

REINFORCEMENT STRUCTURE AND REINFORCEMENT METHOD FOR UNDERWATER STRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a reinforcement structure and a reinforcement method that reinforce an underwater structure such as an offshore scaffold for oil drilling, a sea berth, or a quay.

2. Description of the Related Art

In general, in an underwater structure such as an offshore scaffold for oil drilling, a sea berth, or a quay, an embedment type rigid-frame structure having a plurality of steel pipe piles positioned at the bottom of a body of water and a superstructure work connecting the head portions of the steel pipe piles is used.

The underwater structure having the embedment type rigid-frame structure may be more firmly constructed through reinforcement between the steel pipe piles with inclined or horizontal brace members. If member joints (lattice points) can be bonded under water, there are many advantages in terms of structure and construction. However, there are many limitations on operations under water compared to operations on land, and thus costs and

construction time are increased.

As a reinforcement method (construction method) of such an underwater structure, a jacket construction method has been hitherto used. The jacket construction method is a construction method in which a jacket that is assembled on land in advance is towed to a construction site and is temporarily placed and a steel pipe pile is positioned in the jacket so as to be constructed under water.

However, the jacket construction method has the following defects. (1) In general, many structures in this field are large, and thus there is a tendency of manufacturing costs for manufacture on land to increase. (2) There are many difficulties in transporting structures having massive tares to a construction site, resulting in an increase in cost. (3) In general, the soil at the sea is soft, and thus a structure (jacket) manufactured on land in advance has poor stability during installation. (4) Therefore, in the jacket construction method, piles have to be positioned again. However, a steel pipe in this part has a double structure, and thus unnecessary members are required, resulting in an unnecessary increase in member weight. (5) For the above reasons, the jacket construction method in which manufacture is performed on land in advance requires a huge amount of cost, and a construction time is lengthened.

SUMMARY OF THE INVENTION

The present invention has been made taking the foregoing problems of the techniques according to the related art into consideration, and an object thereof is to provide a reinforcement structure of an underwater structure capable of being constructed at low cost in a short period of time and a reinforcement method.

According to the present invention, there is provided a reinforcement structure of an underwater structure, which reinforces, with a brace member, an underwater structure having an embedment type rigid-frame structure including a plurality of steel pipe piles and a superstructure work that connects head portions of the steel pipe piles, wherein a casing pipe having an inside diameter greater than an outside diameter of the steel pipe pile is provided at an end portion of the brace member, and the brace member is joined to the steel pipe pile by filling a gap between the steel pipe pile and the casing pipe with a grout material in a state where the steel pipe pile is inserted through the casing pipe.

According to the present invention, there is provided a reinforcement method for an underwater structure, which reinforces, with a brace member, an underwater structure having an embedment type rigid-frame structure including a

plurality of steel pipe piles and a superstructure work that connects head portions of the steel pipe piles, the method including: by using the brace member provided with a casing pipe that has an inside diameter greater than an outside diameter of the steel pipe pile at an end portion thereof, inserting the steel pipe pile into the casing pipe, and thereafter filling a gap between the steel pipe pile and the casing pipe with a grout material, thereby joining the brace member to the steel pipe pile.

According to the structure and the method, by filling the gaps between the casing pipes provided at the end portions of the brace members and the steel pipe piles with the grout material to join the two, unlike in the related art, the reinforcement structure may be easily constructed at a site without the need to manufacture the reinforcement structure on land in advance. Moreover, an operation of a diver may be eliminated or significantly reduced, and thus the underwater structure may be reinforced at low cost in a short period of time.

In the reinforcement structure, in the casing pipes, the rubber tubes that block the openings of the gaps formed at the end portions in the insertion direction of the steel pipe piles and the casing pipes by expanding as a fluid is injected into the rubber tubes may be provided. In addition, the brace member may be a tie rod of which the

end portion is connected to be rotatable with respect to the casing pipe. Moreover, the casing pipe may have a structure divided into two or more parts in a peripheral direction surrounding the steel pipe pile.

In the reinforcement method, rubber tubes may be provided at end portions in an insertion direction of the steel pipe pile into the casing pipe, and after inserting the steel pipe pile into the casing pipe, a fluid may be injected into the rubber tubes to expand the rubber tubes before the filling with the grout material, thereby blocking openings of the gap formed at the end portions in the insertion direction of the steel pipe pile and the casing pipe. A tie rod of which an end portion is connected to be rotatable with respect to the casing pipe may be used as the brace member. Furthermore, as the casing pipe, one that has a structure divided into two or more parts in a peripheral direction surrounding the steel pipe pile may be used. In this case, after one casing pipe of the casing pipes respectively provided at both ends of the brace member is mounted to the steel pipe pile, the one casing pipe may be moved downward along the steel pipe pile, and thereafter the other casing pipe may be mounted to the other steel pipe pile.

According to the present invention, by filling the gaps between the casing pipes provided at the end portions

of the brace member and the steel pipe piles with the grout material to join the two, unlike in the related art, there is no need to manufacture the reinforcement structure on land in advance, and moreover, an operation of a diver may be eliminated or significantly reduced, thereby reinforcing the underwater structure at low cost in a short period of time.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a configuration diagram of a reinforcement structure of an underwater structure according to an embodiment of the present invention;

FIG. 2 is an explanatory view illustrating an example of the construction order of a reinforcement method for the underwater structure according to the embodiment, FIG. 2(A) is an explanatory view illustrating a state where steel pipe piles are positioned at the bottom of the sea, FIG. 2(B) is an explanatory view illustrating a state where a horizontal brace member is installed between two steel pipe piles from the state illustrated in FIG. 2(A), and FIG. 2(C) is an explanatory view illustrating a state where inclined brace members are installed between the two steel pipe piles from the state illustrated in FIG. 2(B);

FIG. 3 is a plan view of the underwater structure illustrated in FIG. 1;

FIG. 4 is a partial cutaway perspective view illustrating a state where casing pipes are bonded to the steel pipe pile;

FIG. 5 is an explanatory view illustrating an example of the construction order of a bonding method for the steel pipe pile and the casing pipes, FIG. 5(A) is an explanatory view illustrating a state where the steel pipe pile is inserted into the casing pipes to be installed at a predetermined height position, FIG. 5(B) is an explanatory view illustrating a state where rubber tubes attached to the casing pipes expand from the state illustrated in FIG. 5(A), and FIG. 5(C) is an explanatory view illustrating a state where gaps between the steel pipe piles and the casing pipes are filled with a grout material and the steel pipe piles and the casing pipes are firmly joined to each other from the state illustrated in FIG. 5(B);

FIG. 6 is an explanatory view exaggeratedly illustrating the bonding structure of the casing pipes and the steel pipe pile using the grout material;

FIG. 7 is a configuration diagram of a reinforcement structure according to a modification of the reinforcement structure of the underwater structure illustrated in FIG. 1;

FIG. 8 is a configuration diagram of a reinforcement structure according to another modification of the

reinforcement structure of the underwater structure illustrated in FIG. 1;

FIG. 9 is a plan view illustrating a casing pipe having a divided structure used in the reinforcement structure illustrated in FIG. 8; and

FIG. 10 is a configuration diagram illustrating an example of the construction order of the reinforcement method for the underwater structure illustrated in FIG. 8, FIG. 10(A) is an explanatory view illustrating a state where one casing pipe of the inclined brace member is temporarily fixed to the steel pipe pile, and FIG. 10(B) is an explanatory view illustrating a state where by lowering the inclined brace member from the state illustrated in FIG. 10(A) and fixing the one casing pipe to the steel pipe pile, the other casing pipe is fixed to the steel pipe pile.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, an embodiment of a reinforcement method for an underwater structure according to the present invention suitable for a reinforcement structure constructed using the method will be described in detail with reference to the accompanying drawings.

First, before describing the reinforcement method for the underwater structure, a reinforcement structure D of the underwater structure constructed using the

reinforcement method will be described with reference to FIG. 1.

FIG. 1 is a configuration diagram of the reinforcement structure D of the underwater structure according to an embodiment of the present invention.

As illustrated in FIG. 1, the underwater structure (water area structure) A is a pier having an embedment type rigid-frame structure including a plurality of steel pipe piles (supports) 1 positioned by being embedded into the bottom of the sea (the bottom of a body of water) B and a superstructure work (upper structure) 6 that connects the head portions of the steel pipe piles 1, and the steel pipe piles 1 are firmly connected using the reinforcement structure D. The superstructure work 6 is installed above the surface of the water C, that is, in the air.

The reinforcement structure D according to this embodiment includes horizontal brace members (brace members) 2 that connect two steel pipe piles 1 and 1 in the horizontal direction for reinforcement, and a pair of inclined brace members (brace members) 3 and 3 that connect the two steel pipe piles 1 and 1 in a diagonal manner (X-shape) above the horizontal brace members 2 for reinforcement. The horizontal brace members 2 are firmly joined (rigidly joined) by respectively inserting the steel pipe piles 1 into casing pipes (outer insertion pipes) 4

provided at both ends thereof. Similarly, the inclined brace members 3 are firmly joined (rigidly joined) by respectively inserting the steel pipe piles 1 into casing pipes (outer insertion pipes) 5 provided at both ends thereof. As is apparent from FIG. 1, the casing pipes 4 and 5 have larger inside diameters than the outside diameter of the steel pipe pile 1. The horizontal brace members 2 and the inclined brace members 3 may be configured of arbitrary structural materials such as pipe-like bodies, I-section steel, tie rods (see FIG. 8), or cables.

Next, the reinforcement method for the underwater structure will be described.

FIG. 2 is an explanatory view illustrating an example of the construction order of the reinforcement method for the underwater structure according to this embodiment, FIG. 2(A) is an explanatory view illustrating a state where the steel pipe piles 1 are positioned at the bottom of the sea B, FIG. 2(B) is an explanatory view illustrating a state where the horizontal brace member 2 is installed between the two steel pipe piles 1 and 1 from the state illustrated in FIG. 2(A), and FIG. 2(C) is an explanatory view illustrating a state where the inclined brace members 3 are installed between the two steel pipe piles 1 and 1 from the state illustrated in FIG. 2(B).

When the reinforcement structure D is constructed, first, as illustrated in FIG. 2(A), a plurality of lines (in FIG. 2, the configuration of two pipes forming a pair is exemplified) of the steel pipe piles 1 and 1 forming a pair, which constitute the underwater structure A are installed to oppose each other. Next, as illustrated in FIG. 2(B), the steel pipe piles 1 and 1 forming a pair are inserted and mounted into the casing pipes 4 and 4 provided at both ends of the horizontal brace member 2. Subsequently, as illustrated in FIG. 2(C), the steel pipe piles 1 and 1 forming a pair are inserted and mounted into the casing pipes 5 and 5 provided at both ends of the inclined brace member 3, thereby installing the inclined brace members 3 above the horizontal brace member 2. Lastly, as illustrated in FIG. 1, a superstructure work 6 is installed at the head portions (upper ends) of the steel pipe piles 1 and 1 forming a pair.

The steel pipe pile 1 is a support that is vertically positioned at the bottom of the sea B by a pile driving machine using an offshore pile driving boat in order to construct the underwater structure A. The horizontal brace members 2 and the inclined brace members 3 that constitute the reinforcement structure D are assembled between the steel pipe piles 1.

As the order of assembly of the horizontal brace

members 2 and the inclined brace members 3 between the steel pipe piles 1 and 1, first, as illustrated in FIG. 2(B), the steel pipe piles 1 and 1 are inserted from the upper ends thereof into the casing pipes 4 and 4 provided at both end portions of the horizontal brace member 2 to correspond to the steel pipe piles 1 and 1. In addition, the horizontal brace member 2 is mounted to the steel pipe piles 1 and 1 at a predetermined height position by joining the casing pipes 4 and 4 to the steel pipe piles 1 and 1 according to a bonding method described later.

Thereafter, as illustrated in FIG. 2(C), the steel pipe piles 1 and 1 are inserted from the upper ends thereof into the casing pipes 5 and 5 provided at both end portions of the inclined brace member 3 to correspond to the steel pipe piles 1 and 1. In addition, the inclined brace member 3 is mounted to the steel pipe piles 1 and 1 at a predetermined height position by joining the casing pipes 5 and 5 to the steel pipe piles 1 and 1 according to a bonding method described later.

Finally, as illustrated in FIG. 1, the superstructure work 6 such as concrete is installed at the upper surface portion of the underwater structure A using the upper end portions of the steel pipe piles 1 and 1 as an aggregate, thereby constructing the underwater structure A having the reinforcement structure D.

In addition, in this embodiment, as illustrated in FIG. 3, a case where four groups of the steel pipe piles 1 and 1 forming a pair, that is, four steel pipe piles 1 constitute the underwater structure A is exemplified. However, as a matter of course, the number of steel pipe piles 1 may be appropriately changed.

Next, an example of the bonding method for the steel pipe piles 1 and the casing pipes 4 and 5 will be described.

FIG. 4 is a partial cutaway perspective view illustrating a state where the casing pipes 4 and 5 are bonded to the steel pipe pile 1. FIG. 5 is an explanatory view illustrating an example of the construction order of the bonding method for the steel pipe pile 1 and the casing pipes 4 and 5, FIG. 5(A) is an explanatory view illustrating a state where the steel pipe pile 1 is inserted into the casing pipes 4 and 5 to be installed at a predetermined height position, FIG. 5(B) is an explanatory view illustrating a state where rubber tubes 10 attached to the casing pipes 4 and 5 expand from the state illustrated in FIG. 5(A), and FIG. 5(C) is an explanatory view illustrating a state where gaps 7 between the steel pipe pile 1 and the casing pipes 4 and 5 are filled with a grout material 8 and the steel pipe pile 1 and the casing pipes 4 and 5 are firmly joined to each other from the state illustrated in FIG. 5(B).

In the bonding method (joining method), into the casing pipe 4 (or 5) which is one member, the steel pipe pile 1 which is the other member is inserted in a state where the gaps 7 are provided, and the gaps 7 are filled with the grout material (expansive joining material) 8 such as an expansive mortar (see FIG. 5(C)) in the state where the steel pipe pile 1 is inserted into the casing pipes 4 and 5 (see FIG. 5(A)), thereby bonding the steel pipe pile 1 and the casing pipes 4 (5) with expansion pressure and adhesion of the grout material 8 (see FIG. 4).

As illustrated in FIG. 5, at the upper end portions of the casing pipes 4 and 5, a pair of flange portions 9 and 9 which protrude inward in the radial direction and thus block the upper opening of the gap 7 with the steel pipe pile 1 are provided in advance. Similarly, at the lower end portions of the casing pipes 4 and 5, a pair of flange portions 9 and 9 which protrude inward in the radial direction and thus block the lower opening of the gap 7 with the steel pipe pile 1 are provided in advance.

Between the flange portions 9 and 9 at each of the upper end portions and the lower end portions, the rubber tube 10 is disposed to be wound along the entire periphery. For example, a pressure air supply source (not illustrated) such as a compressor is connected to each of the rubber tubes 10 via an air tube 11. In the flange portions 9 and

9 at the upper end portions, an air ventilation hole 14 for facilitating air ventilation in the gaps 7 is formed.

A bonding material injection tube 12 for injecting the grout material 8 to fill the gap 7 and a bonding material checking tube 13 for checking whether or not the gap 7 is filled with the grout material 8 are connected to the casing pipes 4 and 5. The bonding material checking tube 13 may check the injection status of the grout material 8 on the water when being extended to the surface of the water C, and the injection status of the grout material 8 may be checked under water using an underwater TV camera, a small submarine, a diver, or the like.

When the steel pipe pile 1 is bonded to the casing pipes 4 and 5, first, the casing pipe 4 (or 5) is suspended with a wire rope 15, is lowered to cause the steel pipe pile 1 to be inserted therethrough from the upper end, and is set to a predetermined height position (see FIG. 5(A)). Subsequently, pressure air is sent from the air tube 11 to the rubber tube 10 installed between the flange portions 9 and 9 at each of the upper end portion and the lower end portion of the casing pipe 4 (5) so as to expand (see FIG. 5(B)). The rubber tube 10 may be expanded by a fluid, and as the fluid for expansion, as well as pressure air, for example, pressure water or the like may be used.

Due to the expansion of the rubber tubes 10, the

openings (gaps) at the upper end portion and the lower end portion of the gap 7, that is, both end portions in the insertion direction of the steel pipe pile 1 and the casing pipe 4 (5) are closed by the corresponding rubber tubes 10 and 10 that expand. In this state, as illustrated in FIG. 5(C), the grout material 8 is injected through the bonding material injection tube 12 from a bonding material injection device (not illustrated) installed on a workboat to fill the gap 7, thereby firmly bonding the casing pipes 4 and 5 to the steel pipe pile 1. In addition, the air tube 11 and the bonding material injection tube 12 are detached after the grout material 8 hardens.

The grout material 8 is made by, for example, incorporating a commercially available expansive material that is used for chemical prestressing concrete, concrete cracking prevention, or concrete incompressibility, into cement mortar in order to exhibit expansibility during mortar hardening, and firmly bonds the casing pipes 4 and 5 to the steel pipe pile 1 with expansion pressure and adhesion during the hardening.

FIG. 6 is an explanatory view exaggeratedly illustrating the bonding structure of the casing pipes 4 and 5 and the steel pipe pile 1 using the grout material 8.

As illustrated in FIG. 6, the peripheral wall of the steel pipe pile 1 is deformed to be narrowed to have a

slightly smaller diameter as a result of the expansion pressure of the grout material 8, and the peripheral walls of the casing pipes 4 and 5 are subjected to an action of expansion deformation to have a slightly greater diameter. As such, in addition to the adhesion of the grout material 8 to the steel pipe pile 1, the hardened grout material 8 exhibits a wedge action for the steel pipe pile 1, and thus the casing pipes 4 and 5 are more firmly bonded to the steel pipe pile 1. In addition, in addition to the wedge action by the grout material 8 as described above, in order to further increase the adhesion to the steel pipe pile 1, a projection (not illustrated) may be provided on the outer peripheral wall surface of the bonding portion of the steel pipe pile 1.

FIG. 7 is a configuration diagram of a reinforcement structure D1 according to a modification of the reinforcement structure D of the underwater structure illustrated in FIG. 1.

The reinforcement structure D illustrated in FIG. 1 has a configuration in which the steel pipe piles 1 are vertically positioned at the bottom of the sea B and the steel pipe piles 1 and 1 are parallel. However, the reinforcement structure D1 illustrated in FIG. 7, for example, constructs an underwater structure A1 having a configuration in which the steel pipe piles 1 are

positioned to be inclined with respect to the bottom of the sea B so as to cause the distance between the steel pipe piles 1 and 1 to be gradually reduced toward the upper end side.

In the reinforcement structure D1, the horizontal brace member 2 is configured to have a divided structure including an inner insertion material 2a and an outer insertion material 2b through which the inner insertion material 2a is inserted, and similarly, the inclined brace member 3 is configured to have a divided structure including an inner insertion material 3a and an outer insertion material 3b through which the inner insertion material 3a is inserted. By changing the fixing positions in the axial direction of the inner insertion material 2a (3a) and the outer insertion material 2b (3b), the length of the horizontal brace member 2 (the inclined brace member 3) may be adjusted to be extensible. The inner insertion material 2a (3a) and the outer insertion material 2b (3b) are finally bonded to each other so as to be configured in one body. The bonding may be performed by the bonding method for the casing pipes 4 and 5 and the steel pipe pile 1 using the grout material 8.

In addition, in the reinforcement structure D illustrated in FIG. 1, the horizontal brace member 2 and the inclined brace member 3 may be configured to have such

a divided structure (extensible structure) as that of the reinforcement structure D1 illustrated in FIG. 7 so as to be able to absorb the error of the interval between the steel pipe piles 1.

FIG. 8 is a configuration diagram of a reinforcement structure D2 according to another modification of the reinforcement structure D of the underwater structure illustrated in FIG. 1.

The reinforcement structure D illustrated in FIG. 1 has a configuration in which by bonding the casing pipes 4 and 5 that are fixed to the end portions of the horizontal brace member 2 and the inclined brace member 3 between the steel pipe piles 1 and 1, tensile force and compression force that occur between the steel pipe piles 1 and 1 are received by the horizontal brace member 2 and the inclined brace member 3. On the other hand, in the reinforcement structure D2 illustrated in FIG. 8, a tie rod of which the length is able to be adjusted by a turnbuckle 16 is used as the inclined brace member 3, and the inclined brace member 3 is connected to the casing pipe 5 to be rotatable by pin connection 17, thereby constructing an underwater structure A2 having a configuration in which only tensile force is received by the tie rod.

Moreover, in the reinforcement structure D2, as illustrated in FIGS. 8 and 9, a structure (in FIG. 8, a

halved structure divided into two parts) divided into two or more parts in the peripheral direction surrounding the steel pipe pile 1, is used for the casing pipe 5.

As illustrated in FIGS. 8 and 9, the casing pipe 5 is configured of a first casing pipe portion 5a that is one member and a second casing pipe portion 5b that is the other member, by halving the casing pipe 5 that is a hollow cylinder along the axial direction. The first casing pipe portion 5a and the second casing pipe portion 5b are joined by joining ribs 18 protruding from the end surface side portions in the outside diameter direction through bolts 19, welding, or the like in a state where the end surfaces thereof come into close contact with each other, and thus are connected in one body and become a cylindrical member, thereby surrounding the periphery of the steel pipe pile 1. Even in a case where the casing pipe 5 having the halved structure is used, the bonding of the casing pipe 5 and the steel pipe pile 1 may be performed by the bonding method using the grout material 8 described above.

In addition, as a matter of course, a tie rod as the brace member may be connected to the casing pipe 5 by the pin connection 17 other than by the divided structure. In addition, as a matter of course, in the reinforcement structure D1 illustrated in FIG. 7, the casing pipe 5 having the divided structure (illustrated by double-dot-

dashed line in FIG. 7) may be used.

FIG. 10 is a configuration diagram illustrating an example of the construction order of the reinforcement method for the underwater structure A2 illustrated in FIG. 8, FIG. 10(A) is an explanatory view illustrating a state where the one casing pipe 5 of the inclined brace member 3 is temporarily fixed to the steel pipe pile 1, and FIG. 10(B) is an explanatory view illustrating a state where by lowering the inclined brace member 3 from the state illustrated in FIG. 10(A) and fixing the one casing pipe 5 to the steel pipe pile 1, the other casing pipe 5 is to be fixed to the steel pipe pile 1.

The reinforcement structure D2 illustrated in FIG. 8 is configured so that the casing pipe 5 has the halved structure, and thus is easily constructed for an underwater structure installed in advance, in which the superstructure work 6 is installed at the head portions of the steel pipe piles 1. That is, when the reinforcement structure D2 is constructed for an underwater structure that is installed in advance, first, as illustrated in FIG. 10(A), to the upper portion of one steel pipe pile 1 of the steel pipe piles 1 and 1 positioned at the bottom of the sea B to form a pair, the upper portion being exposed to the surface of the water C, one casing pipe 5 of the inclined brace member 3 is temporarily fixed. Since the casing pipe 5 has the

divided structure into the first casing pipe portion 5a and the second casing pipe portion 5b, below the superstructure work 6, the casing pipe 5 may be caused to abut against the upper portion of the steel pipe pile 1 from the side surface so as to be easily mounted. In addition, the temporal fixing means connecting the first casing pipe portion 5a and the second casing pipe portion 5b so as not to be separated from each other and fixing the casing pipe 5 so as to be movable along the steel pipe pile 1 by fastening the bolt 19 so as not to come away.

Here, the inclined brace member 3 is able to be oscillated by the pin connection 17. Therefore, in a state where the other casing pipe 5 that is not temporarily fixed at this time (in FIG. 10(A), the second casing pipe portion 5b extending in the transverse direction) is evacuated to a position that is not interfered by the superstructure work 6, the temporal fixing of the one casing pipe 5 may be smoothly performed.

Next, as illustrated in FIG. 10(B), the one casing pipe 5 that is temporarily fixed is moved downward along the steel pipe pile 1 while having the steel pipe pile 1 inserted therethrough, and the one casing pipe 5 is fixed (permanently fixed) to the steel pipe pile 1 in a state of reaching a predetermined height position. The permanent fixing may be performed by joining the casing pipe 5 and

the steel pipe pile 1 as in the bonding method using the grout material 8 after fastening the bolts 19 with a predetermined fastening strength through an underwater operation. Subsequently, the other casing pipe 5 of the inclined brace member 3 is fixed (permanently fixed) to the steel pipe pile 1, thereby constructing the underwater structure A2 having the reinforcement structure D2. Therefore, in a pier or the like that is installed in advance, there is no need to temporarily remove the superstructure work 6 or the like, and the construction time and costs may be significantly suppressed. Moreover, an underwater operation may be performed only for the permanent fixing of the casing pipe 5 that is temporarily fixed, and the operation of bonding the casing pipe 5 to the steel pipe pile 1 may be performed only by a remote operation such as the injection operation of the grout material 8 as illustrated in FIG. 5, thereby significantly reducing an underwater workload.

In addition, in FIG. 10, the case where the single inclined brace member 3 is mounted between the two steel pipe piles 1 and 1. However, in a case where the two inclined brace members 3 and 3 are mounted in a diagonal manner, for example, after the casing pipes 5 and 5 which become the lower sides of both the inclined brace members 3 and 3 are temporarily fixed, both the inclined brace

members 3 and 3 are lowered, and then permanent fixing or the like may be performed. In addition, as illustrated in FIG. 8, even when a plurality of lines of inclined brace members 3 are mounted between three or more steel pipe piles 1, construction may be performed in substantially the same order. Moreover, as a matter of course, even the casing pipe 5 having the divided structure illustrated in FIG. 9 may be installed in the same order as in FIG. 2 at a pier that is newly installed or the like.

As described above, according to the reinforcement structure D (D1 and D2) of the underwater structure according to this embodiment, the casing pipes 4 and 5 having inside diameters greater than the outside diameter of the steel pipe pile 1 are provided at the end portions of the horizontal brace member 2 and the inclined brace member 3, and in the state where the steel pipe pile 1 is inserted into the casing pipes 4 and 5, the gaps 7 between the steel pipe piles 1 and the casing pipes 4 and 5 are filled with the grout material 8, thereby joining the horizontal brace member 2 and the inclined brace member 3 to the steel pipe pile 1. In the reinforcement structure D (D1 and D2), by filling the gaps 7 between the casing pipes 4 and 5 provided at the end portions of the horizontal brace member 2 and the inclined brace member 3 and the steel pipe piles 1 with the grout material 8 so as to join

the two, the underwater structure A (A1 and A2) may be reinforced and constructed at low cost, in a short period of time, and with high reinforcement strength.

That is, according to the reinforcement method of constructing the reinforcement structure D (D1 and D2), unlike the related art, the reinforcement structure D (D1 and D2) may be easily constructed at a site without the need to manufacture a structure (jacket) or the like in advance on land. In addition, the operation of bonding the casing pipes 4 and 5 to the steel pipe pile 1 may only be a remote operation such as the injection operation of the grout material 8 or the like as illustrated in FIG. 5, the permanent fixing of the casing pipe 5 that is temporarily fixed as illustrated in FIG. 10, or the like, an underwater workload may be eliminated or be significantly reduced, and thus the underwater structure A (A1 and A2) may be reinforced and constructed at low cost in a short period of time. In addition, according to the reinforcement method, a relative positional relationship between members may be freely set according to the circumstances of a construction site without the limitations on the depth of water or size, and thus the reinforcement structure D (D1 and D2) may be constructed while arbitrarily selecting bonding positions. Moreover, the horizontal brace member 2 and the inclined brace member 3 may be easily mounted to the steel pipe pile

1, and thus the construction time may further be reduced, thereby further reducing construction costs.

In the casing pipes 4 and 5, the rubber tubes 10 that block the openings of the gaps 7 formed at the end portions in the insertion direction (axial direction) of the steel pipe piles 1 and the casing pipes 4 and 5 by expanding as a fluid is injected into the rubber tubes 10 are provided. Accordingly, the grout material 8 is prevented from leaking from the gaps 7, and thus the bonding operation of the casing pipes 4 and 5 and the steel pipe pile 1 may be more smoothly performed.

As the inclined brace member 3, the tie rod of which the end portion is connected so as to be rotatable with respect to the casing pipe 5 may be used. Here, when the casing pipe 5 provided in the tie rod is constructed to have the structure divided into two or more parts in the peripheral direction surrounding the steel pipe pile 1, it is possible to more easily mount the casing pipe 5 to the periphery of the steel pipe pile 1, and thus this configuration may be particularly effectively used in a case where a pier or the like that is installed in advance is reinforced with brace members. That is, when the casing pipe 5 having the divided structure including the first casing pipe portion 5a and the second casing pipe portion 5b is used, the inclined brace member 3 may be easily

mounted to the steel pipe pile 1 below the superstructure work 6 without the removal of the superstructure work 6 at the pier installed in advance, thereby further suppressing the construction period and costs.

In addition, as a matter of course, the present invention is not limited to the above-described embodiments, and may be freely modified in a range without departing from the concept of the present invention.

For example, in the embodiment, a configuration in which the horizontal brace member 2 and the inclined brace member 3 are used as brace members is exemplified. However, as a matter of course, only one of the horizontal brace member 2 and the inclined brace member 3 may be used.

What is claimed is:

1. A reinforcement method for reinforcing an underwater structure having an embedment type rigid-frame structure including a plurality of steel pipe piles and a superstructure work that connects head portions of the steel pipe piles, the reinforcement method comprising the steps of:

providing rubber tubes at end portions in an insertion direction of the steel pipe pile into a casing pipe that has an inside diameter greater than an outside diameter of the steel pipe pile and has a structure divided into two or more parts in a peripheral direction surrounding the steel pipe pile, a brace member that is extensible being connected to the casing pipe;

inserting the steel pipe pile into the casing pipe;

injecting a fluid into the rubber tubes, after inserting the steel pipe pile into the casing pipes, to expand the rubber tubes, thereby blocking openings of a gap formed at the end portions in the insertion direction of the steel pipe pile and the casing pipe; and

filling the gap between the steel pipe pile and the casing pipe with a grout material, thereby joining the brace member to the steel pipe pile,

wherein, after one casing pipe of the casing pipes respectively provided at both ends of the brace members is mounted to the steel pipe pile, the one casing pipe is moved downward along the steel pipe pile, and thereafter the other casing pipe is mounted to the other steel pipe pile, and

wherein at least one of the two or more parts of the casing pipe is connected to the end portion of the brace

member in advance before the brace member is joined to the steel pipe pile.

2. The reinforcement method according to claim 1, wherein the end portion of the brace member is connected to be rotatable with respect to the casing pipe.

3. The reinforcement method according to claim 1 or 2, wherein the brace member is a tie rod.