

METHOD AND APPARATUS FOR PILE-DRIVING

BACKGROUND OF THE INVENTION

(a) Field of the Invention

The present invention relates to a method for driving pile such as steel pile, H sections pile, steel tube pile or concrete pile, and an apparatus therefor.

(b) Description of Prior Art

In the past, for a method of driving piles such as steel pile, H sections pile, steel tube pile or concrete pile, there have been proposed a pressure pile driver/extractor for driving piles with static load, or a vibratory hammer for driving piles with vibration. For these prior processes are jointly used so-called water jet process, depending on the driving length of a pile or a condition in the ground. According to such water jet process, along a steel pile is mounted to a pipe having its lower end provided with a nozzle and its upper end connected to a pump. Compressed water fed from the pump is then squeezed out from the nozzle to be jetted, thus forming an excavation hole below a lower end of the steel pile and removing sand therefrom in association with dissipation of water.

According to such prior water-jet jointly type process, driving stress can be reduced by suppressing the increase of stress between the lower part of steel pile and the ground, owing to highly pressurized water jet. Particularly, for silty or gravel bed, though not well recognized yet, water jet which is controlled with respect to its pressure and quantity can permit pore water pressure among soil particles to be raised,

thus moving the particles to remove stones and rocks positioned below the steel pile for easier driving.

However, when the steel pile is driven into gravel where stones and rocks are each solidly joined due to the particles consisting of sand and clay, driving efficiency will fall. To solve such problem, conventional process has tried to prevent such fall of the driving efficiency by increasing the pressure and quantity of water jet. With such approach, however, the driving efficiency could not be enhanced up to your expectation, even when two pressure-feeding pumps are used.

In Fig.8 (A) and (B) showing explanatory sections where compressed water 3 is sprayed from nozzle 2 provided at a lower end of steel pile 1. As shown in Fig.8 (A), compressed water 3 sprayed from nozzle 2 permits soil particles surrounding gravel 6 to be carried along steel pile 1 onto the ground together with water, whereby excavation hole 4 can be formed in the ground, as illustrated by arrow 5. However, even with such process, gravel 6 consisting of stones and rock pieces cannot be removed unless sufficiently affected by compressed water 3. Consequently, relatively a large-sized mass 8 consisting of multiple gravels 6 still remains within the ground, so that it would be an obstacle to driving of steel pile 1.

With the increased pressure and quantity of compressed water 3, the excavation hole 4 can be still deeper and a large amount of soil particles 7 is delivered onto the ground along steel pile 1 together with water, in which case, however, on a bottom of such large-sized excavation hole 4 inevitably deposits a great mass 8 consisting of multiple gravels 6

unaffected by compressed water 3. As a result, it will become more difficult to drive steel pile 1. If the pressure of compressed water 3 is increased twice that at the initial stage as described above, such increase of the pressure only results in requirement for more compressor-related devices and higher cost, and yet you cannot expect improvement of driving efficiency commensurate with such higher cost. Even worse, it is expected that driving efficiency will be sometimes degraded against your expectation.

SUMMARY OF THE INVENTION

Accordingly, it is a main object of the present invention to provide a method and apparatus for driving a pile which can improve driving efficiency at lower cost.

In accordance with an aspect of the present invention, there is provided a method for driving piles with compressed water being jetted from a lower end thereof, which is characterized in that a pile is driven into the ground with the compressed water being jetted downwardly from a nozzle for jetting compressed water therefrom which is provided at a lower end of the pile. At the same time compressed air is also being injected downwardly from another nozzle for jetting compressed air therefrom which is also provided at a lower end of the pile.

In accordance with another aspect of the present invention, there is provided an apparatus for driving piles comprising:

- a pile driver for driving a pile into the ground,
- a nozzle for jetting therefrom compressed water downwardly which is provided at a lower end of the pile,
- a compressed water supply for supply of compressed water to said nozzle therefor,

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another nozzle for jetting therefrom compressed air downwardly which is provided at a lower end of the pile, and a compressed air supply for supply of compressed air to said nozzle therefor.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the invention will be apparent to those skilled in the art from the following description of the preferred embodiments of the invention, wherein reference is made to the accompanying drawings, of which:

Fig. 1 is a schematic side view showing a first embodiment of

the invention.

Fig.2 is a section showing a steel pile of a first embodiment of the invention, to which is mounted a pipe.

Fig.3 is an enlarged section showing a lower end of a pipe of a first embodiment of the invention.

Fig.4 is a partially cut-away perspective view showing a lower end of a steel pile of a first embodiment of the invention.

Fig.5 is an explanatory section showing a lower end of a steel pile of a first embodiment of the invention, which is actually driven into the ground.

Fig.6 is a section of a testing device of a first embodiment of the invention, wherein Fig.6(A) is a section obtained by water jet, while Fig.6(B) by jointly used water and air jet.

Fig.7 is a schematically perspective view showing a second embodiment of the invention.

Fig.8 illustrates an explanatory section for explaining a prior art, wherein Fig.8(A) is a partially enlarged explanatory section with compressed water being sprayed at lower pressure, while Fig.8(B) an explanatory section at higher pressure.

DESCRIPTION OF PREFERRED EMBODIMENTS

Hereinafter is described a first embodiment of the present invention with reference to Figs.1 to 6.

In a first embodiment, the present invention is adapted to an extractor jointly used pile driver for driving a pile by applying static load to a steel pile. Reference numeral 12 designates steel pile wall consisting of a plurality of steel piles 11, to which is fixed extractor jointly used pile driver

13, having fixing leg 14 sandwich the above plural steel piles 11. Shifting device (not shown) permits the fixing leg 14 to be movable along the longitudinal length of the steel pile wall 12, said fixing leg 14 having a plurality of holding portions 14A at its lower part, thus holding the steel pile wall 12 to fix the pile driver 13 thereto. The pile driver 13 has holding arms 15 for holding steel pile 11, and pressure pile driver/extractor means 16 for raising and lowering the holding arms 15.

A pipe 21 removably mounted to along the steel pile 11 comprises external tube 22 and internal tube 23, thus forming compressed water passage 24 between an inner surface of the external tube 22 and an outer surface of the internal tube 23, while forming compressed air passage 25 within the internal tube 23. At a lower end of the pipe 21 is provided nozzle 26 for compressed water, which has inner surface 26A tapering toward the lower end, as shown in Fig.3. At a lower end of the nozzle 26 for compresses water is positioned the said internal tube 23, thus forming another nozzle 27 for compressed air. As shown in Fig.2, at an upper side of the pipe 21 is integrally provided jig 28, to which is rotatably mounted hook 29 anchorable to an upper edge of the steel pile 11. The jig 28 has stopper wire 30 therebelow and sling wire 31 thereabove. The lower part of the pipe 21 is fixed to the steel pile 11 with steel band 32 having legs 32A at both sides thereof, and has protrusions 26B thereon, thus sandwiching the steel band 32, as shown in Fig.4.

Referring again to Fig.2, at an upper end of the pipe 21 are provided water hose adapter 33 communicating with the

compressed water passage 24, and air hose adapter 34 communicating with the compressed air passage 25 respectively. The water hose adapter 33 is connected through high pressure resistant hose 35 to high pressure pump 36 or compressed water supply connected to water tank 37 in which is stored water by submerged pump 38, while the air hose adapter 34 through hose 39 to air compressor 40 or compressed air supply.

Now the driving action of steel piles 11 with the use of the above apparatus will be explained.

The pipe 21 is lifted up with the sling wire 31 of jig 28, while the hook 29 thereof is anchored to the upper edge of the driving steel pile 11. Pipe 21 is placed within concave portion 11A of steel pile 11, and the lower part thereof is fixed with band 32, whose legs 32A are welded to steel pile 11. As shown in Fig.2, stopper wire 30 is positioned at outer surface side of steel pile 11. Thus, if hook 29 is detached from steel pile 11, the tumbling of steel pile 11 can be still prevented owing to the stopper wire 30.

As shown in Fig.1, after the holding arms 15 of pile driver 13 fixed to steel pile wall 12 allow steel pile 11 to be fixed, the static load is applied to the steel pile 11 with the use of pile driver/extractor means 16, thereby pressing the steel pile 11 into the ground until it arrives at a predetermined depth. Then, the holding arms 15 are detached therefrom, which are raised again in preparation for the next operation. Such driving process will be repeated to successively drive steel piles 11. During such driving process, high pressure pump 36 and air compressor 40 are each actuated, thereby spraying compressed water W squeezed by nozzle 26,

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while injecting compressed air A as well. Thus, there can be formed excavation hole 41 below the lower end of the steel pile 11, as shown in Fig.5. The gravels 42 stored in the excavation 41 are vibrated by the force deriving from compressed water W and air A, while soil particles (not shown) attached to gravels 42 are removed such that the removed particles are delivered onto the ground along the surface of steel pile 11 together with dissipated water. At the same time, when compressed air A rises in a state of foam "a", it vertically vibrates gravels 42, thereby generating so-called lift-up effect. With such effect, the gravels 42 are stirred or agitated, so that the soil particles which bind each gravel 42 are removed from the mass 8 referred to in the preceding paragraph as to the prior art, and then, decomposed into fine gravels 42, as a result. In addition, stirring action owing to the foam "a" of the compressed air A permits the driving resistance of the steel pile 11 to be drastically lowered.

After the steel pile 11 is driven in the above manner, the pipe 21 is detached by lifting up the same with the use of sling wire 31, while the steel band 32 is disconnected from welded part of the legs 32A due to the force associated with the lifting of the pipe 21, thus enabling the lifting up of pipe 21 only.

Hereinbelow is shown a Table 1 related to a result in an experiment where a steel pile of 7 meters length is driven into a gravel bed, which shows interesting data obtained from contrast of those according to prior compressed water jet jointly used driving method to those based on the present invention where compressed water and air jet are jointly used,

each of which using a hydraulic pile driver/extractor of 90 ton class.

TABLE 1

	nozzle jet pressure (kg/cm ²)		driving resistance	driving time (minute)
Pile driving with compressed water jet jointly used. (a single tube exclusively used for water.)	water150		65	
	water100		55	40
	water 70		40	35
	water 50		30	32
	water 30		40	38
Pile driving with compressed water jet and compressed air injection jointly used. (a double tube consisting of external and internal tubes used.)	water150	air 5	35	15
	water100	air 5	30	12
	water 70	air 5	20	10
	water 50	air 5	10	6
	water 30	air 5	15	9

As is evident from the Table 1, according to the prior pile-driving method of compressed water jet jointly type, when the nozzle jet pressure is raised from 50Kg/cm², for example, to 100Kg/cm², the driving pressure is raised from 30 to 55 tons, which proved that mere increase of the jet pressure cannot reduce the driving pressure.

This teaches that when pressure driving a steel pile in a gravel bed, the increase of the jet pressure results in deeper excavation formed below the steel pile such that a mass of gravels is accumulated on the bottom thereof to increase the driving pressure. On the other hand, when the nozzle jet pressure is lowered from 50Kg/cm^2 , for example, to 30Kg/cm^2 , yet the driving pressure is raised. Consequently, it has proved that efficient operation can be possible only after the most suitable jet pressure is set, corresponding to the condition of the foundation. and mere increase of the jet pressure cannot improve the efficiency for pile-driving. Incidentally, the reason for blank of pile-driving time in the Table 1 corresponding to the nozzle jet pressure of 150Kg/cm^2 or above in the prior pile-driving method of compressed water jet jointly type, is that reactive pile of the hydraulic pile driver/extractor was pulled out in the midst of the experiment such that the further operation could not proceed.

In addition, according to the pile-driving method of compressed water and air jet jointly type of the invention, the pile-driving resistance indicated the lowest value when the nozzle jet pressure is 50Kg/cm^2 , which proved to be drastically reduced with the parallel injection of compressed air at 5Kg/cm^2 , as compared with the prior pile-driving method of compressed water jet jointly type. Such reduction of the pile-driving resistance was caused by the lift-up effect of foams generated in association with the jet of the compressed air, such that the gravels were stirred to make pores among the gravels floating within a pool in the excavation hole, thus reducing the pile-driving resistance of the steel pile.

As clearly shown in the Table 1 obtained from the above experiment, the additional jet of compressed air has proved to be able to drastically reduce the pile-driving resistance.

Referring to Fig.6 (A) and (B), there is provided an experimental model the present inventor made, in which plural stones 52 and sand 52A were placed on a bottom of cylindrical container 51, into which was inserted a lower end of double tube 54.

Under such condition, an experiment was conducted with respect to mere jet of water 53, and additional jet of air under the same condition, whose results were visually compared. As shown in Fig.6(A), when only water 53 is jetted, the sand 52A among the stones 52 were removed, shifting upward together with water 53, while stones 52 were deposited on the bottom of the container 51. In such case, it proved that the higher the pressure of water 53 was, the denser deposition of the stones 52 occurred with less clearances or pores among the same below the double tube 54.

On the other hand, when air was jetted at the same time the water 53 was jetted, it proved that there could be developed some force to lift up stones 52 together with sand 52A owing to the rise of air in the form of foams, so that the additional injection of air at the same time as the jet of water could enlarge pores among stirred stones 52 as compared with the jet of water 53 only.

According to a first embodiment of the invention, there is provided a method for driving steel pile 11 into the ground with the aid of jet or injection of compressed water W and air A from the lower end of the steel pile, wherein compressed

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water W jetted from the lower end of steel pile 11 allows soil particles binding each gravel 42 to be removed so as to form excavation hole 41 therebelow. Then, the gravels 42 stored within the excavation hole 41 are allowed to vibrate owing to injection force from compressed air A and water W, while each gravel 42 is vertically stirred during the rise of compressed air A in the form of large foam "a" to generate pores thereamong, whereby the pile-driving resistance of steel pile 11 can be reduced to improve pile-driving efficiency when driving piles in gravel bed.

Further, there is also provided an apparatus for driving steel pile 11 with the jet or injection of compressed water W and air A from the lower end of the steel pile, which comprises: a pile driver/extractor 13; a nozzle 26 for compressed water, said nozzle 26 being provided at a lower end of the steel pile 11; a high pressure pump 36 for supply of compressed water W to the nozzle 26; another nozzle 27 for compressed air A, said nozzle 27 being also provided at the lower end of the steel pile 11; an air compressor 40 for supply of compressed air A to the nozzle 27 for compressed air A, whereby compressed water W is jetted from the nozzle 26 for compressed water to form excavation hole 41 below the lower end of the steel pile 11, while at the same time, compressed air A is injected from the nozzle 27 therefor. Then, with the injection or jet force resulted from compressed air A and water W, the gravels 42 stored within the excavation hole 41 are allowed to vibrate, while each gravel 42 is vertically stirred during the rise of compressed air A in the form of large foam "a" to generate pores among the gravels 42.

Thus, the lower end of the steel pile 11 can be driven into the ground by applying relatively a small force thereto, and yet such apparatus is inexpensive as it uses relatively a compact air compressor. Further, as the compressed air A can be directly injected from the nozzle 27 provided at the lower end of the steel pile 11, the water within the excavation hole 41 can be greatly bubbled, thereby efficiently stirring the gravels 42 to make them float therein, which makes it easier to drive the lower end of the steel pile 11 into each clearance among the gravels 42. In addition, as the nozzle 27 for compressed air is positioned either on the same plane or downward relative to the lower end of the nozzle 26 for compressed water, the compressed air A whose pressure is lower than that of the compressed water W can be successfully injected.

In Fig.7 showing a second embodiment of the invention, the same portions as those described in a first embodiment will be designated as common reference numerals, and their repeated detailed description will be omitted.

In a second embodiment, vibratory pile-driver/extractor 13A such as a vibratory hammer is employed for pile-driving device. The vibratory pile-driver/extractor 13A has built-in vibrator 62 and chuck 61 therebelow for holding an upper part of steel pile 11, which is operatively lifted up by crane 63 while it is connected to actuating power generator 65 through operation unit 64. With the structure thus made, operation unit 64 is so operated that vibrator 62 is allowed to vibrate through a power source of the actuating power generator 65, thereby driving steel pile 11 into the ground with compressed

water W and air A being jetted or injected from the lower end of the steel pile 11 in the same manner as that of a first embodiment.

According to a second embodiment of the invention, there is provided a pile-driving apparatus which comprises: a vibratory pile-driver/extractor 13A; a nozzle 26 for compressed water, which is provided at a lower end of the steel pile 11; a high pressure pump 36 for supply of compressed water W to said nozzle 26; a nozzle 27 for compressed air A, which is also provided at a lower end of the steel pile 11; an air compressor 40 for supply of compressed air to said nozzle 27, thereby improving the efficiency for pile-driving with the use of relatively inexpensive apparatus in the same manner as that of a first embodiment.

Incidentally, the present invention should not be limited to the foregoing embodiments, but can be modified within a scope of the invention. For example, the present invention can be applied not only to steel pile, but to relatively long pile such as H sections pile, steel tube pile or concrete pile. Further, various types of pressure or vibratory pile-driver/extractor may be optionally selected. Furthermore, the feed tube for compressed air may be separate from that for compressed water instead of using a double tube of the embodiment.

What is claimed:

1. A method for driving piles with compressed water being jetted from a lower end thereof, which is characterized in that a pile is driven into the ground with the compressed water being jetted downwardly from a nozzle for jetting compressed water therefrom which is provided at a lower end of the pile, at the same time compressed air being also injected downwardly from another nozzle for jetting compressed air therefrom which is also provided at a lower end of the pile.

2. An apparatus for driving piles comprising:
a pile driver for driving a pile into the ground;
a nozzle for jetting therefrom compressed water downwardly which is provided at a lower end of the pile;
a compressed water supply for supply of compressed water to said nozzle therefor;
another nozzle for jetting therefrom compressed air downwardly which is provided at a lower end of the pile;
a compressed air supply for supply of compressed air to said nozzle therefor.

3. A method for driving piles according to claim 1, wherein said nozzle for compressed air has its lower end positioned below a lower end of said nozzle for compressed water, whereby the compressed air which is less pressurized than the compressed water is jetted from below said nozzle for compressed water, thereby allowing the compressed water to form an excavation hole below the end of the pile, while allowing the compressed water and compressed air to stir gravels contained in said excavation hole, forming pores among the gravels, into which the pile is to be driven.

4. An apparatus for driving piles according to claim 2, further comprising: a pipe removably provided along said pile, said pipe having outer and inner tubes to define a passage for compressed water between an inner surface of the outer tube and an outer surface of the inner tube; and another passage for compressed air within said inner tube,
wherein said nozzle for compressed water is disposed at a lower end of said passage

for compressed water, and likewise, said nozzle for compressed air is disposed at a lower end of said passage for compressed air, while said compressed water supply is connected to an upper end of said passage for compressed water, and likewise, said compressed air supply is connected an upper end of said passage for compressed air.

5. An apparatus for driving piles according to claim 2 or 4, wherein said nozzle for compressed air is disposed approximately flush with or below the lower end of said nozzle for compressed water, said nozzle for compressed air allowing the jetting of air less pressurized than the compressed water.

6. An apparatus for driving piles according to one of claims 2, 4 and 5, said nozzle for compressed water comprising an inner surface which tapers toward the lower end thereof.

7. An apparatus for driving piles according to claim 4, wherein a lower end of said pipe is fixed to the pile with a steel band having legs at both sides, said legs being welded to the pile, while said pipe is provided thereon with protrusions that engageably sandwich the band, whereby the lifting-up motion of said pipe permits said welded legs to be broken.

8. A method for driving piles according to claim 1, wherein said pile is steel pile, H-sections pile, steel tube pile or concrete pile.

9. An apparatus for driving piles according to claim 2, wherein said pile is steel pile, H-sections pile, steel tube pile or concrete pile.