GROUTING OF OFFSHORE STRUCTURES

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References Cited
UNITED STATES PATENTS
3,564,856 2/1971 Blount et al. ....................... 61/46
3,597,930 8/1971 Rochelle ....................... 61/46

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ABSTRACT
A method for grouting the annulus between the jacket and piling in the legs of an offshore structure in which air is introduced to expel water from the lower end of the annulus, and grouting material is pumped into the annulus at the bottom, displacing air upwardly. When sufficient grouting material is introduced to balance the hydrostatic head of the sea water, the grouting is allowed to set up. Additional grouting material may then be introduced from the top.

2 Claims, 5 Drawing Figures
GROUTING OF OFFSHORE STRUCTURES

CROSS-REFERENCE TO RELATED APPLICATION

Part of the disclosure herein relates to subject matter disclosed in the application of Max Bassett, Ser. No. 358,009, filed May 7, 1973, now abandoned. Such subject matter is the invention of Bassett, is claimed in his application, and is not claimed herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the grouting of offshore structures.

2. Description of the Prior Art

Offshore structures have come into increasing use in recent years to support platforms for drilling oil and gas wells and for producing oil and gas from such oil wells. Such structures may be erected in water from comparatively shallow depths up to several hundred feet deep. A variety of forms of structure and methods of construction of such platforms have been utilized. One such method which has been found to be particularly desirable in deep water is that which is illustrated, for example, in U.S. Pat. No. 3,209,544 to Borrmann, in which the legs of the structure are fabricated and assembled on shore. The legs are hollow, and may be sealed to make the structure buoyant, so that it can be towed out to the desired offshore location. Valves in the legs are opened to allow flooding with sea water, so that the leg structure will sink in a vertical position and settle onto the bottom. As the legs sink they fill with water up to the water level of the sea. It will be appreciated that the legs will sink into the ocean bottom a distance dependent upon the weight of the structure and the softness of the ocean bed.

A platform which is built only on such legs would have a high degree of instability, particularly in heavy storms. It has, therefore, been the practice to more rigidly connect the structure to the ground by driving hollow steel pilings down through the legs, which then become jackets for the pilings. When a piling is dropped down through a jacket, it knocks off the seals closing the bottom ends of the jackets, so that the jackets tend to sink deeper into the bottom, and mud and silt from the bottom may enter the annulus between the piling and the jacket.

When the piling has been fully driven (usually to refusal), it has been the practice to fill the annulus between the piling and the jacket with a grouting material which solidifies in place. This not only increases the rigidity and, therefore, the strength of the structure, but also helps to keep out water so as to prevent corrosion of the piling. If the grouting fills the annulus all the way down to the bottom of the jacket, the piling is protected through the soft mud of the sea bed.

Various methods have been utilized for grouting such structures. One method, as shown in the aforesaid Borrmann patent, for example, requires the use of a seal member at the bottom of the annulus. In this method the grouting material is pumped into the bottom of the annulus and rises upwardly therein to the top. This method usually requires the use of divers, and in addition, it often fails to produce fully satisfactory results because water cannot be effectively excluded from the annular space so that the grouting material becomes diluted and difficult to set.

Evans et al., in U.S. Pat. No. 3,492,824, describe a method comprising injecting air through a nipple into the top of the annulus to expel water through a nipple at the bottom of the annulus, and then injecting grouting material through the bottom nipple. The grouting material is supposed to rise up through the annulus to the water line, displacing air out the top. As a practical matter such a system would be very unsatisfactory. The ocean bed is normally soft and porous at the bottom of the jacket so that as soon as enough grouting material is pumped in to overcome the hydraulic head of the overlying sea water, the grouting material would begin to run out the bottom of the jacket and would be lost. Thus, it would be necessary to utilize some kind of seal or closure at the bottom of the annulus to hold the grouting in.

Evans et al. also disclose a method whereby air is injected into the nipple at the bottom of the annulus to drive the water upwardly through the annulus out the top. It is apparent that such a system would be extremely inefficient in expelling water, since the air, being lighter, will rise up through the water. The same problem of losing grout out the bottom would also exist in this method.

Blount et al., in their U.S. Pat. No. 3,564,856, disclose another grouting system in which the grouting material is injected through nipples at the bottom of the annulus. They use water to wash out mud from the location of their injection nipples upwardly, but they make no attempt to remove water or mud from below the injection point. Furthermore, their annulus is filled with water at the start, which must be expelled upwardly by the rising grouting material. Thus a large excess of grouting material would be necessary in order to insure that all of the water is expelled out of the top of the annulus.

Olsen and Bassett disclose, in their U.S. Pat. No. 3,601,999, a system which avoids many of the problems encountered in other grouting systems. As described in the patent, in this system air is injected into the top of the annulus under sufficient pressure to drive the water out the bottom of the annulus, and then grouting material is injected into the top of the annulus.

SUMMARY OF THE INVENTION

According to the present invention, water is expelled from the annular space out its lower end by the application of air pressure, and fluid grouting material is introduced into the lower end of the annular space while sufficient air pressure is maintained on the annular space to prevent water from returning, and the grouting material is allowed to set up in the annular space. By this method any possibility of air being entrapped in the grouting material and forming a void in it is avoided, since the grouting material rises upwardly in the annulus and displaces the air.

Other features of the invention may be best explained in connection with the accompanying drawing and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an elevational view showing a typical installation of an offshore structure on the sea bed;

FIG. 2 is a semi-schematic view of apparatus suitable for practicing one embodiment of the method of this invention;
FIG. 3 is an enlarged fragmentary vertical sectional view of one of the legs of the structure of FIG. 1, showing the method of expelling the water from the annulus between the jacket and the piling of the legs;

FIG. 4 is a fragmentary sectional view, similar to the lower portion of FIG. 3, and showing a portion of the grouting material in place according to one embodiment of the invention; and

FIG. 5 is a fragmentary vertical sectional view of one of the legs of the structure showing the grouting material in place.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the drawing, a typical offshore structure 10 is shown, such as is used in the oil and gas industry for offshore drilling and production. The structure 10 as shown is only the base portion which is being installed on the sea bed 12, prior to providing the base portion with the usual platform and superstructure (not shown). The structure 10 includes a plurality of supporting legs, each in the form of a tubular jacket 13 which extends downwardly from above the water line 14 into the sea bed 12, the several leg jackets being secured together by cross members 15 and diagonals 16 in a conventional manner. As is known, the sea bed is usually comparatively soft and porous, and in many instances the structure 10 (not including pilings) will sink of its own weight until the jackets 13 sink as much as 30 feet into the sea bed.

When the structure 10 is properly placed the pilings 17 are driven through the jackets into the sea bed, usually to the point of refusal, to provide a final support for the platform. As shown, the pilings are normally of tubular steel, and are usually of at least one pipe size smaller than the size of the jackets, so that an annular space 18 exists between each piling and its surrounding jacket. The annular space is not, of course, uniform, since no means are used to center the piling in the jacket. On the average, however, the annulus will have a radial thickness of from 1 inch to 2½ inches, in leg jackets measuring from 16 inches to 54 inches in diameter. It is this annulus which must be filled with grouting material, particularly in the region of the lower end of the jacket 13, not only in order to attain leg rigidity sufficient to withstand tides, storms, ocean currents and the like, but also to protect the piling and the inside of the jacket against corrosion by sea water and air.

After the piling 17 has been driven through the jacket 13 into the sea bed 12, the piling is cut off at the upper end of the jacket and the two components are secured together as by welding in a heavy steel ring 19, prior to installation of the deck and other superstructure. The welding in of this ring 19 provides a pressure tight seal at the top of the annulus 18.

One form of apparatus which has been found suitable for performing the method of this invention is shown in somewhat schematic form in FIG. 2. In this structure two pressure tanks 30, 32 are provided for storage tanks for dry cement. These pressure tanks may, for example, be of the type provided with an air slide bottom, as shown in U.S. Pat. No. 2,609,125 to Schemm or as shown in U.S. Pat. No. 2,934,223 to Scruby et al. In such structure dry cement is put into the tanks and lies on a porous sloped bottom, and air flowing through the bottom fluidizes the material in the tank to cause it to flow down the slope. In the structure shown air for such fluidizing is provided by a low pressure air compressor 34, from which air passes through conduits 36, 38 to tanks 30, 32 respectively. Valves 40, 42 are provided to control flow to one or the other of the tanks.

Fluidized cement is carried from the pressure tanks through conduits 44, 46 through which flow is controlled by valves 48, 50. The fluidized cement flows from one of the tanks at a time to a surge tank 52 provided with a suitable dry material valve 54 at its lower end. The valve may, for example, be of the type shown in U.S. Pat. No. 2,858,966 to Pfening. When the valve 54 is opened the dry cement falls into a hopper 56 which is connected at its lower end to a mixing chamber 58. A nozzle 60 extends into the mixing chamber, perpendicular to the outlet of the hopper 56 and coaxially with a mixed cement line 62. Water is provided to the nozzle 60 by means of a suitable pump 64 which takes suction from a water storage tank 66 through a water line 68. The water tank may be provided with any convenient gauge so that the amount of water used can be accurately determined.

It will be appreciated that cement falling from the hopper 56 into the mixing chamber 58 is thoroughly admixed into water sprayed from the nozzle 60. The mixture passes through the line 62 into a slurry tub 70. A suitable pump 72 mounted in a discharge line 74 is connected to pump the fluid grouting material into one of lines 73, 75. Line 73 is connected to the annulus between the jacket 13 and the piling 17 near the upper end of the annulus, and is provided with a valve 76 and a check valve 77 to allow flow only toward the annulus. As seen in FIGS. 3, 4 and 5, line 75 is connected to the annulus near the sea bed, and is provided with a valve 78 and a check valve 79, as well as a valve 80 adjacent the connection to the jacket. Valve 80 is preferably remotely operable. In addition, line 75 is preferably provided with a connection to valve 80 which is readily separated from a remote location, so that the line 75 can be removed without the use of a diver. A dump line 88 is also connected to line 74, and is provided with a valve 90. This may be used to dispose of grouting material which cannot be used.

For the pump 72, centrifugal pumps are satisfactory in many instances, but where high pressure is required, as in deep water installations, a reciprocating pump may be more desirable.

To provide high pressure air for expelling water from the annulus and for the grouting operation, a high pressure air compressor 81 is provided. This air compressor provides air through a conduit 82, fitted with a suitable valve 83, a pressure gauge 84, and a bleed line 86 having a valve 85 therein. The pressure gauge is preferably one which reads in feet of sea water, for a purpose which will hereinafter be explained. To avoid getting grout in the air line, the line 73 may be connected below, and on the same side of the jacket as, conduit 80, as shown in FIGS. 3, 4 and 5.

In the practice of a preferred embodiment of the method of this invention, air under pressure is introduced into the annulus 18 by operating the compressor 81 and adjusting the valve 83 to allow flow through the line 82 to the annulus, bleed valve 85 being closed. As air pressure is increased in the annulus, it will force the water therein downwardly and out the bottom. In some instances, however, the jacket 13 may be resting within a highly compacted bottom formation so that the air pressure available is insufficient to force water through...
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In such an event water under high pressure may be pumped into the annulus by means of the pump 72 until the formation is broken down enough to allow water to be forced through it by air pressure. The pump is then shut off and air pressure utilized to expel the water from the annulus.

As has previously been noted, mud, comprising seawater and such solid materials as may form the sea bed, will in many cases fill the annulus from the bottom of the jacket to approximately the level of the bottom of the sea bed 12. It is particularly important that substantially all of such mud be removed from the annulus, so that there will be no voids in the grouting material which is to be placed therein. Such voids, filled with mud and sea water, not only greatly reduce the strength and rigidity of the structure, but also provide means by which corrosion of the piling and of the interior of the jacket is greatly accelerated. The expulsion of water in the annulus out the bottom of the annulus helps to wash out the mud.

When all of the water has been expelled from the annulus this will be apparent from the surface because air escaping from the bottom of the annulus may be detected as air bubbles rising to the surface. At this time the compressor may be stopped and valve 83 closed. Valve 85 may then be opened to bleed air pressure from the annulus until the bubbles stop rising to the surface. The pressure gauge 84 should then read a pressure equal to the pressure head of the sea water. This pressure is held on the annulus to insure that water and mud do not come back up into the annulus at the bottom.

In some instances it may be desirable to further wash out mud at the lower end of the annulus. This may be accomplished by circulating additional water through the annulus, using the pump 72 to pump water. Since this water falls a substantial distance in the annulus, it will have a tendency to erode any mud remaining in the annulus. If desired, air pressure in the annulus can be increased at this time to insure that the circulating water is blown out the bottom of the annulus.

When the operator is satisfied that the annulus has been properly cleaned of mud, circulation of the water is stopped and air pressure is again brought back to a level just enough to keep water and mud out of the lower end of the annulus, i.e. equal to the sea water head. The structure is now ready for grouting.

The preferred grouting material to use is an expanding type grouting material, i.e. one which expands during at least a portion of the setting period. Such a material has a greater bond to steel in shear than ordinary grouting materials. This has been found to be an important consideration in achieving a maximum strength structure. Expanding type cements have been known for use in the construction industry, where they are known as “self-compensated” cements. One expanding type cement useful to form expanding type grouting materials is that sold under the trademark CHEM-COMP manufactured by Texas Industries, Inc. Also, various additives, such as sodium chloride or sodium sulfate, may be added to cement to make it expand.

To make the grouting material, water is mixed with the cement in the ratio recommended by the cement manufacturer or in accordance with the standards of the American Petroleum Institute. Such water ratios make a fluid grouting material which may have a viscosity from 5 to 20 poises. A grouting material within this range is viscous enough that it will have little tendency to flow through the mud in which the jacket 13 is positioned. Such grouting materials usually have a density of from about 14 to 16 pounds per gallon (i.e. about twice the density of water) although grouting materials having densities outside this range may also be used in the practice of the method of this invention.

According to the present invention, grouting material from the tub 70 is first pumped by the pump 72 down line 75, valve 76 being closed and valve 78 being open. In a typical grouting operation, an initial batch of grouting material is pumped into the annulus at the lowest possible point at a rate of, for example, 2 to 3 barrels per minute. As this grouting material is pumped in, preferably air pressure is released enough to compensate for the pressure head exerted by the grouting material, so that the pressure at the bottom of the annulus is maintained high enough to prevent water and mud from rising in the annulus, but not so high that excessive amounts of grouting material flow out the bottom of the annulus. This operation may be continued until a hydrostatic balance between the grouting material and the head of sea water is reached. At this point no air pressure is required to prevent water from moving upwardly into the annulus. In a typical situation the annulus should then be approximately one-half full of grout, since the density of the grout is approximately twice that of sea water.

When the air pressure in the annulus has been reduced to atmospheric, the compressor 81 and its associated conduit valve and pressure gauge may be moved to another leg of the platform to begin expelling water from that leg.

In many instances it is then desirable to pump in enough additional grouting material to get at least about 8 to 10 feet of additional height of grouting material in the annulus. The pressure created by this additional grouting material will force the grouting material out the bottom of the annulus and carry out any water that may have seeped upwardly and any mud that may remain at the bottom of the annulus. This grouting material which is forced out will flow into any voids in the mud created by the water which was previously expelled from the annulus, and in many cases the pressure of the grouting material will force the surrounding mud away from the lower end of the jacket. If desired, additional grouting material can be introduced in the annulus at this time to increase the amount which is expelled from the bottom of the annulus. This expelled material when it sets up will form a foundation bell which will greatly increase the stability of the structure.

Such expulsion of grouting material from the bottom of the annulus may be achieved at an earlier stage of the grouting operation by maintaining a pressure at the bottom in excess of the pressure needed to balance the head of the sea.

Valve 80 is now ready to be closed, and preferably line 75 is disconnected from the valve and retrieved. The grouting material in the annulus is allowed to set up sufficiently that it will support an additional column of grouting material on top of it. Then valve 78 in line 75 is closed, and valve 76 in line 73 is opened. The pump 72 is utilized to pump additional grouting material into the upper end of the annulus, filling the annulus to the top, or as high as desired.

Although it is preferred to inject as much grouting material as possible through the lower opening con-
nected to line 75, it may be desirable in some instances to inject a lesser amount at the bottom, allowing it to set up and injecting the remainder at the top.

Alternatively, injection of grouting material into the bottom of the annulus may, if desired, be discontinued at an earlier time, with the valve 80 then being closed and line 75 disconnected, and the cement in the annulus is allowed to set up.

As a further alternative, sufficient grouting material may be pumped in to form a plug in the bottom of the annulus below the connection of line 75, this grouting material preferably being made of a quick-setting cement, followed by a small amount of slower setting grouting material. The amount of quick-setting cement should be such that it will all be below the connection of line 75, so that additional slower setting material may be injected through this line. When the quick-setting plug sets up, it will prevent water from rising in the annulus, so air pressure may be released. The following slower setting material will not set up, so that additional grouting material may then be pumped in through line 75 to fill the annulus as high as desired, even all the way to the top of the annulus. The present plug provides a support for the additional grouting material, preventing it from flowing out the bottom. In this embodiment of the invention it is usually necessary to have only enough of the quick-setting grouting material to fill the annulus a distance of from 1 to 3 feet, because this has been found to be sufficient, when set up, to support the weight of the fluid grouting material which is to be put on top of it, filling the annulus up to above the water line.

Quick-setting cements are well known in the art, usually being formed by adding a material such as calcium chloride. For example, any of the various quick-setting cements described in the aforesaid patent to Blount et al. may be used satisfactorily. It will be appreciated that this short portion of quick-setting grouting material will set up quite rapidly as compared to the regular grouting material.

Although the grouting operation of this invention has been described in terms of grouting the legs of a new offshore structure, it is apparent that the procedure is also suitable for grouting old completed structures which were not grouted upon initial construction. The method of this invention can also be used in grouting structures in which a seal is provided at the bottom of the annulus, if the seal is one which will allow water to flow outwardly from the annulus. In some prior art grouting procedures an inflatable packer is used to close the bottom end of the annulus. Such packers can be deflated as necessary to allow expulsion of water or grouting material from the lower end of the annulus.

Although several embodiments of the invention have been shown and described herein, the invention is not limited to such embodiments but instead extends to the full scope of the accompanying claims.

I claim:

1. A method of grouting an offshore structure having at least one supporting leg including a tubular jacket extending downwardly from above the waterline into the sea bed and a piling driven through said jacket deeper into the sea bed with an annular space existing between the inside of the jacket and said piling; said method comprising the steps of sealing the upper end of said jacket to said piling so as to close said annular space at the upper end of the jacket; introducing compressed air into said annular space under sufficient pressure to expel substantially all of the water from said space through the lower end of the jacket; introducing fluid grouting material into said annular space at a point adjacent the lower end of the jacket after the water has been expelled from said space as aforesaid; simultaneously with the introduction of said grouting material gradually releasing the air pressure in said annular space at a rate which will maintain a pressure sufficient to prevent ingress of water through the lower end of said jacket but insufficient to force a substantial proportion of the grouting material out of the lower end of the jacket, whereby the level of the grouting will rise in the annular space, displacing air upwardly; stopping the introduction of grouting material when the air pressure is reduced to substantially atmospheric pressure, permitting the grouting material to set, introducing additional grouting material into said annular space at a point adjacent the upper end of the jacket, and permitting the additional grouting material to set.

2. Method of grouting an offshore structure having at least one supporting leg including a tubular jacket extending downwardly from above the waterline into the sea bed and a piling driven through said jacket deeper into the sea bed with an annular space existing between the inside of the jacket and said piling, said annular space being closed at its upper end and open to the sea bed at its lower end, said method comprising the steps of introducing compressed air into the upper end of said annular space under sufficient pressure to force substantially all of the water in the annular space out the lower end thereof, thereby reaching an air pressure in said annular space sufficient to overcome the pressure head of the overlying sea water, introducing fluid grouting material into said annular space at a point adjacent the lower end of the jacket after substantially all of the water has been expelled from said annular space as aforesaid, said fluid grouting material comprising a first quick-setting portion and a second portion which sets more slowly, the amount of said first quick-setting portion being sufficient to form an annular plug in said annular space below the point of introduction of said fluid grouting material but being insufficient to form a plug in said annular space at or above said point of introduction, allowing the quick-setting portion to set up, releasing the air pressure in said annular space, injecting additional slower setting fluid grouting material at said lower point sufficient to substantially fill said annular space, and allowing said additional grouting material to set.