SYSTEM AND METHOD FOR UNDERSEA MICROPILE DEPLOYMENT

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ABSTRACT

A system for deploying an undersea anchor is provided, where the system includes a controller programmed and configured to monitor the drilling and grouting of micropiles in real-time and compare the metrics detected by such monitoring against pre-determined design criteria to substantially ensure micropile deployment meets the design criteria upon completion of the drilling and grouting process during micropile deployment. The system may also include means for pre-tensioning the micropiles after deployment, where the controller is programmed and configured to determine whether the pre-tensioning process conforms to design criteria.
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RELATED PATENT APPLICATIONS


BACKGROUND

[0002] The present invention relates to the drilling, monitoring, placement and pre-tensioning of micropiles configured for use and deployment in an undersea environment.

[0003] In that regard, micropiles have been employed historically to withstand compressive and tensile loads in terrestrial contexts. Where it is desired to secure an anchor to a seafloor bed, conventional approaches to appropriate design and proper application of an anchor or foundation system on a seafloor site are often based on expensive and time-consuming geotechnical survey and analysis of survey results of the seafloor on which the anchor or foundation will be installed.

[0004] Also, without pre-stressing, a conventional marine micropile anchor installed on a seafloor, lake bed or river bed may be subjected to fatigue, corrosion, cracking, uplift and an inability to deal with lateral loading. Other conventional anchor systems used in a marine environment do not incorporate pre-stressed elements and thus may be subject to these same problems. The present systems and methodologies provide beneficial improvements to the prior art systems.

SUMMARY

[0005] A significant portion of the geotechnical survey effort required for conventional approaches to planning seafloor anchors can be eliminated by measuring seabed properties in real-time, in-situ as part of the anchoring or foundation system micropile installation process. The system and method of the present application differs from what currently exists. During micropile anchor installation as described herein, seafloor properties may be measured and adjusted for in real-time during the drilling process, eliminating the need for geotechnical surveys in advance of the installation. A considerable amount of time and expense is required for current micropile anchor planning and installation and this time and expense may be reduced dramatically or eliminated with the system and method of the present disclosure. Further, the real-time measurement of seafloor properties during installation of anchors ensures the best anchor performance at a fraction of the time and expense.

[0006] A typical candidate anchoring site may have relatively homogeneous rock or other competent material covered with a sand/mud overburden of moderate thickness. In these cases, the holding capacity of a micropile may vary linearly with the embedment depth in the rock. Measured drilling parameters such as torque, push and rate of advance may be used to determine the transition point between sediment and rock. Therefore, the required drilling depth can be determined very accurately to maximize installation efficiency. Similarly, in the case where the overburden is extensive, additional micropile lengths can be installed so the full required embedment depth into competent material is met.

[0007] In addition, the drilling rate of advance in rock or any other material can be measured for a given set of conditions and yield information regarding seabed strength. Significant variations in the strength of the seabed could be identified during drilling and adjustments to the operations such as varying the total micropile embedment length to obtain the required holding capacity could be made. Measure-while-drilling modeling and simulation software will allow for installation planning that only depends on general seafloor parameters, not on detailed geotechnical survey results. Various seafloor parameters for modeling and simulation may dictate corresponding actions for micropile anchor installation planning. Sensor input to the measure-while-drilling software will determine the corresponding real-time control during drilling to install the micropile anchor.

[0008] A possible exemplary process for making the system of the present disclosure may be as follows: measure-while-drilling modeling and simulation software may be coded in cooperation with subject matter experts specifying the logic for the program. The suite of down-hole sensors may be selected to provide input to the real-time monitoring software that would be coded to effect adjustments to the drilling control accordingly. The modeling and simulation planning software would be optional to the real-time drilling sensors and monitoring software. It is not intended or required that the planning software must be integrated with the real time monitoring software but it is anticipated that such integration may be possible within the scope of the present disclosure.

[0009] The system of the present disclosure may be further operated in the following exemplary fashion: measure-while-drilling modeling and simulation software may allow for drilled and grouted seafloor micropile anchor installation planning. Micropile anchor installation may be controlled by the use of sensors placed within the hole being drilled and/or on the drill itself that measure real-time parameters of the drilling progress and the calculated drilling adjustments required to determine the required anchor holding capacity. Once installed, micropile strength also can be confirmed or verified as part of the installation process.

[0010] Pre-stressing the micropiles used to secure a sea anchor or marine mooring to the bed of a body of water may help to limit or restrict structural movement of the anchor due to anchor micropile elongation caused by cyclic and dynamic loads. Micropiles used for such anchors are typically made of steel that are driven into a position within the bed to provide resistance to movement of the anchor. When the anchor is subjected to forces being placed on the anchor by an object or structure that is connected to the anchor, these forces are transmitted to the micropiles, which can deform the micropiles or possibly shift them. This may compromise the integrity of the anchor, making it more likely to fail, or may permit an undesirable movement or displacement of the object or structure secured to the anchor.

[0011] In the context of the present application, pre-stressing means the intentional creation of permanent stresses in a structure for the purpose of improving the structure’s performance under various service conditions. For marine applications of micropiles, it is desirable that each micropile in an anchor or other bottom fixing assembly be load tested to verify its capacity and that load be “locked in” to maintain a pre-stress to counteract the stresses resulting from the applied vertical and/or lateral mooring load to the assembly. Pre-stressing will help limit or restrict structural movement caused by cyclic and dynamic loads. Micropile pre-stressing for the purpose of achieving an anchor system capable of resisting vertical and lateral mooring loads is innovative and
un-proven in the sub-sea environment; however, it is vital if micro-piles are to be used efficiently for mooring systems.

[0012] Pre-stressing may provide the following benefits for a marine grouted micropile anchor system:

[0013] Proof test. Each micropile may be pre-stressed to ensure that it will hold its design load in accordance with industry standards.

[0014] Maintain axial compressive force. Pre-stress creates an axial compressive load in each grouted micropile, which in turn generates a lateral frictional resistance by means of the interaction between a template frame or micropile head and the seabed soil.

[0015] Eliminate uplift. Pre-stress will help avoid unequal load distribution in a micropile system. It counteracts uplift and overturning loads caused by environmental loads from wind, waves and current.

[0016] Eliminate fatigue. Fatigue failure is minimized since the effects of cyclic loading that causes fatigue failure may be reduced or eliminated.


[0018] Corrosion protection. Any micropile elongation will progressively break down and crack the protective grout cover, possibly leading to corrosion and failure of the micropile. Pre-stress eliminates micropile elongation through the grout column thus maintaining the corrosion protecting grout cover.

[0019] The system and method of the present disclosure differs from that currently exists. This system and method represent a new capability for micropiles or micropiles used in a marine environment.

[0020] A conventional non-pre-stressed system can allow movement of individual micropiles, which will lead to premature failure of the anchor and also will not help the anchor deal with any loads other than pure tension loads. The dynamic forces exerted on objects and structures secured to anchors in a marine environment are likely if not certain to place loads other than pure tension loads on the anchors to which they may be secured. Pre-stressing each individual micropile used as part of a sea anchor and locking that stress or load into each individual micropile will help maintain the compressive stress in each micropile and will serve to limit or restrict structural movement of the micropile and therefore the anchor.

[0021] The system and method of the present disclosure may incorporate the following elements, even though it is not intended to limit the scope of the present disclosure to just this set of exemplary elements: connecting a jacking or pre-stressing system to an anchor micropile; remotely operating the jacking system; applying a tension load to the micropile in increments with the jacking system while measuring the load and any elongation of the micropile; upon reaching a specified load or loading condition, lock load at that level; and disconnecting the jacking system from the micropile after locking the load and applying a similar process to any remaining unstressed micropiles.

[0022] The pre-tensioning device is attached to micropile. The pre-tension load is applied to the micropile. The pre-tensioned micropile is locked with a locking device. The system is moved to the next micropile. As pre-tension is applied, the micropile elongation and load will be measured using remote system controller until desired load is reached. [0023] The most common and accurate way to pre-stress an anchor is direct pull, which may use a hydraulic jack that connects directly either at the anchor head or at a pulling head attached to the pre-stressing steel. Hydraulic jacks capable of developing 100 percent of the specified minimum tensile strength (SMTS) of available micropiles are available and can be adapted for sub-sea use. The jack frame typically bears against a steel plate while the hydraulic jack transfers a direct tension load to the anchor. When the pre-stress load is reached, a nut or other locking device may be turned against the anchor bearing plate, and the load from the jack may be released. The locking device or nut prevents the steel from relaxing back to its original length to maintain the pre-tension. Additional elongation in the anchor rod only occurs if the applied load exceeds the pre-stress load. The pre-stress load is typically 133% to 150% of the design load to allow for minor load relaxation, which may typically occur once the jack load is released.

[0024] A pressure gauge and dial gauge are used for terrestrial applications, but sub-sea pre-stressing may require a marined load cell and a linear displacement transducer if the jacking device is to be controlled remotely. A remotely operated micropile pre-stressing system according to the present disclosure for use in a sub-sea setting may include the direct pull apparatus or jacking device, a load lock-off system, load-displacement measurement system and the mechanism and controller required to pre-stress multiple micropiles on a single template or anchor.

[0025] It is anticipated that commercially available conventional components may be marined and integrated into the system of the present disclosure. A remote control and underwater operation capability will need to be developed for these conventional components to permit the system and method of the present disclosure to operate as described herein. Algorithms to account for different depths of water where the sea anchors may be positioned will need to be developed to ensure that the load measured accurately reflect the load that a micropile is being subjected to.

[0026] Thus, in one embodiment, a system is provided for more effectively deploying an underwater anchor, where the system comprises a controller programmed and configured to monitor the drilling and grouting of micropiles in real-time and compare the metrics detected by such monitoring against pre-determined design criteria to substantially ensure micropile deployment meets the design criteria upon completion of the drilling and grouting process during micropile deployment. In some embodiments, the system further comprises means for pre-tensioning the micropiles after deployment, where the controller is programmed and configured to determine whether the pre-tensioning process conforms to design criteria.

BRIEF DESCRIPTION OF THE FIGURES

[0027] The aforementioned objects and advantages of the present invention, as well as additional objects and advantages thereof, will be more fully understood hereinafter as a result of a detailed description of a preferred embodiment when taken in conjunction with the following drawings in which:

[0028] FIG. 1 shows a perspective schematic view of one embodiment of the present invention;

[0029] FIG. 2 shows an elevational schematic view of the embodiment of FIG. 1.
FIG. 3 shows a flow chart reflecting one methodology of the present invention;

FIG. 4 shows a perspective schematic view of an alternative embodiment of the present invention.

DETAILED DESCRIPTION OF CERTAIN EMBODIMENTS

By way of example, and referring to FIGS. 1 and 2, one embodiment of the present system comprises an anchor system 10 suitable and configured for use in securing a buoyant load from a sea floor, whether or not the sea floor is generally horizontal, slightly sloped, or significantly sloped. In that regard, one example of anchor system 10 comprises an anchor plate 12 that may comprise a frame of generally planar configuration, but may be structured and/or reinforced in one of numerous possible arrangements. In the example shown in FIG. 1, the anchor plate comprises bearing plates 14 for securing a plurality of micropiles 16 at relative angles to each other; i.e., one set directed at a first angle, and a second set at a second angle. Even within each set, the angle of deployment of the micropiles 16 may be different relative to each other. The bearing plates 14 serve to permit the deployment and post-tensioning of the micropiles, as discussed below. The anchor plate further comprises one or more anchor points 18 from which the buoyant load may be secured. In this example, the anchor points 18 comprise cable shackles or eyes to which a cable may be secured to tie-down whatever load bearing device is desired, including a buoy, an oil rig, a monument, etc.

The micropiles are secured to the bearing plate mechanically via a nut and washer arrangement 20, although other mechanical means may be employed. Each micropile is contemplated to comprise a length of threaded rod 22, one or more couplings 24 to join the rods 22 together to extend the length of the micropile as needed for depth of deployment, and a drill bit 26 at the distal tip of the micropile for creating the bore into which the micropile is deployed. Referring to FIG. 2, it can be appreciated that a drill 28 can be employed to bear against the bearing plates 16 to drill the micropile in rod section 22, joining them together using the couplings 24. Such a drill 28 can be remotely controlled and powered through cable 30. In that regard, any micropile drill may be employed.

In the example shown in FIGS. 1 and 2, the anchor system 10 has been deployed pursuant to design criteria based upon a pre-existing geophysical and soil condition survey to assess the ability of the anchor location to bear the desired load. Referring to FIG. 3, one example of an inventive methodology can be described. It is contemplated that a measure-while-drilling technique be employed to more effectively deploy an anchor system, such as that shown in FIGS. 1 and 2, as well as FIG. 4 described below. The advantages of such a technique are addressed above. It is also contemplated that a pre-tensioning technique be employed as well for effective anchor system deployment, the advantages of which are also addressed above. The invention described herein may employ one or both of the techniques as desired, but will be described as being used together for purposes of simplicity. It should be noted that as part of the micropile deployment, it is typical for a thin grout to be delivered while the drill is being drilled, and then following completion of the drilling process, when the micropile is fully deployed, a rich grout is delivered to surround the micropile and create a grout/soil interface with sufficient friction to resist the desired load upon the anchor system.

With reference to FIG. 3, an anchor deployment system comprises a drill, a grout system, a tensioning and instrumentation system, a data feedback system, and a controller. Such an arrangement is by example only. In this example, the drill is configured to be controlled pursuant to certain metrics, as is the grout system, so that certain metrics are measured in real-time during the drilling and grouting process and measured against the desired design criteria to better ensure that the resulting deployed micropiles and anchor system are compliant with the design criteria. In that regard, in one embodiment, certain drilling sensors are monitored, including torque, rate of advance, applied force, and rotational speed, which can be measured using, for example, a hydraulic pressure sensor, a linear sensor, a load cell, and a rotation sensor, respectively. Likewise, during delivery of first the thin grout and then the rich grout, both flow and pressure are monitored using a flow meter and a pressure transducer, respectively. In the case of the rich grout, density may also be monitored using a densimeter if so desired. During the drilling and grouting process, feedback from the various sensors are provided to the feedback system (i.e., Data Acquisition System), and fed to the controller for purposes of employing software that compares the progress of the deployment with the desired design criteria. This permits adjustments to be made in both the drilling and grout delivery metrics to accommodate any deficiencies encountered. Once the micropile has been appropriately deployed, along with the rich grout, with time for the grout to set, the system can then actuate the tensioning system by applying a pile-tensioning mechanism to load the micropile in tension before tightening the micropile against the bearing plate or the anchor plate, depending upon whether a bearing plate is used. The pre-tensioning system would be controlled and compared against a micropile performance model loaded into the controller for purposes of knowing when to stop the pre-tensioning step. Once completed, the result is a micropile that meets the desired design criteria. Following such procedure with the balance of the suite of micropiles permits an effective deployment of an anchor system sufficient to meet the load requirements desired. If so desired, multiple drills 28 may be employed simultaneously to speed up the process where there are a large number of piles being deployed. The same may be true for the pre-tensioning mechanism.

Referring to FIG. 4, another example of an anchor system 110 can be appreciated. As described above, the anchor plate 112 may be one of any number of possible configurations, such as that shown in FIG. 4, where the micropiles 116 are arranged radially rather than in a grid pattern. In the example shown, the micropiles 116 are also deployed normal to the anchor plate 112. In this particular example, a multi-pile drilling system 128 is employed, where at least two micropiles 116 are being drilled and deployed simultaneously, each individually controlled by the controller based upon the metrics detected in the feedback loop. The drill 128 can then be removed upon complete deployment of the micropiles, leaving the anchor plate 112 in place.

It is contemplated that the systems and methods of the present invention may be applied to terrestrial micropile and anchor construction. There may be land-based micropile and anchor construction locations that do not permit the control and operation systems to be positioned at the anchor site.
The systems of the present invention may permit the control of the jacking system to be handled remotely, whether the anchor location is underwater or in a difficult location above water. It is anticipated that embodiments of the present invention may preferably have a robust testing and calibration capability to ensure that micropiles are subjected to accurately measured loads.

Persons of ordinary skill in the art may appreciate that numerous design configurations may be possible to enjoy the functional benefits of the inventive systems. Thus, given the wide variety of configurations and arrangements of embodiments of the present invention the scope of the invention is reflected by the breadth of the claims below rather than narrowed by the embodiments described above.

What is claimed is:

1. A system for more effectively deploying an undersea anchor, the system comprising a controller programmed and configured to monitor the drilling and grouting of micropiles in real-time and compare the metrics detected by such monitoring against pre-determined design criteria to substantially ensure micropile deployment meets the design criteria upon completion of the drilling and grouting process during micropile deployment.

2. The system of claim 1, further comprising a means for pre-tensioning the micropiles after deployment, where the controller is programmed and configured to determine whether the pre-tensioning process conforms to design criteria.

3. The system of claim 1, further comprising drilling means for deploying the micropile into a seabed floor, and a grouting system for delivering thin grout during the drilling process and rich grout following micropile deployment.

4. A method for more effectively deploying an undersea anchor, the method comprising employing a controller to monitor the drilling and grouting of micropiles in real-time and compare the metrics detected by such monitoring against pre-determined design criteria to substantially ensure micropile deployment meets the design criteria upon completion of the drilling and grouting process during micropile deployment.

5. The method of claim 4, wherein monitoring comprises detecting the torque applied, the linear advancement, the load and the rotation of the micropile during deployment.

6. The method of claim 5, wherein monitoring comprises detecting the flow rate and pressure of the grout during delivery.

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