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(54) SUBMERGIBLE PILE DRIVING METHOD AND APPARATUS FOR CONTINUOUS OPERATION

(71) We, HOLLANDSCHE BETON GROEP N.V., a Dutch Company, of Generaal Spoorlaan 489, Rijswijk, The Netherlands, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates in general to a method and apparatus for subaqueous pile driving at considerable depth, comprising a vessel having a hoisting device and a pile driving device which is mounted for substantially vertical movement in a subframe which is connected to the hoisting device.

During sub-aqueous pile driving the pile driving device is supplied with hydraulic energy for its operation, and there should be a hydraulic return line. Electric lines are also required for carrying out measurements which may be read on the ships so that the personnel in charge can properly monitor and control the operation. Underwater television may be provided, and compressed air supplied to a casing embracing the pile driving device to provide air in the region where the ram strikes the head of the pile. At a considerable driving depth this means that considerable lengths of several hoses have to be lowered, which not only requires large reels with a full stock of hoses but results in the hoses easily becoming entangled. Further, when the pile driving apparatus is suspended from the hoisting device by a flexible cable, the cable presents an obstruction over a considerable portion of its length. The flexible cable also permits the pile driving apparatus to rotate about the vertical axis, which increases the problems that already exist with hoses.

From one aspect, the present invention consists in apparatus for sub-aqueous pile driving at considerable depths, comprising a vessel having a hoisting device and a pile driving device which is mounted for substantially vertical movement in a subframe which is guided on guiding cables extending downwardly from the vessel and which is connected to the hoisting device by means of torsion resisting tube sections which form a string of tube sections and which also serve as supports for conduits for the supply of hydraulic fluid, compressed air and electricity to the pile driving device, which conduits extend from the vessel towards the pile driving device, and between the subframe and the pile driving device said conduits are formed by flexible hoses, along the tube sections said conduits are formed by tubes attached to the tube sections and between the vessel and a coupling piece included in the string of tube sections, said conduits are formed by further flexible hoses.

Since the major part of the distance between the hoisting device and the pile driving device which has been lowered is taken up by a tube string, the drawbacks arising from the tendency of the apparatus to twist and the elasticity of the cable are avoided, since the tube string has a higher torsional stiffness and a substantially lower elasticity in the longitudinal direction.

Furthermore, since the parts of the conduits formed by the tubes are attached to the tube string these tubes are no longer suspended in loose coils. Inasmuch as during the pile driving process relative movement between the subframe and the pile driving device must be possible, the hoses extending between the subframe, to which the lower end of the tube string is connected and the pile driving device have a length which is dependent upon the length of the reciprocal movement of the pile driving device.

By using tube sections, it is possible to lower the pile driving device in a stepwise manner. This is no disadvantage during the lowering of the pile driving device. During the pile driving process it may be necessary to connect additional tube sections as the driving progresses thereby maintaining sufficient rigidity of the connection between the hoisting device and the subframe throughout the driving range. It is no longer necessary to run the tube parts of the supply conduits along said additional tube sections

during pile driving because the energy to the pile driving device is supplied continuously via these tube parts which are attached to the initial tube string sections. Thus, said additional tube sections may be connected without interruption of the pile driving process. The lengths of the further hoses, and the coupling piece to which they are connected at the upper end of the tube string make it possible to continue the pile driving without interruption because the energy supply is continuous.

The connection between the tube parts of the supply conduits attached to the tube string, preferably also consists of a coupling piece included in the lowermost tube section of the tube string. The coupling piece which is nearer the upper end of the tube string may be provided with connecting members having stop valves therein, if necessary, with remote control. This is of particular importance for the supply of hydraulic fluid since the stop valves permit disconnection of the upper coupling piece without loss of fluid pressure and to ready it for the next operation. In addition, individual measures can be taken for blowing out the supply conduits with pressurized fluid, at least those parts of them attached to the tube string, and for bleeding them.

The further hoses connecting the upper coupling piece with appropriate sources of energy on the vessel preferably run over rollers disposed on either side of the centre line of the tube string, and thus these hoses may be suspended in the water next to the ship without any problem. No reels are required, which simplifies the apparatus.

From another aspect, the present invention consists in a method of continuous sub-aqueous pile driving in which a pile suspended from cables on a ship is lowered to the sea bottom by paying out the cables, a subframe in which a pile driving device is mounted for vertical movement is lowered with the pile or after lowering of the pile, the pile driving device is brought into engagement with the top of the pile and hydraulic fluid, compressed air and electrical energy are supplied to the pile driving device through conduits which include flexible hoses extending between the pile driving device and the subframe, characterized in that the subframe and thus the pile driving device is guided along the cables in its descent by sequentially connecting a plurality of torsion resisting tube sections together in a continuous string, with the lowermost tube section being connected to the subframe and the uppermost tube section being suspended from a hoisting device on the ship, said tube sections having attached thereto tubes forming parts of said supply conduits, coupling a coupling piece for the said tube sections upper end of the tube string prior to operating the pile driving device with the pile in contact with the sea bottom, coupling further flexible hoses forming parts of said supply conduits to the coupling piece, operating the pile driving device, and connecting additional tube sections into the tube string above the coupling piece as the pile driving progresses, whereby energy is continuously supplied to the pile driving device via said supply conduits, and the pile driving may therefore continue uninterrupted as the additional tube sections are connected into the string.

For the purposes of the invention it is not important whether the pile and pile driving device are lowered simultaneously, or whether the pile is first lowered and subsequently the pile driving device is lowered onto it.

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

Figure 1 is a diagrammatic view of an apparatus constructed in accordance with the invention preparatory to pile driving;

Figure 2 shows the situation when the pile driving device of the apparatus of Fig.1 has been lowered; and

Figures 3 and 4 are diagrammatic views of the lower part of Figure 2 during the process of pile driving;

Figure 1 shows a vessel in the form of a ship 1 and a hoisting device constituted by a crane 2, as well as an extended cantilever platform 3 from where the pile driving operations take place. The ship carries two winches 4 with cables 5, and a pile 7 is suspended on the cables by means of a disconnectable crossbar 6.

Figure 1 shows the situation in which the pile has already been slightly lowered and a pile driving device 8 has already been disposed on the head of the pile, said device being mounted for substantially vertical reciprocating movement in a subframe 9. The subframe is provided with an upper crossbar 10 on which a tube section 12 is secured via a coupling piece 11, said tube section being suspended on a hoisting cable 14 of the crane 2 by means of a detachable eye 13. Reference numeral 15 indicates a rack with tube sections 12. For connecting or detaching a tube section, a tube string formed of tube sections 12 is supported on the cantilever platform 3 by means of supporting beams 16 which project beneath the flange of the uppermost tube section and which are movable into and out of supporting engagement with this tube section. The lowering and lifting of the tube string, thus, takes place in a stepwise manner. One or more hoses 17 are present between the crossbar 10 and the pile driving device 8.

Figure 2 shows the situation at the end of the process of lowering, in which the pile and pile driving device have reached the ocean floor. It can be seen from Figure 2 that the pile driving device is suspended on a string of tube sections 12 by means of subframe 9 and crossbar 10, in which tubes in the form of pipelines 18 and 19 run along each tube section. These pipelines may consists of pipe lengths or of hoses or pieces of hoses clamped on the tube string by means of spring clips or the like. The

couplings between the pipelines on the sections of the tube string may be implemented in a variety of ways well known in the art. Such couplings may be made manually as additional tube sections 12 are added to the string, or may be made automatically by male and female coupling members provided in the tube section flanges which mate as the sections are joined.

The upper section of the tube string has a coupling piece 20 with connecting members 21, 22 having stop valves 23, 24 therein. Further hoses 25 and 26 are coupled to the connecting members, pass over rollers 27 and 28, and run downwardly to hang in the water. Their ends are connected to appropriate sources of energy, including hydraulic fluid, compressed air and electrical energy, on the ship.

Thus, the hoses 25, 26, pipe lines 18, 19 and hoses 17 form together, conduits for the supply of hydraulic fluid, compressed air and electricity to the pile driving device.

The hoses 25 and 26 should have such a length that the pile can be driven into the ground without interruptions, since interruption of the process of pile driving means that when resuming the process again a higher initial resistance has to be overcome, which is time consuming and a waste of energy. Therefore, hoses 25 and 26 should have a length which is related to the distance to be covered by the pile driving device and said distance, again, depends on the length of the pile to be driven into the soil.

Whereas Fig. 2 illustrates the position of the subframe and the pile driving device with respect to each other at the end of the process of lowering, Fig. 3 illustrates the position of pile driving device 8 and subframe 9 in relation to each other at the beginning of the process of pile driving. The upper cross bar 10 of the subframe is spaced by a distance 30 from the pile driving device, said distance being required to compensate for the movement of the ship 1 in a seaway.

Figure 4 shows the position of subframe 9 and pile driving device 8 with respect to each other after covering a distance 31, which forms part of the complete distance to be covered during pile driving.

During the pile driving process the subframe is stationary and it is therefore possible to connect a new tube section 12 to the upper end of the tube string without interrupting the process. When the position illustrated in Fig. 4 has been reached with a distance 30′ between the lower crossbar of the subframe 9 and the pile driving device 8, said distance being required to compensate for the movements of the ship, it is then possible to bring the subframe again into the position shown in Fig. 3 without interrupting the pile driving process.

WHAT WE CLAIM IS:—

1. Apparatus for sub-aqueous pile driving at considerable depths, comprising a vessel having a hoisting device and a pile driving device mounted for substantially vertical movement in a subframe which is guided on guiding cables extending downwardly from the vessel and which is connected to the hoisting device by means of torsion resisting tube sections which form a string of tube sections and which also serve as supports for conduits for the supply of hydraulic fluid, compressed air and electricity to the pile driving device, which conduits extend from the vessel towards the pile driving device, and between the subframe and the pile driving device said conduits are formed by flexible hoses, along the tube sections said conduits are formed by tubes attached to the tube sections and between the vessel and a coupling piece included in the string of tube sections said conduits are formed by further flexible hoses.

2. An apparatus as claimed in claim 1, wherein the coupling piece is provided with connecting members coupled to said further hoses and having stop valve therein.

3. An apparatus as claimed in claim 1 or 2, wherein rollers are provided on the vessel for guiding the further hoses.

4. A method of continuous sub-aqueous pile driving in which, a pile suspended from cables on a ship is lowered to the sea bottom by paying out the cables, a sub-frame in which a pile driving device is mounted for vertical movement is lowered with the pile or after lowering of the pile, the pile driving device is brought into engagement with the top of the pile and hydraulic fluid, compressed air and electrical energy are supplied to the pile driving device through conduits which include flexible hoses extending between the pile driving device and the subframe, characterized in that the subframe and thus the pile driving device is guided along the cables in its descent by sequentially connecting a plurality of torsion resisting tube sections together in a continuous string, with the lowermost tube section being connected to the subframe and the uppermost tube section being suspended from a hoisting device on the ship, said tube sections having attached thereto tubes forming parts of said supply conduits, coupling a coupling piece for the said tube sections to the upper end of the tube string prior to operating the pile driving device with the pile in contact with the sea bottom, coupling further flexible hoses forming parts of said supply conduits to the coupling piece, operating the pile driving device, and connecting additional tube sections into the tube string above the coupling piece as the pile driving progresses, whereby energy is continuously supplied to the pile driving device via said supply conduits, and the pile driving may therefore continue uninterrupted as the additional tube sections are connected into the string.

5. A method as claimed in claim 4, wherein the addition tube sections are connected in to the tube string by supporting the upper end of the tube string on support means on the ship, disconnecting the hoisting device from the tube

string, connecting an additional tube section into the string, connecting the hoisting device to the added tube section, and removing the support of the support means from the upper end of the tube string.

6. A method of continuous subaqueous pile driving, substantially as hereinbefore described with reference to the accompanying drawings.

7. Apparatus for subaqueous pile driving, constructed arranged and adapted to operate substantially as hereinbefore described with reference to the accompanying drawings.

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CHARTERED PATENT AGENTS

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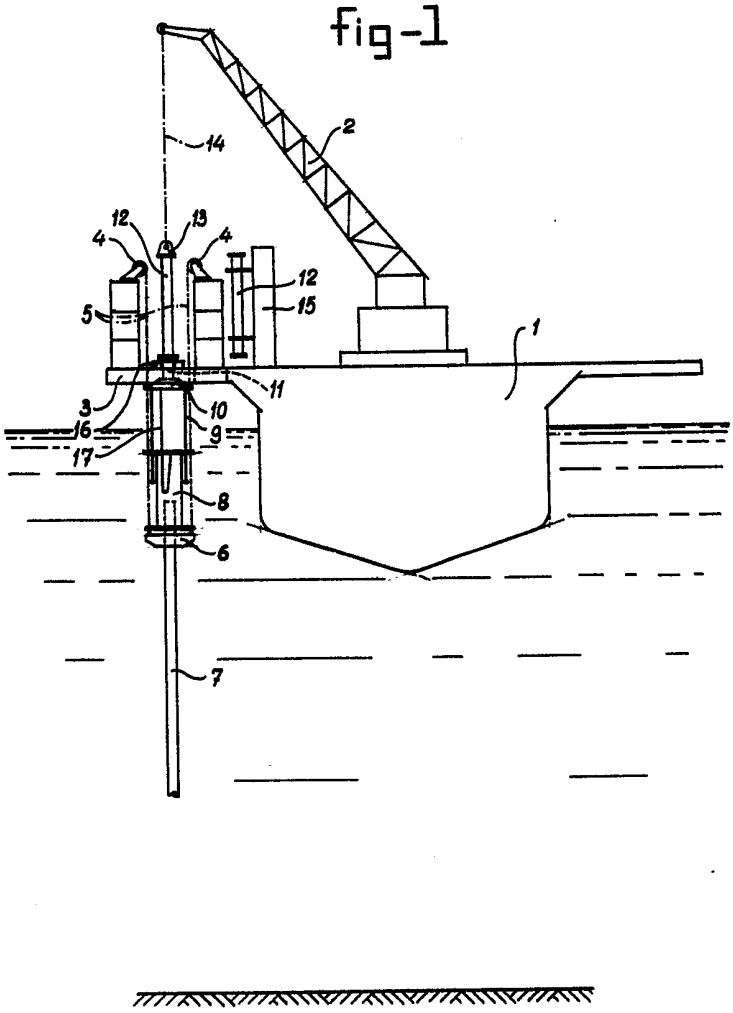
3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

fig-1



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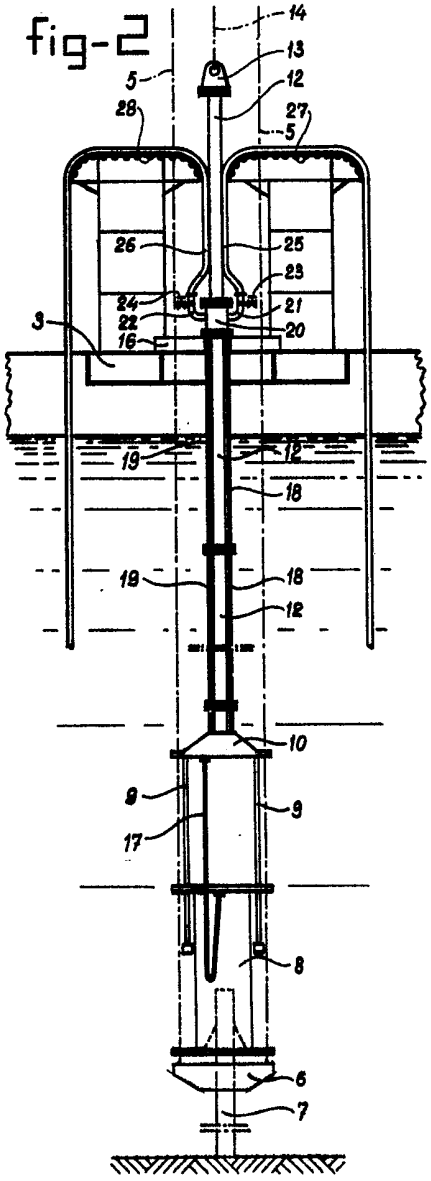
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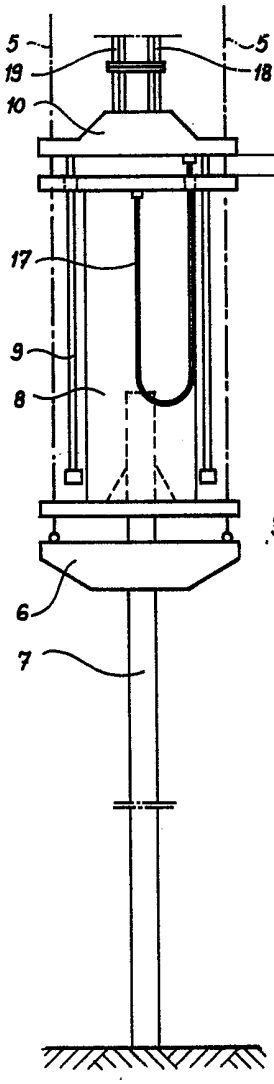

fig-4