

Dec. 24, 1968

H. C. DUYSER ET AL

3,417,828

METHOD FOR DRIVING FILES AND SIMILAR OBJECTS

Filed Feb. 3, 1966

2 Sheets-Sheet 1

FIG. 1

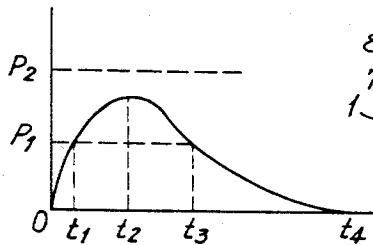


FIG. 4

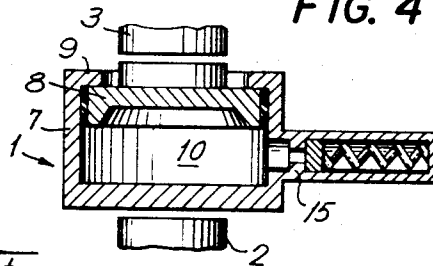


FIG. 2

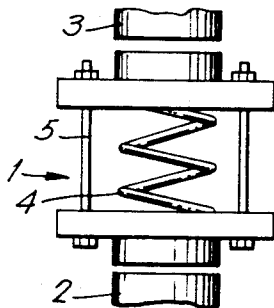


FIG. 5

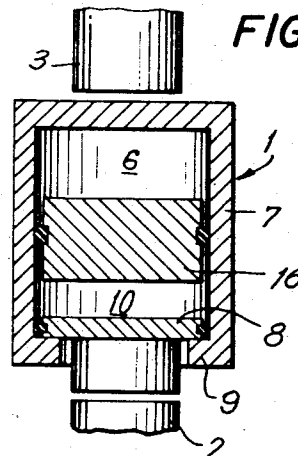


FIG. 3

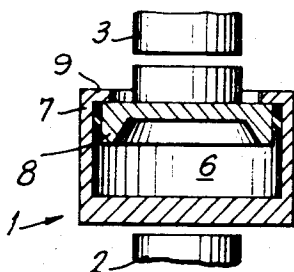
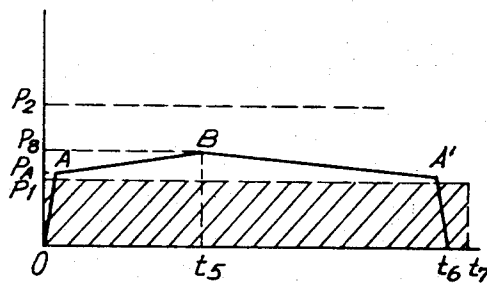


FIG. 6



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FIG. 7

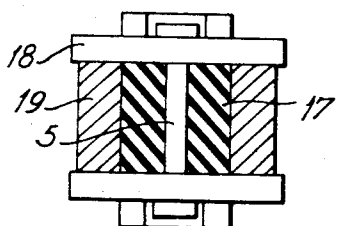


FIG. 8

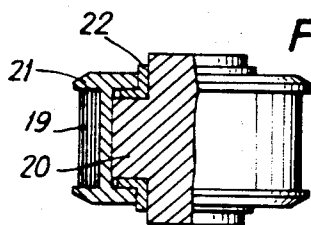


FIG. 9

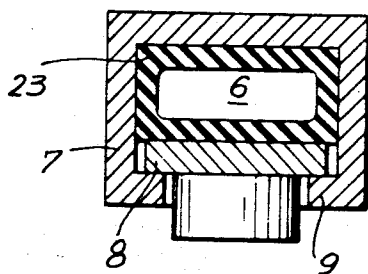


FIG. 11

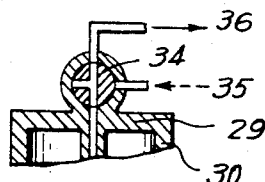
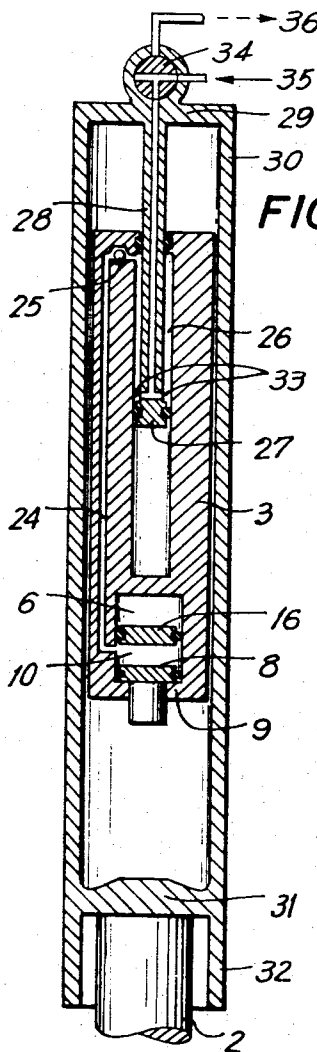


FIG. 10



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METHOD FOR DRIVING PILES AND SIMILAR OBJECTS

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ABSTRACT OF THE DISCLOSURE

A pile driving apparatus having a resilient cap or shoe between the pile head and the hammer, said cap or shoe being precompressible and maintainable in a particular state of precompression such that when the hammer strikes the cap, substantially no energy is lost by dissipation and the maximum impact force which is transmitted through the cap to the pile is less than the critical force at which the pile is damaged.

This invention relates to a method of driving piles and the like, in which use is made of a hammer, which is dropped from some height and transmits its kinetic energy to the pile when the blow strikes the pile head.

The impact force created during the energy transmission from the hammer to the pile may in practice not exceed such a value that the pile head is shattered. In order that the pile may penetrate into the ground, the impact force should however at least reach a minimum value, which depends upon the nature of the ground. If the pile may not be subjected to tensile stresses, or may only be subjected to low tensile stresses, the energy transmission must occur within a minimum time period, which among other factors depends upon the pile length and the impact diagram.

To satisfy the above conditions, a so-called cap is often used, a resilient, but if exceeding a certain compressive force, permanently deformable means, which is placed between the pile head and the hammer. In its usual form the cap comprises a steel jacket, retaining elastic material with stiff resilience, usually composed of hard wood, that must be loaded parallel to the fiber, in the form of a plug, with under it a soft wood filling, which should be loaded perpendicular to the fiber. This cap is considered on the one hand to render a reasonable force distribution on the pile head by elastic deformation, and on the other hand to prevent the impact force, exerted on the pile, from exceeding a value, which is dangerous for the pile, by dissipating a portion of the energy by permanent deformation—scatter—of the wooden filling. The soft wood filling soon loses its deformability so that it is necessary to periodically replace said filling. By using such a cap a time-impact force diagram is obtained, wherein a rather considerable portion of the impact force is usually below the aforesaid required minimum. For that reason also the energy is imperfectly transmitted. Finally, when using such a cap, both the resulting impact diagram and the duration of the impact among others depend upon the deformability of the filling, which decreases as a result of the hammering action, and are both by no means optimally favorable for reducing the aforesaid tensile stresses in the pile. Instead of soft wood other materials, such as rubber and plastics, are used for the filling of the cap, but these also cannot eliminate the disadvantages of the known method. These disadvantages moreover require that for driving longer and heavier piles heavy hammers must be used.

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According to one aspect of the present invention an improved method of driving piles and the like is provided, and an apparatus which may be used for the purpose, in which the kinetic energy of the hammer is more completely utilized, because the useless consumption of energy in the initial and final periods of the impact is avoided and the necessity of dissipating energy by permanent deformation is eliminated by providing a resilient means between the hammer and the pile head, characterized by creating and maintaining a precompression in said resilient means, so that immediately from the beginning under each hammer blow the minimum required force, sufficient to overcome the ground resistance, will be available, while under the impact said resilient means is deformed to a relatively great extent, with a corresponding relatively small increase of the force.

It is a further object of the invention to provide a time-impact force diagram of such favorable form and duration in which even in relatively long piles the creation of tensile stresses with certainty can be avoided. This object is achieved by eliminating the permanent deformation and by proper selection of the resilient means.

In order that the invention and its advantages may be more clearly understood, reference will now be made to the accompanying drawings, in which:

FIGURE 1 schematically shows the graph of the force exerted on the pile during each striking action, plotted in a time-impact force diagram, when using the known cap.

FIGURES 2-5 show the principle of the device according to the present invention.

FIGURE 6 shows a time-impact force diagram obtained by using the device according to the invention, and also the theoretically optimum diagram.

FIGURES 7-9 are sections of various embodiments.

FIGURE 10 is a section of a complete hammer, with a built-in precompressed resilient means in accordance with the invention, in which the value of the precompression is automatically maintained.

FIGURE 11 is a partial view of the top of FIGURE 10 showing the control valve in a different position.

FIGURE 1 schematically represents a stroke diagram, in which the level P_1 indicates the minimum force required to overcome the ground resistance, opposing the penetration of the pile, and P_2 represents the maximum force that is, the force which should not be exceeded in order to prevent damage to the pile. Such a diagram as the following disadvantages:

(1) The energy transmitted from the hammer over the time $O-t_1$ and t_3-t_4 is useless because the impact is then smaller than the force P_1 , which is necessary to overcome the ground resistance.

(2) Because of its more or less triangular shape the diagram has a relatively high apex, so that the critical force P_2 can be reached quite too easy.

(3) The maximum impact force is achieved in a very short time t_2 already, so that when driving relatively short piles, relatively high tensile stresses may occur.

Since by increasing the drop height the time length of the diagram is hardly increased but the maximum impact force does increase, and consequently both the danger of shattering the head of the pile is created and in case of longer piles the creation of non-allowable tensile stresses, in practice the required energy for the driving action cannot be obtained by dropping a hammer of relatively light weight over a great height, but a relatively heavy hammer must be used which requires a heavier installation and is accomplished at the cost of mobility.

In the embodiments according to the invention for the compressible filling of the resilient means, which is mounted between the pile head and the hammer, a ma-

terial or combination of materials is selected, which is capable of resiliently receiving the entire fall energy of the hammer, thus enabled by the said precompression principle, whereby the maximum force created thereby, can be previously determined at a value which prevents damage to the pile.

The thereby obtained time-impact diagram is shown in FIGURE 6, wherein the theoretically optimum diagram is shown in the shaded portion. The diagram clearly shows the following favorable characteristics:

(1) The minimum required force P_1 is very rapidly reached and until practically the last instant of the impact at least maintained, so that no useless energy is transferred to the pile.

(2) The maximum value P_B of the diagram can previously and exactly be determined and with certainty be fixed below the critical value P_2 .

(3) The maximum impact force is not reached until after a relatively long time t_5 , so that only in relatively long piles do tensile stresses occur, which moreover in that case are not proportional to P_B , but to the so much smaller value $P_B - P_A$. As a result of the relatively long impact duration t_6 , the invariable minimum value of which may previously be determined, only in very long piles can tensile stresses of any significance exist, which in such case are proportional to P_B .

The improved apparatus according to the invention is substantially based on the following principles:

(1) The construction 1, positioned between the pile head 2 and the hammer 3, which will be elastically deformed by the dropping hammer 3 during the impact, is already precompressed to a certain extent by a force, operating in the same direction as the impact force of the hammer 3.

Compression of the construction 1 by the falling hammer 3 will not be possible until the impact force has reached the value used for the precompression. FIGURE 2 shows an example hereof, in which the helical spring 4 is precompressed by tightening the bolts 5.

(2) The elastic material 6, which will be compressed by the hammer 3 is precompressed under uniform pressure, so that compression is not possible until the impact force of the hammer 3 has created the same pressure in the elastic material 6. FIGURE 3 shows an example hereof, in which in a cylinder 7 under a piston 8 a gas 6 is precompressed, with a collar 9 of the cylinder 7 limiting the stroke length of the piston 8.

(3) The medium 10, which must be deformed by the hammer 3, is substantially incompressible, but readily deformable. This deformation is opposed by an elastic construction 11, which is precompressed, so that deformation by hammer 3 is not possible until the impact force has created a pressure in the medium 10, which is equal to the precompressed. FIGURE 4 shows an example hereof, within a cylinder 7 under a piston 8 a liquid 10 being present, which is precompressed by a piston 12, on which in the housing 13 the spring 14 operates. The collars 9 and 15 limit the stroke lengths of the respective pistons 8 and 12.

(4) In the housing 7 is a flying piston 16 having on one side the incompressible, but readily deformable medium 10 and on the other side the gaseous medium 6. At one end of the housing 7 is closed by the piston 8, with the stroke length thereof being limited by the collar 9, as is indicated in FIGURE 5. The medium 10 is precompressed by means of the gas 6.

The stroke diagram of all the basic embodiments may be represented schematically as shown in FIGURE 6. The buckling point A in the diagram will be at a pressure level P_A determined by the precompression. The displacement to reach A is determined by the deformation of the stiff-elastic construction 1 as a result of the precompression, that is the elongation of the bolt 5 in FIGURE 2, the deformation of the cylinder 7 and the collar 9 in FIGURES 3, 4 and 5. Since said construction 1, in view

of the great forces, will be very stiff, the displacement to reach point A will be small, so that the graph OA in the diagram will be very steep.

The following part AB of the graph is determined by the force required to deform the resilient construction, that is the spring 4 and 14 respectively in FIGURES 2 and 4 and the gas column 6 in FIGURES 3 and 5, so that the slope of AB can be adjusted within wide limits by the selection of materials and volumes.

According to the invention there are selected, firstly, such a precompressed in the resilient means that the buckling point A will be above or at least close to the level P_1 (FIGS. 1 and 6) which indicates the minimum force required to overcome the ground resistance opposing the penetration of the pile, and secondly, such a low modulus of elasticity of the resilient means that the point B will remain below the level P_2 which represents the force which should not be exceeded in order to prevent damage to the piles. Accordingly the pile cannot be damaged, even if the pile does not penetrate at all. The deformation in the resilient means will proceed entirely elastic, so that in said means little or no energy is lost.

According to the invention the steep onset of the graph OA in the diagram according to FIGURE 6 has moreover the great advantage, that the extent of the deformation of the elastic means under the influence of the blow is limited in proportion to the energy transmission, so that the development of heat in the elastic means remains low, which is affirmed by experiments. Thus, materials may be used, which without precompression would soon be unusable because of heating.

FIGURE 7 shows a basic drawing according to the invention, in which the gas of FIGURE 3 is replaced by a cylindrical element 17 of soft rubber or similar material, which is retained between steel plates 18, linked by one or more bolts 5, and in which a uniform precompression is created without deformation by a binding 19 with a string which is wound under stress, or a strip of an elastic material such as rubber.

FIGURE 8 shows a suitable further development of the principle of FIGURE 4, in which the core 20 of rubber or similar material is enclosed by a hollow metal cylinder 21, composed of adjacent thin radial lamellas, bearing upon the metal edges 22. The hollow cylinder 21 is wrapped with a string or similar strip of elastic material 19 under stress. With sufficient load the core 20 can push the lamellas 21 of the cylinder apart against the force exerted by the material 19.

FIGURE 9 shows a suitable further development according to the principle of FIGURE 3, in which, however, the gaseous medium 6 is precompressed in a deformable envelopment 23 of rubber or similar material, which is supported on all sides by the housing 7 and the therein located piston 8, with the displacement of which is limited by the collar 9.

FIGURES 10 and 11 show a complete pile driving apparatus according to the invention, of which the hammer incorporates the precompressed resilient means, with means whereby the value of said precompression is automatically maintained. The hammer is provided at its lower end with the resilient means according to the principle of FIGURE 5, in which the space with the liquid medium 10 being connected thru a conduit 24, incorporating a non return valve 25, sealing in both directions, with the space 26 above the piston 27 in a vertical bore in the hammer 3. The piston 27 is carried by a hollow piston rod 28 which is integral with or fixed to the end wall 29 of a housing 30 in which the hammer 3 moves, the bottom of the housing 30 being provided with an anvil plate 31, and guiding means 32 for the pile 2. The hollow piston rod 28 is provided at the lower end with openings 33 communicating with the space 26 above the piston 27, and is connected at its upper end to a three-way control valve 34 carried by the end wall 29. The three-way con-

trol valve can be operated to connect the hollow piston rod through a conduit 35 with a pump for pumping and compressing the liquid medium (FIGURE 10), or to a conduit 36 (FIGURE 11) discharging into the liquid supply tank. The spaces or conduits 10, 24, 26, 28, 35 and 36 are continuously filled with the liquid medium. The liquid in the space 10 also serves as a seal to prevent leakage of the compressed gas 6.

The operation of the apparatus is as follows:

With the three way valve 34 in the position of FIGURE 10 liquid is introduced under pressure through conduit 35 and the hollow piston rod 28 and openings 33 into the space 26. This hydraulic pressure on the effected piston area of the piston 27 causes an upward force on the hammer 3, which moves upward in the housing 30 with a velocity, which is dependent upon the pump capacity. When it reaches its uppermost position, the hammer 3 produces an impulse which causes the three way control valve 34 to change from the position shown in FIGURE 10 to the position shown in FIGURE 11, so that the space 26 above the piston 27, which is filled with the liquid medium, is now in open communication through the openings 33, and the hollow piston rod 28 with the discharge conduit 36. The hammer 3 can fall freely in the housing 30 under the force of gravity, the liquid medium being expelled from the space 26 without causing resistance, since the channels and conduits are of sufficiently large dimensions. In its lowermost position, the hammer 3, through its ram 8 which projects below the bottom of the hammer, hits the anvil plate 31 and transmits its kinetic energy to the pile 2. A relatively thin plate of a suitable material (not shown) may be located between the anvil plate 31 and the pile 2 to ensure a uniform force distribution on the pile head. During this impact the precompressed resilient means situated at the bottom of the hammer 3, will function according to the diagram of FIGURE 6. Depending upon the energy absorption by the pile 2, which is again dependent upon the resistance of the ground, the hammer 3 will more or less bounce up in its housing 30, at the time of impact an impulse is produced to operate the three-way control valve 34 to change its position back to that shown in FIGURE 10, whereby the space 26 above the piston 27 is again pressurized by the pump and the hammer 3 is moved. To maintain constant the compression of the gas 6 in the cylinder chamber above the free piston 16, during each upward movement of the hammer 3, a communication is established via the non return valve 25 and the conduit 24 with the liquid filled space 10 below the piston 16. By employing a return valve 25 of such construction that it will only open until a preliminary determined and adjustable pressure valve, and provided that this value is below the pressure which must be created in space 26 in order to move the hammer 3 upwards, it is possible to ensure that, during each upward movement of the hammer 3, the desired pressure of the liquid medium in the space 10 will be automatically maintained or restored prior to the next impact. The herein described method is adaptable to a fully automatically operating hammer. The transferred energy can be regulated during the operation by modifying the drop height, which could, for example, be accomplished by producing the impulse for changing the three way control valve 34 from the position shown in FIGURE 10 to the position shown in FIGURE 11, before the end of the upward movement of the hammer 3. Externally operated means may be provided for adjusting when said impulse is automatically created. A further refining for increasing the efficiency of the apparatus consists in providing an accumulator in the supply conduit 35, so that the intermittently required maximum output from the pump can be obtained by a continuous output, from a smaller pump.

It should be understood that the present disclosure is for the purpose of illustration only, and that this inven-

tion includes all modifications and equivalents which fall within the scope of the appended claims. Accordingly the invention may, for example, be applied to driving into the ground of embankment constructions and other similar objects, and, in fact to any application where the characteristic of the precompressed resilient means is utilized, irrespective of the ultimate purpose of its use.

We claim:

1. A method for driving a pile comprising applying an impact force to a regulable resistance device interposed between the force and a pile to be driven, adjusting the resistance in said device such that upon initial application of the force to the device, the force is unyieldingly resisted such that the force builds up to a predetermined intensity above a particular minimum value, after which the force is transmitted to the pile by said device at an intensity level below a predetermined maximum value as established by the magnitude of resistance adjustment.

2. A method as claimed in claim 1 wherein said resistance in said device is adjusted to a particular value such that when the applied force exceeds a preestablished maximum intensity, the resistance yields and transmits to the pile a force which is lower than a preestablished maximum value which is to be applied to the pile.

3. Apparatus for the driving of a pile by the blows of a hammer, said apparatus comprising means in the path of the hammer for receiving the blows therefrom and for transmitting, to the pile to be driven, a force which has a value between a predetermined minimum and a predetermined maximum, said means comprising a regulable and precompressible device adjusted to a predetermined elastic resistance for receiving the energy of the blows and for transmitting said energy to the pile as a force which has a value between said minimum and maximum.

4. Apparatus according to claim 3 wherein said regulable and precompressible device includes a compressible substance and means for precompressing the substance to a preestablished degree whereby the latter has a predetermined elastic resistance for transmitting the energy of the blows to the pile.

5. Apparatus according to claim 3 wherein said precompressible device includes a cap containing a compressible substance.

6. Apparatus according to claim 5 wherein the means for precompressing the substance comprises at least one elastic tie connection.

7. Apparatus according to claim 4 wherein said substance is a gaseous medium and said means for precompressing the substance includes a device for directly compressing the gaseous medium.

8. Apparatus according to claim 3 wherein said substance is a liquid medium.

9. Apparatus according to claim 5 wherein said cap comprises a solid material of elastic composition.

10. Apparatus according to claim 9 wherein said cap comprises an upper and a lower plate, said elastic material being retained between said plates, at least one tie bolt connecting said plates so that a precompression of the elastic material may be effected.

11. Apparatus according to claim 4 wherein said compressible substance is a rubber core and said precompressing means comprises elastic material wound on said core with prestress.

12. Apparatus according to claim 11 wherein said precompression device includes a hollow metal cylinder comprising adjacent thin radial lamellas, which are centered by edges, said rubber core being disposed in the cylinder, said prestressed elastic material encircling said cylinder.

13. Apparatus according to claim 4 wherein said precompressible device includes a cap, said substance being a gaseous substance, and a rubber container in said cap for containing the gaseous substance.

14. Apparatus according to claim 4 wherein said precompressible device includes a cap, said substance being a gaseous substance, said cap defining a space for said

gaseous substance, said means for precompressing the substance including a piston closing said space in part and in contact with the gaseous substance, and means for displacing the piston to regulate the pressure of the gaseous substance in said space.

15. Apparatus according to claim 3 wherein said hammer and said precompressible device are constituted as a unitary assembly which includes a housing containing said hammer and said precompressible device.

16. Apparatus according to claim 15 wherein said precompressible device defines a space containing said compressible substance which is a gaseous medium, said precompressing means comprising a piston bounding said space in part and in contact with the gaseous medium therein, and means for displacing the piston under the pressure of a liquid medium to regulate the pressure of the gaseous medium in said space.

17. Apparatus according to claim 16 wherein said space and piston are contained in the hammer which moves up and down, and said precompressing means includes means for regulating the pressure of said liquid medium, which acts on the piston, during each upward movement of the hammer.

18. Apparatus according to claim 17 wherein said precompressing means comprises a valve means for controlling the supply of the liquid medium to the piston and the means for regulating the pressure of the liquid medium includes a non-return valve between said piston and the valve means for maintaining the pressure of the liquid acting on the piston at a constant value during upward movement of the hammer.

19. Apparatus according to claim 18 wherein said

assembly comprises a hollow piston fixed in said housing, said valve means being a three-way valve coupled to the hollow piston for selectively supplying the same with pressurized liquid medium or withdrawing the pressurized liquid medium, said hammer being slidably mounted on said hollow piston, said hammer having a passageway connecting the hollow piston with the movable piston via said non-return valve, said hammer having a chamber surrounding the hollow piston which is adapted for receiving the pressurized liquid medium to raise the hammer.

20. Apparatus according to claim 19 wherein said three-way valve is operated in synchronization with the piston to connect the three-way valve in alternation with the supply of pressurized liquid medium and exhaust.

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U.S. Cl. X.R.

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