The invention relates to a pile installation frame comprising one or more tubular noise reduction elements (1, 31, 32, 33) having a cylindrical wall (2) and a center line (8). The elements (1, 31, 32, 33) are along their length provided with spaced-apart positioning devices (12, 13, 14) that are radially retractable with respect to the centerline, for centering a pile (7) driven through the tubular element (1, 31, 32, 33) along the center line (8). The positioning devices are retracted when the hammer passes downward into the space bounded by the cylindrical wall.

Fig 2
Description

Field of the Invention

[0001] The invention relates to a pile installation frame comprising one or more tubular noise reduction elements having a cylindrical wall. The invention also relates to a method of driving a pile into the sea bed using such a pile installation frame.

Background of the Invention

[0002] From Cowrie Eng-01-2007 (ISBN 13 978-0-9554279-4-7) a number of solutions are known for mitigating harmful and disturbing underwater noise generated when driving large piles into the sea bed, for instance when installing foundations for offshore wind turbines. When driving steel piles of diameters of 2 to 4.5 m and weighing up to 400 tons into the sea bed using hydraulic piling hammers, the noise that is generated can be mitigated by providing a air bubble curtain around the piles or by using a cylindrical silencer member around the pile. This cylindrical construction can be formed of telescopic elements resting on the sea bed and projecting above water level, or by a foam-coated steel tube that is lowered around the pile via a crane.

[0003] It is also known to use a silencer frame in the form of a tripod having three interconnected hollow cylindrical legs, which frame is transported in a horizontal orientation on a barge to the installation site where it is placed into a vertical position onto the sea bed for driving piles through the hollow legs of the frame.

[0004] It is an object of the present invention to provide a silencer frame and an installation method which mitigate harmful noises when driving piles into the sea bed, which results in reliable and accurate installation of the piles and which allows handling of a variety of differently sized piles.

[0005] It is a further object of the present invention to provide a silencer frame which allows accurate positioning of the frame onto the sea bed and which provides accurate control of the pile position.

[0006] It is again an object of the invention to provide a silencer frame allowing adequate access to the pile head during hammering the pile into position.

Summary of the Invention

[0007] Hereto the cylindrical walls of the pile installation frame according to the invention are along their length provided with spaced-apart positioning devices that are radially retractable with respect to the centerline, for centering a pile driven through the tubular element along the center line.

[0008] The centering devices may comprises retractable elements that are hydraulically, pneumatically or electrically driven to be displaceable in a radial direction from the inside of the cylindrical walls towards the center line. When starting driving a pile into the sea bed, the pile is placed within the confines of the cylindrical wall and all centering members are extended to press against the pile. In this way, the pile is aligned along the center line of the cylindrical wall, with its top part extending above water level. Next, the piling hammer is placed on the pile head and the pile and hammer are driven downward into the space of the cylindrical wall. When the pile is lowered, the upper positioning devices are retracted when the pile reaches the axial direction directly above the upper positioning devices to allow the pile hammer to pass along these upper positioning devices when the pile is driven down into the sea bed.

[0009] The radial displaceability of the positioning devices furthermore allows accurate centering of different diameter piles, which piles may range in diameter from 1 m to 2.5 m.

[0010] The positioning devices may with one end be connected to the inner surface of the cylindrical wall and can comprise at a free end a sliding or rotating member for providing a sliding or rotating contact with a pile that is driven along the center line.

[0011] The positioning devices may for instance comprise a bar linkage, a scissor mechanism, a linear motor or the like, connected with one side to the inner wall and provided with hydraulic, pneumatic or electrical power and control leads that extend to above the water surface. At the free ends of the extendable element of the positioning device a wheel or slide pad is provided for rotationally or slidingly engaging with the outer surface of the pile when it is driven into the sea bed. The wheel or slide pad may be formed of reinforced natural or synthetic rubber, PTFE, nylon or combinations thereof to result in reduced friction upon contact with the moving pile.

[0012] In a preferred embodiment, the installation frame comprises two or more cylindrical walls, interconnected via frame members, the frame comprising a lifting member attached to the frame members for connection to a lifting device. By integrating a number of cylindrical walls via frame members, a foundation pile configuration comprising multiple piles, can be applied onto the sea bed in a single step, for instance from a crane vessel having a crane or an A-frame for lifting of the frame member and for lowering it on to the sea bed and releasing the frame at the site of deployment. The weight of the installation frame may range from 500 to 5000 tons, such as for instance about 1200 ton.

[0013] Alternatively, the pile installation frame according to the invention may be provided with ballastable buoyancy tanks, and can be towed to the installation site, after which the frame is ballasted such that the cylindrical chambers come to rest on the sea bed.

[0014] In a further embodiment, the installation frame comprises at the bottom a leveling member for instance comprising a hydraulic cylinder or an expandable body of adjustable volume, connected to a volume control member above water level for leveling the cylindrical wall by varying the volume of the member. Such a leveling
member may comprise a plate that rests near the lower edge of the cylindrical chamber on the sea bed. The cylinder or the expandable body and may be actuated or be inflated with air, water or mud to increase its volume, respectively, in order to result in a vertical orientation of the center line of the cylindrical chambers and a consequent vertical application of the foundation piles into the sea bed.

In a further embodiment, the cylindrical wall comprises an inner and an outer wall and is divided into compartments, the compartments being connected to a pressurization device for adjusting the pressure in the compartments depending on the water depth of the compartment. The chambers may have a height of 20 meters or more, and may have compartmented hollow walls for effective damping of noise. By pressurizing each compartment to a level corresponding to its depth below water, the water pressure forces may be equalized and deformations due to the water pressure on the compartments may be prevented.

Brief description of the drawings

Figs. 1-3 show different stages of the process of driving a pile into the sea bed and corresponding radial positions of the positioning devices, Figs. 4 and 5 show schematic cross-sectional views of a triangular and a rectangular pile installation frame of interconnected cylindrical walls, Fig. 6 schematically shows a work vessel lowering a pile installation from onto the sea bed via a crane, Fig. 7 schematically shows a work vessel towing a ballastable pile installation frame to the site of deployment, Fig. Fig. 8 schematically shows the different control lines connecting the pile installation frame to the work vessel, Fig. 9 show a pile installation frame using pressure compensated compartments and a bubble curtain, and Fig. 10 shows a detail of a leveling member according to the invention.

Detailed description of the invention

Fig. 1 shows a cross-sectional view of a tubular noise reduction element 1 comprising a cylindrical wall 2 resting with a lower end 6 on the sea bed 3 and projecting with an upper end 4 above water level 5. A foundation pile 7, for instance for forming a foundation of an offshore wind turbine, is placed along a longitudinal center line 8 of the cylindrical noise reduction element and is hammered into the sea bed 3 via the hydraulically operated hammer 10. Control lines for the hammer 10 are attached to a working vessel that is not shown in the drawing.

The pile 7 is guided inside the cylindrical wall by extendable positioning devices 12, 13 and 14. These positioning devices may comprise a scissor arm 15 with at the end a guide wheel 16. The scissor arms of the positioning devices 12-14 may be electrically, hydraulically or pneumatically controlled from the working vessel. When the pile 7 is hammered into the sea bed by the hammer 10, the pile slides along the wheels 16 while it is aligned along the longitudinal center line 8 by the inwardly directed radial pressure exerted by the positioning devices 12-14.

When the pile 7 is driven down into the sea bed 3 and the hammer 10 passes the upper end 4 of the cylindrical wall 2, the arms 15 of the upper positioning device 12 are retracted towards the wall 2, such that the hammer 10 can freely pass along the positioning device 12, while the lower positioning devices 13, 14 remain engaged with the pile 7.

As can be seen in figure 3, middle positioning devices 13 are retracted when the hammer passes along the mid part of the cylindrical wall 2. For retraction and/or expansion, the arms 15 of the positioning devices 12,13,14 are connected to electrical, hydraulic or pneumatic drive members 17,18,19 that are in turn attached to control lines running to a working vessel, or which may be operated via ultrasonic commands from the working vessel.

The cylindrical walls 2 may be double-walled having an inner wall 20 and an outer wall 21. The space between the walls 20, 21 may be filled with an insulating foam, air bubbles or may be empty for achieving the desired reduction of noise generated by the hammer 10 impacting on the pile 7. Within the cylindrical space 23, air bubbles may be formed near the lower end 6 in order to provide further noise reduction.

Figure 4 shows a top view of a pile installation frame 30, having three cylindrical walls 31,32, 33 interconnected in a triangular configuration by frame members 35,36,37. Figure 5 shows a square arrangement of cylindrical walls in an installation frame 30 for placing four foundation piles in a rectangular pattern. Air bubbles may be formed inside the space of the cylindrical walls and/or in the space between the cylindrical walls.

Fig. 6 shows a working vessel 40 supporting a 2000 ton crane 41 that lifts the installation frame 42 via a cable 43 attached to lifting member 44, such as an eye or shackle, on the frame 42. After lowering the cylindrical walls 45, 46 onto the sea bed, the cable 43 may be released from the eye 44 and the crane 41 may be used for lowering a pile inside the cylindrical walls 45, 46 and hammering it down into the sea bed.

Fig. 7 shows an alternative embodiment of a working vessel 40 towing an installation frame 42 that is provided with a ballastable tank 47 to the site of deployment. When in the right position, a ballast control unit 49 on the vessel 40, that is connected to the ballast tank 47 via a schematically indicated electrical and pneumatic control line 48, effects deballasting of the tank 47 such
that the cylindrical chambers come to rest on the sea bed. The piling operation can be effected from another work vessel having a crane and control units for operating the hammer or from the same working vessel 40.

Fig. 8 shows an embodiment in which the cylindrical walls 2 are supported on a leveling member in the form of mud mats 50, 51, the volume of which is controlled via inclination control unit 52 on the working vessel 40 and electrical, hydraulic and/or pneumatic volume control line 53. The control unit 52 insures that the walls 2 have a vertical orientation on the sea bed, such that the pile upon being guided by the positioning devices 12,13 and 14, is driven vertically downwards. The drive members 17, 18 and 19 of the positioning devices 12,13 and 14 are controlled, in dependence on the vertical position of the hammer 10, by a positioning control unit 54 and a schematically indicated positioning control line 55. When the hammer 10 reached the position just above one of the positioning devices, the respective positioning device is retracted by control unit 54 such that the hammer 10 can pass. The hammer 10 is operated from the working vessel 40 via hammer control line 57.

Fig. 9 shows an embodiment in which the cylindrical wall 2 comprises an inner wall 20 and an outer wall 21, which walls define a hollow space that is divided into compartments 60, 61, 62 and 63. Each compartment is connected to a pressure control unit 65 on the working vessel 40 for being pressurized with air, depending on the depth of the compartment below water level, in order to withstand the prevailing water pressure. At the lower end 6, air nozzles 66 may be provided for forming a curtain of bubbles 70 inside the cylindrical wall 2 for further noise reduction. A bubble control unit 67 on the working vessel 40 via bubble control line 71. The hydraulic cylinder 73 is connected to a plate, the inclination position can be controlled. Instead of using a hydraulic cylinder 73 it is also possible to use an expandable body, connected to a plate, the inclination control unit (52) being adapted for varying the expansion volume of the expandable body.

Fig. 10 shows the lower side of a cylindrical wall 32 of a frame 37, resting on the sea bed, connected via flanges 74, 75 to a sleeve 72 housing a cylinder 73 and an extension body 76. The extension body is connected to a plate 50, that is also in the art referred to as "mud mat". The hydraulic cylinder 73 is connected via the leveling control line 53 to inclination control unit 52 on the vessel. By expansion or contraction of the cylinder 73, the plate 50 is raised or pressed against the sea bed, and the inclination of the frame 37 relative to a vertical position can be controlled. Instead of using a hydraulic cylinder 73 it is also possible to use an expandable body situated below the plate 50 and being inflatable by air, nitrogen or water.

Claims

1. Pile installation frame (30) comprising one or more tubular noise reduction elements (1, 31,32,33) having a cylindrical wall (2) and a center line (8), the elements (1, 31,32,33) being along their length provided with spaced-apart positioning devices (12,13,14) that are radially retractable with respect to the centerline, for centering a pile (7) driven through the tubular element (1, 31,32,33) along the center line (8).

2. Pile installation frame (30) according to claim 1, wherein the positioning devices (12,13,14) are with one end connected to the cylindrical wall (2,20) and comprise at a free end a sliding or rotating member (16) for providing a sliding or rotating contact with a pile (7) driven along the center line (8).

3. Pile installation frame (42) according to claim 1 or 2, comprising two or more noise reduction elements (1,31,32,33), interconnected via frame members (35,36,37), the frame comprising a lifting member (44) attached to the elements (1,31,32,33) for connection to a lifting device (41,43).

4. Pile installation frame (30) according to claim 1 or 2, the frame being provided with at least one ballastable buoyancy tank (47).

5. Pile installation frame (30,42) according to any of the preceding claims, comprising near the bottom (6) of the cylindrical wall (2) a expandable or displaceable support member (50,51,73) for contacting the sea bed, and connected to an inclination control unit (52) above water level for adjusting the position of the plate.

6. Pile installation frame (30,42) according to claim 5, wherein the leveling member (50,51) comprises an expandable body, connected to a plate, the inclination control unit (52) being adapted for varying the volume of the expandable body.

7. Pile installation frame (30,42) according to claim 5, the leveling member (50,51) comprising a hydraulic cylinder (73) connected to a plate, the inclination control unit (52) being adapted to expand or retract the cylinder.

8. Pile installation frame (30,42) according to any of the preceding claims, wherein the cylindrical wall (2) comprises an inner and an outer wall (20,21) and is divided into compartments 60,61,62,63, the compartments being connected to a pressurization device (65) for adjusting the pressure in the compartments depending on the water depth of the compartment.

9. Method of installing a pile into the sea bed, comprising the steps of:

- providing a pile installation frame (30,42) according to any of the preceding claims,
- lowering the cylindrical wall (2) in a vertical po-
sition, with a lower part (6) onto the sea bed (3) and an upper part (4) extending above water level,
- placing a pile (7) along the center line (8) of the one or more cylindrical walls (2),
- displacing the positioning devices (12,13,14) in the direction of the center line (8) to press against the outer surface of the pile (7),
- hammering the pile downward through the cylindrical wall (2) using a hammer (10), while retracting the upper positioning devices (12) toward the center line to allow the hammer (10) to pass along the positioning devices.
Fig 10
### Documents Considered to Be Relevant

<table>
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<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
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**The present search report has been drawn up for all claims.**

**Location of search:** Munich  
**Date of completion of the search:** 14 October 2011  
**Examiner:** Geiger, Harald

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