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(54) FLEXIBLE SAND DRAIN FOR SOFT GROUND AND METHOD FOR CONSTRUCTING THE SAME IN THE SOFT GROUND

(71) We, CHIYODA CHEMICAL ENGINEERING & CONSTRUCTION COMPANY LIMITED, a Japanese corporate body, of 1580 Tsurumi-cho, Tsurumi-ku, Yokohama-shi, 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 sand drain and more particularly to a flexible sand drain embedded in soft ground and the method of constructing the same.

Where a sand drain is to be provided in soft ground, mere formation of a sand pillar by drilling the ground and filling sand thereinto renders the sand pillar incapable of withstanding a shearing force originating with the displacement of the soft ground, with the result that the sand pillar is bent and finally pinched off, namely, has the upper and lower portions separated from each other, often failing to attain the proper function of a sand drain. To avoid these difficulties, there has hitherto been used a sand drain constructed by filling sand into a protector made of such cloth or paper as is not easily breakable. In the United States Patent No. 3,396,541 is set forth a typical sand drain using a protector made of woven fabric.

The sand drains proposed to date consist of a large diameter sand pillar thus having a large shearing area, and a protector prepared from material of great tensile strength. However, a sand pillar constructed by the prior art has been readily broken by a shearing force. Moreover, the soft ground in which a sand drain is usually provided tends to exert an extremely strong shearing force on the sand drain especially when it is additionally subjected to a compressive load. A conventional sand drain has been found

to have limited capacity to withstand such shearing forces.

The prior art protector of woven fabric has such small meshes as allow the influx of water into the sand filled in the protector, but prevent the sand therein from passing out of the protector. Accordingly, the flow of underground water into a sand drain causes clay entrained with the water to have its passage obstructed by the fine meshed wall of the protector, consequently forming a water-impermeable film on the protector. As a result, the protector has its fine meshes clogged, obstructing the passage of water into a sand drain, and reducing the drainage of water for which the sand drain is primarily intended. Though it might be considered advisable to build many large sand drains at a location to be drained in order to eliminate the above-mentioned difficulties, it takes a great deal of time to construct large diameter sand drains in a required number one by one. Prior to the present invention no method of constructing sand drains was known which enabled a number of such drains to be constructed at the same time by a single pile driver.

Moreover, the construction of a large diameter sand drain consumes a great deal of sand, and a protector used with such sand drain is subject to rigid requirements in respect of quality and mechanical strength, and unavoidably becomes expensive, resulting in economic disadvantage.

It is accordingly an object of this invention to provide a flexible sand drain for soft ground which maintains a water-draining capacity over a long period, is readily rendered sufficiently flexible to match any displacement of soft ground, and is consequently less subject to shear breakage than previously known sand drains.

Another object of this invention is to 90

provide a method for constructing such sand drains in soft ground.

According to this invention, there is provided a flexible sand drain including a sand pillar and a tubular protector holding said sand pillar, said protector comprising plain woven fabric constituted by warps and wefts of water-repellent, anti-weathering, chemically-noncorrosive monofilaments so interlaced as to make intra-filament meshes large enough to allow the flow of the sand of said sand pillar out of said protector.

The protector, in use, does not allow such a substantial amount of the sand of the sand pillar to escape as would cause reduction in the required diameter of the sand drain.

The protector should preferably be formed by arranging the warps lengthwise of the protector and the wefts circumferentially of the protector at right angles to the warps, causing the protector as a whole to present a lattice formation.

For fabrication of a protector, it is preferable to superpose two elongate sheets of woven fabric and join the sheets along lines slightly inset from both lengthwise edges to provide lug portions extending lengthwise of the protector, thereby preventing the protector from being twisted when it is inserted into a casing. The intra-filament meshes are chosen to have an area of 2.0 to 3.0 mm². A suitable protector is one prepared from two sheets of monofilament woven fabric having a thickness of 300 to 500 deniers, which has a diameter of 5 to 25 cm, which has a lengthwise tensile strength of more than 100 kg and a crosswise tensile strength of more than 75 kg per 5 centimetre width of said protector as measured when said protector is flattened and which has an extensibility of less than 5%.

The method of this invention for constructing sand drains in soft ground comprises the steps of arranging in a regular polygonal form a plurality of casings having a sufficiently large inner diameter to receive protectors consisting of monofilament woven fabric bearing sufficiently large meshes to permit the passage of sand filled into said protectors, and provided at the top with a freely operable sealing cover; driving said casings into said soft ground at the same time by a vibro-hammer mounted on a pile driver; connecting the upper ends of said protectors to the outlets of a hopper mounted on said pile driver after said protectors are inserted into said casings and filling sand in said protectors using the vibration of said vibro-hammer to form a sand pillar; introducing compressed air into said casings with the respective sealing covers closed; and extracting said casings

out of said soft ground while said casings are being vibrated by said vibro-hammer, the extraction of said casings being assisted by the lubricating action of the sand which has passed through the meshes of said protectors into a gap between said casings and protectors; thereby firmly setting in said soft ground, sand drains comprising said protectors and sand pillars held therein.

It is possible to insert the protector into the casing and fill the protector with sand before the casing is driven into the ground.

Where a sand drain is constructed in soft ground under water, provision of a rod having a length equal to or larger than the water depth between the vibro-hammer and a casing enables the casing to be driven into the soft ground under water so as to bring the upper end of the casing near the surface of said ground.

This invention will be described by way of example with reference to the accompanying drawings in which:

Fig. 1 is a perspective view of a tubular protector used with a flexible sand drain according to this invention which is constructed in soft ground;

Fig. 2 is a fractional enlarged view of the protector of Fig. 1;

Fig. 3 is a cross-sectional view of the protector of Fig. 1;

Fig. 4 schematically illustrates the method of this invention for building a sand drain in soft ground;

Fig. 5 is a front elevation of the main part of a pile driver used in constructing the sand drain of Fig. 4;

Fig. 6 is a cross-sectional view on line 6-6 of Fig. 5;

Fig. 7 is a cross-sectional view on line 7-7 of Fig. 5;

Fig. 8 schematically shows the condition of the pile driver of Fig. 5 where casings are suspended therefrom in a state ready to be driven into soft ground; and

Fig. 9 schematically indicates the condition of the pile driver where it is ready to drive casings into underwater soft ground.

Throughout the figures, the same parts are denoted by the same numerals.

A sand drain 10 comprises a tubular protector 11 and a sand pillar 12 formed of sand 13 filled therein (Fig. 4).

The protector 11 is formed in the following manner. Water-repellent, anti-weathering, chemically-noncorrosive monofilaments are roughly interlaced into the lattice form to provide plain woven fabric 15, whose enlarged view is given in Fig. 2. Referring to Fig. 2, the vertically extending monofilaments 14 are warps 16 and the horizontally extending monofilaments 14 are wefts 17. As later described, the intrafilament meshes 18 of the fabric 15, namely, the openings defined by the adjacent warps 16 and ad-

jacent wefts 17 are each chosen to have an area of 2.0 to 3.0 mm². To provide intra-filament meshes 18 having the above-mentioned size, it is advised to use monofilaments 14, or warps 16 and wefts 17, both having a thickness of 300 to 500 deniers. Experiments show that, as measured per 5 cm width when flattened, the protector 11 should have a lengthwise tensile strength along the warps 16 of more than 100 kg and a cross-wise tensile strength along the wefts 17 of more than 75 kg, and an extensibility of less than 5%. Polyethylene, for example, may be used as a suitable material of monofilaments which meets the above-mentioned requirements.

The protector 11 is formed, as shown in Fig. 1, by superposing two narrow strips of the above-mentioned fabric 15 obtained by cutting along the warps 16 and joining both strips along the lines 19 each of which is located about 20 mm inset from an adjacent length-wise edge of the strips (hereinafter the lines 19 are referred to as the "joints"). The joints are formed by thermal fusion, sewing or interlacing together of the warps 16 of the two strips of fabric 15. Thus, the protector 11 comprises a main body 20 defined between the joints 19 and two pairs of lengthwise elongate lugs 21 disposed adjacent to the main portion 20. The lugs 21 of each pair positioned outside of the joints 19 may be fused or interlaced together. In the protector 11, the warps 16 are arranged lengthwise and the wefts 17 are interlaced therewith at right angles, minimizing the extensibility of the former in the lengthwise direction and that of the latter in the crosswise direction.

The distance between the joints 19 of the fabric 15, namely the width of the main body 20 is chosen to range between about 8 cm and about 39 cm depending on the required diameter for the sand drain to be constructed in order that, where the protector 11 is expanded by being filled with sand, it may have a circular cross-section, as shown in Fig. 3, of 5 to 25 cm in diameter D.

The protector 11 is inserted, as shown in Fig. 4, into a casing 22 previously driven vertically into soft ground and then filled with sand 13. When the casing 22 alone is pulled out, a sand drain 10 remains.

A pile driver 23 shown in Figs. 5 to 8 is provided with a vibro-hammer 24. Arms 25 horizontally extending from the side wall of the vibro-hammer 24 engage upright guiding members 26 to permit the vertical movement of the vibro-hammer 24. To the bottom of the vibro-hammer 24 is attached a power transmitting block 27, to the bottom end of which a fixing plate 28 is fixed to receive the casings 22. Case-fixing means 28a (Fig. 6) are provided on the fixing plate

28 at the apices S of a polygon whose center lies on the axis 0 of the block 27. Though the polygon is a square in Figs. 5 to 8, any other polygon may obviously be used. The block 27 is fitted with a sand hopper 29 bored with a plurality of outlets 29a which, when the casings 22 are fitted to the fixing plate 28, are brought right above the upper ends 22a of the casings 22.

The guiding members 26 are fitted at the lower end 26a with a horizontal guide plate 31 bored with openings 30 (Fig. 7) through which the casings 22 are conducted to the apices of the aforesaid polygon.

Referring to Fig. 8, the vibro-hammer 24 can be lifted to any desired height with the aid of a wire 34 by a drive means 33 mounted on the base 32 of the pile driver 23.

There will now be described the process of simultaneously constructing sand drains in soft ground. First, the vibro-hammer 24 of the pile driver 23 is lifted to such height that when the upper ends 22a of the casings 22 are attached to the fixing plate 28, the casings 22 can be set fully upright on the soft ground 35. Under this condition, the casings 22 are positioned, as previously described, at the apices of a polygon.

Upon completion of the above-mentioned preliminary operation, the wire 34 is loosened to actuate the vibro-hammer 24. The casings 22 are simultaneously driven by the vibration of the vibro-hammer 24 into the soft ground 35 until the lower ends 22b of the casings 22 are brought down to the prescribed depth. Thus, a plurality of casings 22 can be efficiently driven simultaneously, as easily understood, into the soft ground 35 by a single pile driver 23. Fig. 4 illustrates the sand drain - constructing method of this invention. Though, for brevity of description, only one casing 22 is indicated in Figs. 4(A) to 4(C), a plurality of casings 22 are driven at the same time by a single pile driver shown in Figs. 5 to 8. Fig. 4(A) shows the conditions in which the driving of the casing 22 has been completed. To the upper end 22a of the casing 22 is hinged a freely operable sealing cover 36. With the sealing cover 36 kept open as shown in Fig. 4(B), the protector 11 is inserted into the casing 22 to the prescribed depth. To facilitate said insertion, it is advised to attach a hook 37 to the lower end portion 11b of the protector 11 and suspend a weight 38 from the hook 37. The weight 38 consisting, for example, of sand wrapped in a piece of woven fabric enables the protector 11 to be easily brought down to the bottom of the casing 22. Alternatively, it is possible to fasten or close the lower end portion 11b of the protector 11 and place an initial quantity of sand in the lower end portion 11b of the protector 11. To effect the easy insertion of the protector 11 into

the casing 22, a clearance to 2 to 5 mm is allowed between the inner wall of the casing 22 and the outer wall of the protector 11 depending on the diameter of the latter.

- 5 Accordingly, a casing 22 which receives a protector 11 of 5 to 25 cm in diameter is chosen to have an inner diameter of about 5.4 to 26 cm.

- 10 The two pairs of lugs 21 formed all along both lengthwise edges of the protector 11 (Figs. 1 to 3) enable the protector 11 to be inserted into the casing 22 without being in a twisted condition, a condition which would hamper the subsequent filling of sand into the protector 11.

- 15 Upon completion of the insertion of the protector 11, its upper end 11a is connected to the corresponding outlet 29a of the sand hopper 29 so firmly as to prevent the upper end 11a from falling off the outlet 29a. Thereafter, the vibro-hammer 24 is made to vibrate to let fall sand 13 from the hopper 29 into the protector 11. As the sand 13 is gradually filled into the protector 11 a small portion of the sand 13 flows out, as shown in Fig. 4 (C), through the intrafilament meshes 18 (Fig. 2) of the protector 11 to fill a gap 39 between the protector 11 and casing 22 for a purpose described herein-
after. However, most of the sand 13 is retained in the protector 11 to form a sand pillar 12. When the sand 13 is filled up to that part of the protector 11 which is still positioned above the ground 35, then the upper end 11a of the protector 11 is taken off the corresponding outlet 29a of the sand hopper 29 and received in the casing 22 in a folded state.

- 20 The upper end 22a of the casing 22 is closed with the sealing cover 36, which is tightened by a latching device 40. Thereafter compressed air is introduced into the casing 22 through an inlet pipe 41 disposed at the upper end of the casing 22. The casing 22 is pulled out of the ground 35 by the drive means 33 (Fig. 8), while being vibrated by the vibro-hammer 24. During the withdrawal of the casing 22, compressed air acts to push the sand drain 10 downward so as to prevent it from being lifted by soft soil. Further, the sand 13 which has passed through the intrafilament meshes 18 of the protector 11 into the gap 39 between the protector 11 and casing 22 prevents the protector 11 from being brought into contact with the casing 22, namely, acts as a sort of lubricant, thereby saving the protector 11 from damage caused by friction heat resulting from said contact and enabling a sand drain 10 to be firmly set underground without being pulled out together with the casing 22. The application of compressed air and the presence of the sand 13 in the gap 39 jointly help the casing 22 alone to be removed from the ground

35 without causing the protector 11 to be pulled up also. Thus is constructed, as shown in Fig. 4 (D), the sand drain 10 having the protector 11 filled with the sand 13. On the sand drain 10 is mounted a load 42.

70 The vibration to which the casing 22 is directly subjected when it is driven into ground and the vibration indirectly imparted to the casing 22 when the protector 11 inserted into the casing 22 is filled with sand 13 cause the water in the soft ground 35 to gradually collect around the periphery of the casing 22. When the casing 22 is pulled out, a space is left into which flows the water in the soft ground which had gathered around the periphery of the casing 22 due to vibration being imparted thereto. Thus, upon the withdrawal of the casing 22, the collected water is immediately shifted to the periphery of the protector 11 filled with sand 13, but does not intrude into the sand as the interstices of the sand drain are filled with compressed air. When the casing 22 is fully pulled out of the ground, compressed air previously introduced into the casing 22 is ejected to the ground surface, the air passing through the peripheral wall of the protector 11 constituting the sand drain 10 and along the space, thereby causing the water already gathered around the periphery of the protector 11 to gush out of the ground. That water is also displaced out of the ground as the space becomes filled by the ground closing round the drain.

100 When the condition of the sand drain is stable, water drains from the ground into the sand drain and thence to the ground surface.

105 When the sand drain 10 is constructed in the soft ground 35 as shown in Fig. 4 (D), clay particles enter the sand pillar 12 through the intrafilament meshes 18 of the protector 11 together with the water from the soft ground. It is true that clay particles are retained among the sand drains 13 of the sand pillar 12 in increasing amounts with time, slightly reducing the water-draining capacity of the sand drain 10. As compared with the prior art sand drain, however, wherein the fine meshes of the protector cause a water-impermeable film of clay to be formed on the outer wall of the protector and in consequence obstruct in a relatively short time the passage of the water from the soft ground into the sand pillar in the protector, the sand drain of this invention displays a far smaller decrease with time in the water-draining capacity, because the meshes 18 of the protector 11 are less likely to be clogged. During the normal use of the sand drain of this invention, the above-mentioned clogging can be practically overlooked.

125 Placement of a load on soft ground generally gives rise to complicated displacements in the various parts of the ground. 130

With the prior art sand drain, therefore, the sand pillar has a very large diameter (generally more than 40 cm) in order to avoid distortion resulting from the displacement of ground strata and further the protector is prepared from material of very great tensile strength. In contrast, the sand drain 10 of this invention is not made sufficiently rigid like that of the prior art to maintain an upright position against any displacement of ground strata, but, as illustrated in Fig. 4 (E), is rendered freely flexible to flex under a shearing force while maintaining the continuity of structure, thereby being saved from breakage due to the effects of a shearing force and always retaining a fixed diameter, whatever position the sand drain 10 may take.

Further, the protector 11 of this invention is formed of fabric 15 having large sized meshes 18 and is more pliable than the fine meshed protector of the prior art sand drain and assists the flexibility of the sand drain 10.

With the depth of the ground 35 to which the sand drain 10 is driven designated as L and the diameter of the sand drain 10 as D, it has been experimentally proved that if the ratio of L to D exceeds about 40, the sand drain 10 will be fully flexible. Since the sand drain is generally driven to a ground depth of about 10 meters, the diameter D of the sand drain 10 is about 25 cm at maximum. Depending on the condition of the soft ground 35, however, the sand drain 10 is chosen to have a diameter D ranging between 5 and 25 cm. The sand drain 10 of this invention has the above-mentioned small diameter as against the over 40 cm diameter of the prior art sand drain, enabling a plurality of sand drains 10 to be driven into ground at the same time with a shorter construction period than has been possible in the past.

If Barron's theory is applied to the method of constructing a sand drain underground, time required for the settlement of ground due to consolidation will be proportional to the square of the effective diameter of the influence circle of a sand drain. It is known, therefore, that a dense underground construction of small diameter sand drains has a greater economic merit than the sparse underground arrangement of large diameter sand drains.

The tensile strength of the protector has to be such as will enable it to support the weight of sand when the protector is hanging from its upper end and is filled with sand. Since the capacity of the protector to support the weight of the sand pillar 12 it contains per unit peripheral length of the protector 11 is proportional to the diameter D of the protector 11, a small protector diameter offers the advantage of reducing the

required load carrying capacity of the protector.

There will now be described by reference to Fig. 9 the method of constructing the sand drain 10 using the protector 11 of Figs. 1 to 4 in soft ground under sea or fresh water. The pile driver 23 is firmly erected by a leader 43 alongside a piling ship 45 afloat on the water 44. A vibro-hammer 24 has its height adjusted by being vertically moved along the leader 43 with the aid of a wire 34. From the lower end of the vibro-hammer 24 is suspended a power transmitting rod 46 longer than the water depth E. The rod 46 is inserted into a supporting member 47. The supporting member 47 is provided with a fixing means 48, which, when tightened, firmly fixes the member 47 to the rod 46. The fixing means 48 enables the position of the supporting member 47 on the rod 46 to be freely adjusted by vertically moving the supporting member 47 along the rod 46. The casings 22 are securely suspended from the supporting member 47 so as to be arranged in a regular polygonal form. A sand hopper 29 is fixed to the leader 43 such that the outlets 29a of the sand hopper 29 are brought right above the upper ends 22a of corresponding casings 22.

Arms 25, guiding members 26 and guide plate 31 shown in Fig. 9 correspond to those of the pile driver of Figs. 5 to 8.

There will now be described by reference to Fig. 9 the method of constructing sand drains in the soft ground 35 under water 44. First, the rod 46, together with the vibro-hammer 24, is lifted to a proper height, and the casings 22 are fitted to the supporting member 47 so as to be arranged in a regular polygonal form. A protector 11 shown in Figs. 1 to 4 is inserted into each casing 22, and thereafter the rod 46 is lifted together with the vibro-hammer 24. The upper ends 22a of the casings 22 are connected to the outlets 29a of the sand hopper 29 so as to fill sand 13 into the protectors 11 already inserted into the casings 22. The vibro-hammer 24 is operated and the casings 22 are driven into the soft ground 35 under the water 44 by the vibration of the vibro-hammer 24 with the aid of the rod 46. In the event that the upper ends 22a of the casings 22 are still positioned too high above the surface 35a of the soft ground 35 when the vibro-hammer 24 has reached its lowest permissible position near the upper surface of the sand hopper 29, the fixing means 48 can be loosened and the rod 46 can be lifted so that its lower end is at the level of the member 47. With the fixing means 48 tightened to re-grip the rod 46, the vibro-hammer 24 is again operated to drive the casings 22 further into the soft ground 35. Though the water 44 is present on the soft

ground 35, the above-mentioned process enables the casings 22 to be driven into the soft ground 35 until the upper ends 22a of the casings 22 are brought close to the surface 35a of the soft ground 35.

The driving of the casings 22 by the pile driver 23 of Fig. 9 can generally be effected to the prescribed ground depth without adjusting the relative positions of the rod 46 and supporting member 47 in the interim or otherwise carrying out said adjustment only once. Where required, however, adjustment of said relative positions may be repeated any number of times. Upon completion of the driving of the casings 22 into the soft ground 35, compressed air is introduced, as previously mentioned, into the casings 22. The casings 22 alone are pulled out by the vibration of the vibro-hammer 24 and assisted as well as by the lubricating action of sand 13 (Fig. 4 (D)) present in the gap 39 between the casings 22 and the protectors 11 inserted therinto, thereby constructing the same type of sand drains as shown in Fig. 4 (D).

Where casings are driven into soft ground under water by the method and apparatus of the prior art, the upper ends of the casings cannot be submerged underwater, making it necessary to lengthen the casings to an extent at least equal to water depth and consequently giving rise to economic disadvantage. If the protector of this invention should be inserted in such elongate casing, the protector would have to be made long enough to match said extended casing. Otherwise, where there was used a protector long enough to match the ground depth to which the casing was driven, then the protector, after filled with sand, would have to be let fall through the above-mentioned elongate casing. The former case would result in economic disadvantage, while the latter case is an unsatisfactory solution because the protector could be stopped during its fall through the casing and so fail to reach the bottom of the casing.

In contrast, the method of this invention fully eliminates the drawbacks accompanying the prior art process of constructing a sand drain.

The sand-drain forming pile driver described herein is the subject of our co-pending Patent Application No. 32175/75. (Serial No. 1429890).

WHAT WE CLAIM IS:—

1. A flexible sand drain including a sand pillar and a tubular protector holding said sand pillar, said protector comprising plain woven fabric constituted by warps and wefts of water-repellent, anti-weathering, chemically-noncorrosive monofilaments so interlaced as to make intrafilament meshes large enough to allow the flow of the sand

of said sand pillar out of said protector.

2. A sand drain according to claim 1 wherein said warps extend lengthwise of said protector with said wefts intersecting said warps at right angles so as to reduce the extensibility of said protector.

3. A sand drain according to claim 1 or 2 wherein said protector is provided with lugs extending lengthwise for preventing said protector from being twisted when inserted into a casing.

4. A sand drain according to any of claims 1 to 3 wherein said protector has a diameter of 5 to 25 centimetres.

5. A sand drain according to claim 4 wherein said protector has an extensibility of less than 5 per cent, a lengthwise tensile strength of more than 100 kilogrammes and a cross wise tensile strength of more than 75 kilogrammes per 5 centimetre width of said protector as measured when said protector is flattened.

6. A sand drain according to claim 5 wherein said monofilaments have a thickness of 300 to 500 deniers.

7. A method for constructing flexible sand drains in soft ground which comprises the steps of arranging in a regular polygonal form a plurality of casings having a sufficiently large inner diameter to receive protectors consisting of monofilament woven fabric bearing sufficiently large meshes to permit the passage of sand filled into said protectors, and provided at the top with a freely operable sealing cover; driving said casings into said soft ground at the same time by a vibro-hammer mounted on a pile driver; connecting the upper ends of said protectors to the outlets of a hopper mounted on said pile driver after said protectors are inserted into said casings and filling sand in said protectors using the vibration of said vibro-hammer to form sand pillars; introducing compressed air into said casings with the respective sealing covers closed; and extracting said casings out of said soft ground while said casings are being vibrated by said vibro-hammer, the extraction of said casings being assisted by the lubricating action of the sand which has passed through the meshes of said protectors into a gap between said casings and protectors; thereby firmly setting in said soft ground, sand drains comprising said protectors and sand pillars held therein.

8. A method for constructing flexible sand drains in soft ground according to claim 7 wherein said casings are driven into underwater soft ground by a power transmitting rod provided between said vibro-hammer and casings until the upper ends of said casings are brought close to the surface of said soft ground under water.

9. A flexible sand drain for soft ground, substantially as hereinbefore described with

ground 35, the above-mentioned process enables the casings 22 to be driven into the soft ground 35 until the upper ends 22a of the casings 22 are brought close to the surface 35a of the soft ground 35.

The driving of the casings 22 by the pile driver 23 of Fig. 9 can generally be effected to the prescribed ground depth without adjusting the relative positions of the rod 46 and supporting member 47 in the interim or otherwise carrying out said adjustment only once. Where required, however, adjustment of said relative positions may be repeated any number of times. Upon completion of the driving of the casings 22 into the soft ground 35, compressed air is introduced, as previously mentioned, into the casings 22. The casings 22 alone are pulled out by the vibration of the vibro-hammer 24 and assisted as well as by the lubricating action of sand 13 (Fig. 4 (D)) present in the gap 39 between the casings 22 and the protectors 11 inserted therein, thereby constructing the same type of sand drains as shown in Fig. 4 (D).

Where casings are driven into soft ground under water by the method and apparatus of the prior art, the upper ends of the casings cannot be submerged underwater, making it necessary to lengthen the casings to an extent at least equal to water depth and consequently giving rise to economic disadvantage. If the protector of this invention should be inserted in such elongate casing, the protector would have to be made long enough to match said extended casing. Otherwise, where there was used a protector long enough to match the ground depth to which the casing was driven, then the protector, after filled with sand, would have to be let fall through the above-mentioned elongate casing. The former case would result in economic disadvantage, while the latter case is an unsatisfactory solution because the protector could be stopped during its fall through the casing and so fail to reach the bottom of the casing.

In contrast, the method of this invention fully eliminates the drawbacks accompanying the prior art process of constructing a sand drain.

The sand-drain forming pile driver described herein is the subject of our co-pending Patent Application No. 32175/75. (Serial No. 1429890).

WHAT WE CLAIM IS:—

1. A flexible sand drain including a sand pillar and a tubular protector holding said sand pillar, said protector comprising plain woven fabric constituted by warps and wefts of water-repellent, anti-weathering, chemically-noncorrosive monofilaments so interlaced as to make intrafilament meshes large enough to allow the flow of the sand

of said sand pillar out of said protector.

2. A sand drain according to claim 1 wherein said warps extend lengthwise of said protector with said wefts intersecting said warps at right angles so as to reduce the extensibility of said protector.

3. A sand drain according to claim 1 or 2 wherein said protector is provided with lugs extending lengthwise for preventing said protector from being twisted when inserted into a casing.

4. A sand drain according to any of claims 1 to 3 wherein said protector has a diameter of 5 to 25 centimetres.

5. A sand drain according to claim 4 wherein said protector has an extensibility of less than 5 per cent, a lengthwise tensile strength of more than 100 kilogrammes and a cross wise tensile strength of more than 75 kilogrammes per 5 centimetre width of said protector as measured when said protector is flattened.

6. A sand drain according to claim 5 wherein said monofilaments have a thickness of 300 to 500 deniers.

7. A method for constructing flexible sand drains in soft ground which comprises the steps of arranging in a regular polygonal form a plurality of casings having a sufficiently large inner diameter to receive protectors consisting of monofilament woven fabric bearing sufficiently large meshes to permit the passage of sand filled into said protectors, and provided at the top with a freely operable sealing cover; driving said casings into said soft ground at the same time by a vibro-hammer mounted on a pile driver; connecting the upper ends of said protectors to the outlets of a hopper mounted on said pile driver after said protectors are inserted into said casings and filling sand in said protectors using the vibration of said vibro-hammer to form sand pillars; introducing compressed air into said casings with the respective sealing covers closed; and extracting said casings out of said soft ground while said casings are being vibrated by said vibro-hammer, the extraction of said casings being assisted by the lubricating action of the sand which has passed through the meshes of said protectors into a gap between said casings and protectors; thereby firmly setting in said soft ground, sand drains comprising said protectors and sand pillars held therein.

8. A method for constructing flexible sand drains in soft ground according to claim 7 wherein said casings are driven into underwater soft ground by a power transmitting rod provided between said vibro-hammer and casings until the upper ends of said casings are brought close to the surface of said soft ground under water.

9. A flexible sand drain for soft ground, substantially as hereinbefore described with



reference to the accompanying drawings.

10. A method for constructing flexible sand drains in soft ground, substantially as hereinbefore described with reference to the 5 accompanying drawings.

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