foundation.

3. Method according to claim 1 wherein the hydrostatic pressure established in the body of liquid is sufficient to return the foundation to an original position from which it has been displaced due to the yielding nature of the surrounding soil.

4. Method according to claim 3 which comprises regulating the quantity of liquid introduced in accordance with the amount by which the foundation has been displaced from its original position.

5. Method according to claim 1 which comprises forming a short vertical apron extending downwardly from each side face of the foundation beyond the base thereof, said liquid being introduced into the chamber defined between the base of the foundation, the soil below the foundation and said aprons.

6. Method according to claim 5 which comprises ramming a rigid vertical sheet down the side face of the foundation to form said apron.

7. Method according to claim 5 which comprises pouring concrete into a cavity positioned below the base of the foundation and in an extension of a side face thereof to form said apron.

8. Method according to claim 5 which comprises forming an additional apron beneath the base of the foundation intermediate the extensions of the side faces thereof thereby to subdivide said chamber, the liquid introduced into the subdivisions of said chamber having different hydrostatic pressures.

9. Method according to claim 8 wherein said additional apron is positioned substantially at the parting line between soils of unequal compactness.

10. Method according to claim 1 which comprises introducing fresh concrete into the space occupied by said body of liquid under a pressure and at a rate suited to displace said body of liquid.

11. Method according to claim 10 which comprises adding a flocculating agent to said liquid

to enhance the displacement thereof by the concrete.

12. Apparatus for improving the stability of foundations, footings and the like, comprising a folded rubber skin, means for lowering the rubber skin to a predetermined depth along a side face of the foundation, a bent metal sheet member embracing and protecting the free lower edges of the rubber skin, means for supplying a thixotropic liquid under pressure into the space defined between the folds of the rubber skin hereby to distend the skin and consolidate the soil in contact with said side face of the foundation, means for forcing fresh concrete into the space occupied by said liquid thereby to displace said liquid, and means for discharging said liquid from said space as it is displaced by the concrete.

13. Apparatus according to claim 12 comprising pipe lines for the supply and discharge of thixotropic liquid extending through said rubber skin at the fold thereof.

14. Apparatus according to claim 12 comprising pipe lines for the supply of thixotropic liquid extending through the foundation and terminating below said rubber skin.

15. Apparatus according to claim 14 wherein said pipe lines terminate at the boundary surface between the foundation and the soil thereby to enable the supply of thixotropic liquid prior to lowering said rubber skin.

16. Apparatus for improving the stability of foundations, footings and the like, comprising an oblong box having a perforated wall at one side thereof and a cutter at the lower edge, means for lowering the box along the side face of the foundation with the perforated wall turned away from the foundation, an external rubber skin covering said perforated wall, and means for supplying a thixotropic liquid under pressure into the inside of the box thereby to distend said rubber skin and consolidate the soil in contact therewith.

17. Apparatus according to claim 16 comprising a pipe line for supplying thixotropic liquid to the edge of said cutter.

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