

PATENT SPECIFICATION

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(19)



(54) METHOD FOR CONNECTING PILES UNDER THE GROUND

(71) We, NISHIMATSU CONSTRUCTION COMPANY, LTD., a Japanese Body Corporate of No. 13, Shiba Nishikubo Sakuragawa-cho, Minato-ku, Tokyo, Japan do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to a method for connecting piles under the ground. More specifically, the invention relates to a method for connecting piles intimately in the radial direction under the ground to construct an underground structure such as cofferdam.

Known prior techniques for connecting piles under the ground include, for example, the method shown in Figure 1 in which a plurality of piles 1 are driven at intervals each of which is smaller than the diameter of each pile, and then a pile 2 is driven between, and in contact with, two adjacent piles 1 with a certain contact width a , and the method shown in Figure 2 in which a plurality of piles 3 are driven at small intervals and a soil-hardening chemical is poured into spaces among the adjacent piles 3 from above the ground to form a hardened soil portion 5 of a certain width b between the two adjacent piles 3.

The first method however has the defect that when piles 1 or 2 are not driven perpendicularly, the contact width a between piles is not constant over the entire depth. Moreover, since the contact width a is generally small, it is difficult to form a sufficiently effective cofferdam. Application of the second method makes it possible to obtain a larger contact area than in the first method. But since the connecting part 5 is a hardened product resulting from the pouring of a chemical grout from above the ground, both its hardness and its reliability of connection are low.

It is an object of this invention therefore to reduce the defects from these conventional methods in connecting piles under the ground in the radial direction, and to provide a method for connecting piles under the ground by which an underground dam having great ability to check the flow of water can be constructed at a low cost.

This object can be achieved in accordance with the invention by a method which comprises driving a plurality of piles into the ground at predetermined intervals; excavating the spaces between adjacent driven piles to a predetermined depth by means of an auger having a concrete jetting hole at the forward end of its shaft and hardener jetting holes at the peripheral edge of its blade; jetting concrete or mortar from the concrete jetting hole while lifting the auger thereby to fill the concrete or mortar in the cavities below the forward end of the auger; and simultaneously jetting a hardener from the hardener jetting holes at a pressure high enough to dislodge the soil or sand which contacts the outside surfaces of the driven piles to be connected, thereby to mix the dislodged soil and sand with the jetted hardener and to form concreted soil in place.

The invention also provides an auger for use in such method, such auger having holes for jetting hardener at the peripheral edge of its blade, conduits for conducting hardener to said holes, and a hole for jetting concrete at the forward end of the shaft, the shaft being hollow.

Preferred embodiments of the method of this invention are described below with reference to the accompanying drawings in which:-

Figures 1 and 2 are transverse sectional views of an underground dam in accordance with conventional methods;

Figures 3, 4 and 7 are vertical sectional views showing the process steps of the method of this invention;

Figure 5 is a vertical sectional view showing the forward end portion of an auger while it is excavating the ground or is out of operation;

5 Figure 6 is a top plan of the view in Figure 5;

Figure 8 is a vertical sectional view showing the state of the forward end portion of an auger while it is lifted; and

10 Figures 9 and 10 are transverse sectional views of underground dams formed by the method of this invention.

The first step, as shown in Figure 3, is to drive mortar piles 7 into the ground 6 at intervals, and then, as shown in Figure 4, the spaces between the adjacent piles 7 are excavated by an auger 11 to provide holes 10 for forming piles in place. The details of the forward end portion of the auger 11 at this time are shown in Figures 5 and 6. At the forward end portion of a hollow shaft in the auger is provided a hole 12 for jetting mortar sent from above the ground, and in the periphery of a blade 13 of the auger, at least 25 two holes 18 for jetting a hardening agent are provided at symmetrical positions. The hardener jetting holes 18 are connected to a hardener supply source (not shown) by means of a conduit 17 provided within the auger blade 13 and a conduit 16 provided 30 along the shaft of the auger and extending from the ground surface. While the auger 11 is performing an excavating operation, supply of material to these holes 12 and 18 is controlled by a suitable electrical or mechanical means so that mortar and a hardener may not be jetted out from these holes. Instead of providing the conduit 17 within the auger blade 13 and setting up the hardener 40 jetting holes 18 on the circumferential side surface of the auger blade 13, it is possible to extend the conduit 16 from the ground surface to the peripheral edge along the surface of the auger blade 13, and provide a 45 hardener jetting hole at the forward end of the conduit 16.

After holes 10 for *in situ* piles have been formed by the auger 11 in the state shown in Figure 4, the rotation of the auger 11 is stopped. Then, the auger 11 is rotated so that the hardener jetting holes 18 will face the driven piles 7 to be connected to set the positions of the jetting holes 18. Subsequently, while the auger 11 is lifted toward 55 the ground surface without being rotated, mortar is jetted downward from the jetting hole 12, and simultaneously, a hardener such as cement paste is jetted sideways from the jetting holes 18. By so doing, mortar 60 piles 8 are formed in place in the cavities left after the lifting of the auger 11 as shown schematically in Figure 7 and detailedly in Figure 8, and between the mortar piles 8 and the driven pile 7 concreate soil 9 is formed which is a hardened product of a

mixture of the hardener with the soil and sand of the ground scraped off by the high-pressure jetting of the hardener.

The hardener from the jetting holes 18 is forced out by a high-pressure pump so that it will reach as far a point as possible and be well mixed with the soil and sand. Usually a high pressure plunger pump at about 200 Kg/cm² is used. By properly controlling the pressure and selecting the hardener according to the condition of the ground, a firm joint is built by the concreate soil 9 with the desired width *c* between the *in situ* pile 8 and the driven pile 7, as shown in Figure 9.

Alternatively, after the ground has been excavated in the state shown in Figure 4, the auger may be lifted toward the surface of the ground while it is rotated in its reverse direction. According to this embodiment, the hardener is jetted at the entire circumference of the mortar pile 8, and therefore, as shown in Figure 10, concreate soil 9 is formed on the entire circumference of the mortar pile 8.

The piles to be connected are not limited to the driven concrete piles 7 described hereinabove, but may be concrete piles formed *in situ*, or driven steel piles. When an *in situ* pile 7 is to be connected to an *in situ* pile 8, it is desirable to form the pile 8 before the *in situ* pile 7 formed is aged enough, for example within three days after formation, because within this period, the outside surface of the *in situ* pile 7 is still green and it is easy to connect the soil concrete 9 firmly to the pile 7.

Hardeners for forming the concreate soil 9 may be not only a cement paste, but also other materials which increase the strength of soil and sand when mixed with them and enhance their ability to check the flow of water, such as water glass-type chemicals, bentonite, or suspended solids. From the standpoint of strength, the cement paste is most preferred.

The jetting holes 18 in the figures described above are fitted to the lowermost blade 13 of the auger, but are not limited to this embodiment. Preferably, from the stand-point of efficiency they should be fitted to parts near the forward end of the auger. In the figures mentioned, two jetting holes 18 are provided at symmetrical positions on the side end of the auger blade 13, but more jetting holes may be provided to increase the efficiency of excavation and mixing.

Example

The spaces among piles driven at intervals of 55 cm into the ground which were composed of silt-containing sand were excavated to a depth of 12 m by means of an auger having a diameter of 40 cm which was of the type shown in Figures 5 and 6. Then, while being rotated at a speed of 20 revolutions

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per minute, the auger was lifted at a rate of 50 cm per minute, and during this time, mortar was jetted from a jetting hole 12 at the shaft of the auger, and the cement paste was jetted from jetting holes 18 at the auger blade. The jetting pressure for cement paste from the jetting hole 18 was 50 kg/cm².

The mortar had a water/cement ratio (W/C) of 48 per cent and consisted of 201 kg/m³ of fly ash, 853 kg/m³ of sand, 385 kg/m³ of water and 7 kg/m³ of an intrusion aid. It was applied by an extrusion pump at a rate of 120 liters/min. The cement paste had a flow value of 17 seconds and a water/cement. fly ash ratio (W/C + F) of 48 per cent and consisted of 896 kg/m³ of cement, 299 kg/cm³ of fly-ash and 10.5 kg/m³ of an intrusion aid. It was applied by a high-pressure (200 kg/cm²) plunger pump.

As a result, an underground dam was obtained in which mortar concrete piles having a 28-day compressive strength of 240 kg/cm² were connected to one another by concreted soil. This dam had a satisfactory ability to check the flow of water.

The connected parts of piles have high strength because they are formed by concreted soil which consists of a mixture of the soil and sand in place with a hardener (especially mortar). Furthermore, since the soil and sand are mixed with the hardener, the connected parts can be formed with high reliability. The method of this invention can also increase the width of contact of concreted soil with driven piles, and thus reduce the number of piles per unit distance for building an underground dam.

WHAT WE CLAIM IS:-

1. A method for connecting piles to one another in the radial direction under the ground, which comprises driving a plurality of piles into the ground at predetermined intervals; excavating the spaces between adjacent driven piles to a predetermined depth by means of an auger having a concrete jetting hole at the forward end of its shaft and hardener jetting holes at the peripheral edge of its blade; jetting concrete or mortar from the concrete jetting hole while lifting the au-

ger, thereby to fill the concrete or mortar in the cavities below the forward end of the auger; and simultaneously jetting a hardener from the hardener jetting holes at a pressure high enough to dislodge the soil or sand which contacts the outside surfaces of the driven piles to be connected, thereby to mix the dislodged soil or sand with the jetted hardener and to form soil concrete in place.

2. The method of claim 1 wherein the auger is lifted without being rotated.

3. The method of claim 1 wherein the auger is lifted while it is rotated in its reverse direction.

4. A method for connecting piles to one another substantially as hereinbefore described with reference to and as shown by Figures 3 to 10 of the accompanying drawings.

5. A structure comprising piles connected together by the method of any one of the preceding claims.

6. An auger for use in the method according to any one of claims 1 to 4, such auger having holes for jetting hardener at the peripheral edge of its blade, conduits for conducting hardener to said holes, and a hole for jetting concrete at the forward end of the shaft, the shaft being hollow.

7. An auger according to claim 6, wherein the conduits extend along the length of the auger and within the auger blade.

8. An auger according to claim 6, wherein the conduits extend along the length of the auger and along the exterior of the auger blade.

9. An auger for use in the method of any one of claims 1 to 4 and constructed and arranged substantially as hereinbefore described with reference to and as illustrated in Figures 5 and 6 of the accompanying drawings.

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per minute, the auger was lifted at a rate of 50 cm per minute, and during this time, mortar was jetted from a jetting hole 12 at the shaft of the auger, and the cement paste was jetted from jetting holes 18 at the auger blade. The jetting pressure for cement paste from the jetting hole 18 was 50 kg/cm².

The mortar had a water/cement ratio (W/C) of 48 per cent and consisted of 201 kg/m³ of fly ash, 853 kg/m³ of sand, 385 kg/m³ of water and 7 kg/m³ of an intrusion aid. It was applied by an extrusion pump at a rate of 120 liters/min. The cement paste had a flow value of 17 seconds and a water/cement, fly ash ratio (W/C + F) of 48 per cent and consisted of 896 kg/m³ of cement, 299 kg/cm³ of fly-ash and 10.5 kg/m³ of an intrusion aid. It was applied by a high-pressure (200 kg/cm²) plunger pump.

As a result, an underground dam was obtained in which mortar concrete piles having a 28-day compressive strength of 240 kg/cm² were connected to one another by concreted soil. This dam had a satisfactory ability to check the flow of water.

The connected parts of piles have high strength because they are formed by concreted soil which consists of a mixture of the soil and sand in place with a hardener (especially mortar). Furthermore, since the soil and sand are mixed with the hardener, the connected parts can be formed with high reliability. The method of this invention can also increase the width of contact of concreted soil with driven piles, and thus reduce the number of piles per unit distance for building an underground dam.

WHAT WE CLAIM IS:-

1. A method for connecting piles to one another in the radial direction under the ground, which comprises driving a plurality of piles into the ground at predetermined intervals; excavating the spaces between adjacent driven piles to a predetermined depth by means of an auger having a concrete jetting hole at the forward end of its shaft and hardener jetting holes at the peripheral edge of its blade; jetting concrete or mortar from the concrete jetting hole while lifting the au-

ger, thereby to fill the concrete or mortar in the cavities below the forward end of the auger; and simultaneously jetting a hardener from the hardener jetting holes at a pressure high enough to dislodge the soil or sand which contacts the outside surfaces of the driven piles to be connected, thereby to mix the dislodged soil or sand with the jetted hardener and to form soil concrete in place.

2. The method of claim 1 wherein the auger is lifted without being rotated.

3. The method of claim 1 wherein the auger is lifted while it is rotated in its reverse direction.

4. A method for connecting piles to one another substantially as hereinbefore described with reference to and as shown by Figures 3 to 10 of the accompanying drawings.

5. A structure comprising piles connected together by the method of any one of the preceding claims.

6. An auger for use in the method according to any one of claims 1 to 4, such auger having holes for jetting hardener at the peripheral edge of its blade, conduits for conducting hardener to said holes, and a hole for jetting concrete at the forward end of the shaft, the shaft being hollow.

7. An auger according to claim 6, wherein the conduits extend along the length of the auger and within the auger blade.

8. An auger according to claim 6, wherein the conduits extend along the length of the auger and along the exterior of the auger blade.

9. An auger for use in the method of any one of claims 1 to 4 and constructed and arranged substantially as hereinbefore described with reference to and as illustrated in Figures 5 and 6 of the accompanying drawings.

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