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PATENT SPECIFICATION

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(54) DOUBLE COATED PILES

(71) We, NIPPON KOKAN KABUSHIKI KAISHA, a corporation organised and existing under the laws of Japan, of 1-2, Marunouchi-1-chome, Chiyodaku, Japan, do hereby declare the invention, for which the 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:—

The present invention relates to a double coated pile designed to reduce the negative frictional force.

Where a building is constructed on a soft soil, such as clay or a peat deposit, concrete piles or steel piles are usually employed, and the forward ends of these piles rest on a bearing sand layer to support most of the weight of the building, with the remainder of that weight being supported by the soft soil layers, since there is friction between the soil layers and the piles.

Such friction helps to prevent sinking of a pile, i.e. to support the weight of the building when the soft soil layers have satisfactorily settled or hardened, but when the soft soil layer is still in the course of settling, there is a downwardly acting frictional force, which in turn applies an additional load on the forward ends of the piles.

This downwardly acting force, the so-called negative friction, is undesirable, since it considerably reduces the bearing capacity of a pile. In other words, since this negative frictional force reduces the net bearing capacity of the bearing pile, it eventually gives rise to sinking of the pile. Consequently, it is essential to reduce this negative frictional force.

In the past, two types of piles have been proposed to reduce such a negative frictional force, namely, a double pipe structure pile and a bituminous coated pile. A disadvantage of the former type is that its increased weight gives rise to a difficulty in driving the pile, and moreover the accuracy of the pile driving work, as well as the resistance of the pile to the lateral stress of the surrounding soil are diminished. In the case of the latter pile, there are also disadvantages,

namely, the application of a relatively thick bituminous layer of over 3 mm is generally coating operation, with resulting inefficiency and low productivity. Moreover, the application of a bituminous coating on long piles is not an easy matter, and in a hot summer the bituminous layer on a pile tends to soften, thus making impossible, the long-term storage and the transport of a pile. Hence, the coating of the piles has to be carried out in the field. Still another disadvantage is that there is the possibility of a decrease in the adhesion between the pile and the bituminous coating layer, due to the impact forces during the pile driving operation, and there is also the possibility of the bituminous layer being deformed by the circumferential friction. Still another disadvantage is that the effectiveness of the coating in reducing the negative frictional force is itself reduced by gravel or the like which may penetrate into the bituminous layer. Though the above-mentioned deficiencies of a bituminous coated pile have been practically overcome by a prior, proposed coated pile, the protective layer of this coated pile also tends to be subjected to such damage as peeling, etc., due to the vertical soil pressure applied to the pile during the driving. Such damage reduces the effectiveness of the coated pile in reducing the negative frictional force.

In view of the above-mentioned circumstances, it is an object of the present invention to provide a bituminous coated pile which eliminates the foregoing difficulty.

It is another object of the invention to provide a pile which is designed so that the application of a bituminous layer and an outer layer may be effected in a factory and which is capable of being stored over a long period of time and also being transported.

It is still another object of the invention to provide a pile which may be driven into place with a high degree of accuracy without any danger of the protective layer being peeled off or broken during the driving of the pile.

These and further objects will become apparent from considering the following detailed description.

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The present invention provides a double coated pile which comprises, a bituminous layer formed on the outer surface of the pile itself and an outer layer of a synthetic resin, paper or knitted, woven or non-woven fabric of natural or synthetic fibre applied on the surface of the bituminous layer, wherein the composition of the bituminous layer is such that its softening point and penetration lie within a polygon having vertices corresponding to points A (55,20), B(33,240), C(53,10), D(65,10) and E(80,30) on a graph in which the abscissa represents the softening point measured according to ASTM D-36 on the Centigrade temperature scale according to a linear scale, and the ordinate represents the penetration (measured according to ASTM D-5), according to a logarithmic scale, the unit of penetration being 0.1 mm at 25°C.

Another feature of the double coated pile provided in accordance with the present invention is that the composition of the outer layer, (which may, for example, be a polyolefin layer), satisfies the following relation:

$$d \times E \geq 35 N$$

where

d=thickness of the outer layer (cm)

E=Young's modulus of the outer layer (kg/cm²)

N=the hardness of the soil, measured according to JIS A 1219

The invention will be further described with reference to the accompanying Drawings, in which:

Figure 1 is a cross sectional view of a double coated pile according to the present invention, in which numeral 1 designates an outer layer, 2 a bituminous layer, and 3 a pile.

Figure 2 is a graph showing the relationship between the softening point and penetration of the bitumen, in which the abscissa represents the softening point (°C) (measured according to ASTM D-36) according to a linear scale and the ordinate represents the penetration (measured according to ASTM D-5) according to a logarithmic scale.

Figure 3 is a graph depth against axial force in which the curve (a) represents a pile surrounded with the double coating according to the invention, the curve (b) represents a pile coated with a conventional bitumen and the curve (c) represents a pile with no coating.

Figure 4 is a graph showing the relationship between the thickness and Young's modulus of the outer layer and the value of N, (as hereinbefore defined).

The pile according to the invention has two coatings: a bituminous coating formed on the outer surface of a pile, and an outer layer covering consisting of synthetic resin, paper or knitted, woven or non-woven fabric of natural or synthetic fibre applied on the surface of the bituminous layer. In the

illustrated embodiments, the bitumen used consists of asphaltic bitumen, but the present invention is not intended to be limited thereto. If desired, any other type of bituminous substance, such as, a mixture of bitumen with a filler and or polymer, may be equally used in addition to pure bitumen. The polymer may for example be a rubber polymer that can be mixed together with bitumen, such as, butadiene polymer. The thickness of the bituminous layer is selected smaller than that of conventional piles having only a bituminous coating, and the thickness should preferably be 3 mm. or less. More preferably, the thickness should be between 0.3 and 1.0 mm. The required bituminous layer may be applied on the base material by means of a simple method. For instance, a concrete pile or steel pile is rotated in its horizontal position and a bitumen discharge orifice provided above the pile is moved in either direction to form a layer of bitumen on the pile.

To provide the bituminous layer with the desired softening point and penetration, the composition of the bituminous layer is such that these two parameters (as defined above) lie within a polygon having vertices A(55, 240), B(33, 240), C(53, 10), D(65, 10) and E(80, 30) as shown in Figure 2. Preferably these parameters lie in a polygon having vertices I(40, 80), J(48, 20), K(54, 20), L(63, 40) and H(52,100) (as shown in Figure 2).

Applied on the surface of the bituminous layer is an outer layer of a synthetic resin, paper, or knitted, woven or non-woven fabric of natural or synthetic fibre. For example, to apply a coating of synthetic resin, fused synthetic resin is extrusion-coated on the pile by the ordinary method, or alternatively fused synthetic resin is extruded in the form of a tape and wrapped around the rotating pipe to form the coating. Various synthetic resins, may be used such as, polyolefins, (e.g. polyethylene, polypropylene), polyvinyl alcohol, polyvinyl chloride, polyester, and polyamide, although the invention is not limited to these resins.

Alternatively, the outer layer may be composed of a strong paper, such as kraft paper, or it may consist of any knitted, woven or non-woven fabric of inorganic or organic fibrous material, such as, jute, vinylon cloth, glass cloth, glass mat or asbestos sheet which will adhere to the bituminous layer. Such paper or fabric may be impregnated or laminated with the previously mentioned synthetic resins.

While the thickness of the bituminous layer according to the invention is smaller than that of the coated bituminous layer on the conventional piles, the application of the outer layer on the surface of the bituminous layer has the effect of preventing a large force

from being transmitted to the pile and allow the pile to satisfactorily adapt itself to the movement of the soil.

Example 1

Tests were conducted to evaluate the ability to reduce the negative frictional force possessed by a double coated pile according to the invention. The piles used in the tests were steel pipe piles of 609.6 mm. external diameter $\times$ 9.6 mm. thickness $\times$ 12,000 mm. length. Some of these piles were used without any coating, while others were coated with either one of two different bitumens *a* and to the thickness of 0.5 mm and an outer layer of polyethylene of 1.8 mm thickness was further applied on the surface of the bituminous layer. One of the bitumens (*a*) had a penetration and softening point shown as *a* in the polygon HIJKL of Figure 2 and thus was in accordance with the present invention, and the other bitumen (*b*) of conventional type had a penetration and softening point shown at *b* in Figure 2. The bitumen (*a*) had a softening point of 55°C and penetration of 60 (see Figure 2) while those of the bitumen (*b*) were 80°C and 60 (see Figure 2) respectively. To measure the amount of negative frictional force acting on the piles coated with these two different bitumens, the vertical distribution of the axial force caused by the negative frictional force was measured. Namely, covered piles of 12 m long were welded together and they were then driven to the depth of 60 m into a soil consisting of a filled-in sand layer which showed an annual subsidence of 200 to 300 mm. The axial force in the vertical direction was measured by means of strain gauges attached to each pile. Figure 3 shows the vertical distribution of the axial force measured after 350 days. As shown in Figure 3, the negative frictional forces acting on an untreated pile (*c*) and a pile coated with the bitumen (*b*) were respectively about 500 tons (t) and 200 tons, whereas there was a very small negative frictional force of less than 10 tons acting on a pile coated with the bitumen (*a*). If computed in terms of circumferential frictional force, these negative frictional forces are respectively less than about 0.1 t/m² in the case of the pile coated with the bitumen (*a*), about 2 t/m² in the case of the pile coated with the bitumen (*b*) and 5 t/m² in the case of the pile (*c*).

It will be seen from the foregoing that a pile according to the invention, by virtue of the fact that its outer surface is protected with a coating of synthetic resin or the like, has very great practical usefulness in that long term storage of the pile is possible, even in summer, that the pile can be transported without any difficulty, that the pile can be manufactured in a factory thus permitting mass production, that the pile can be driven

with ease and a high degree of accuracy, and that the lateral resistance can be dealt with easily, and particularly when the composition of the bitumen is selected to lie within a polygon defined by the vertices I, J, K, L and H shown in Figure 2. The resulting pile has a very great industrial value in that it is well suited for storage and transportation after manufacture.

However, when a double coated pile is driven into a soil, depending on the conditions of the soil, part of the peripheral outer layer is subjected to buckling at the forward end by the vertical soil pressure applied to the forward end, and this buckling is transmitted to the entire periphery, thus causing the outer layer to be damaged in the longitudinal direction of the pile. While the provision of a collar or rim at the power end of the outer layer has been proposed as a countermeasure, this has the disadvantage that the preparation and attachment of a specially designed collar or rim require complicated work.

Therefore, it is essential that the outer layer itself has a satisfactory strength to overcome the soil pressure applied to the forward end of the pile while it is being driven and thereby to prevent the buckling.

From the strength of materials point of view, this strength is determined according to the thickness of the outer layer and its elastic modulus or Young's modulus.

On the other hand, the most important of all the forces acting on the forward end of the outer layer during the driving is one which acts in the vertical direction and this force is determined by the hardness of a soil. This hardness of the soil is represented by the value of N obtained by a standard soil penetration test. While, in addition to the vertical force, there are other forces, i.e., the frictional force of the soil, and the resistance to slip of the adhesive of the bonding layer, these two forces act in opposite directions and thus they practically cancel each other out. In addition, when the outer layer is pushed outward by the vertical soil pressure, this is opposed by the horizontal soil pressure. Further, the adhesion of the adhesive of the bonding layer to the outer layer and the hoop tension of the outer layer itself also act in the similar manner. These forces act advantageously against the buckling.

Considering the above-mentioned forces acting on the forward end of the outer layer, the relationship between the required thicknesses of the outer layer under certain soil conditions (the values of N) and the Young's modulus was analyzed, and driving tests were also conducted, on full sized piles, thus obtaining the following conclusion.

In other words, it has been found that the peeling off, breaking or the like of the covering on a pile during its driving may be prevented by selecting the composition of the

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outer layer to satisfy, in association with the Young's modulus, the following relation:

$$d \times E \geq 35 N$$

where d, E and N are as defined above.

The above relation is graphically represented in Figure 4, with the value of N as a parameter.

Figure 4 shows that if an outer layer is employed whose thickness and Young's modulus lie in the upper region to the right of lines N=10, N=20 and N=30, respectively, the buckling of the outer layer during the driving operation may be prevented under the corresponding soil conditions. The region corresponding to the line N=30 is hatched.

Example 2

A steel pipe pile of 609.6 mm external diameter $\times$ 9.5 mm thickness $\times$ 12 m length was covered with a layer of bitumen having a thickness of 0.5 mm, penetration of 45 (25°C) and softening point of 55°C and then polyethylene resin having a Young's modulus of 7500 kg/cm² (25°C) was applied to form an outer layer covering of 2.5 mm thick. The pile thus prepared was driven by a Diesel hammer to a depth of 24 m into a soil of the following soil conditions:

Soil conditions:

Depth (m)	Nature of soil layer	Value of N
0—11	medium sand with gravel	7—15
11—15	silt	2—3
15—16.5	grit sand with gravel	25—30
16.5—18	medium sand with silt	5—25
18—24	silt	1
over 24	clayed silt	1—25

Immediately after the completion of the driving of the pile into the soil, the pile was pulled out by a vibro hammer. There was no trace of damage, e.g., peeling to the outer layer.

Example 3

A steel pipe pile similar to that of the Example 1 was covered with a layer of asphalt having a thickness of 0.5 mm, penetration of 55 (25°C) and softening point of 60°C and the pile was then covered with a coating of polypropylene resin having a thickness of 1.2 mm and a Young's modulus of 12000 kg/cm². The pile thus prepared was driven by a Diesel hammer to the depth of 24 m into a soil of the same soil conditions as in the Example 2 and it was immediately pulled out by a vibro hammer. There was no trace

of damage such as peeling to the outer layer covering.

Having regard to the provisions of Section 9 of the Patents Act 1949, attention is directed to British Patent Specification No. 1,402,937, which Claims

A process for the entire or partial coating of a vertical foundation element, such as a concrete or steel pile, with a layer of bitumen that is thicker than is necessary for conventional protection purposes, which comprises coating the element with a bitumen of such a composition that the co-ordinates which, in a softening point-penetration diagram, denote the relationship between said softening point in degrees Centigrade as determined by the ASTM D-36 method and said penetration in tenths of a millimetre as determined by the ASTM D-5 method of the bitumen lie within the area of said diagram which is defined by a polygon with the vertices E(55, 240), F(90, 60), G(83, 20), H(79, 20) K(55, 100), the units of said vertices being, respectively, degrees Centigrade and tenths of a millimetre.

WHAT WE CLAIM IS:—

1. A double coated pile which comprises a bituminous layer formed on the outer surface of the pile itself, and an outer layer of a synthetic resin, paper or knitted, woven or non-woven fabric of natural or synthetic fibre, applied on the surface of the bituminous layer, wherein the composition of the bituminous layer is such that its softening point and penetration lie within a polygon having vertices corresponding to points A(55, 240), B(33, 240), C(53, 10), D(65, 10) and E(80, 30) on a graph in which the abscissa represents the softening point (measured according to ASTM D-36) on the Centigrade temperature scale according to a linear scale, and the ordinate represents the penetration (measured according to ASTM D-5), according to a logarithmic scale, the unit of penetration being 0.1 mm. at 25°C.

2. A double coated pile according to claim 1, wherein the bituminous layer is a layer of asphaltic bitumen.

3. A double coated pile according to claim 1, wherein the bituminous layer is a layer of a mixture containing a bitumen and a filler and/or a polymer.

4. A double coated pile according to claim 1, wherein the composition of the bituminous layer is such that its softening point and penetration lie within a polygon having vertices corresponding to points I(40, 80), H(52, 100), L(63, 40), K(54, 20), and J(48, 20) on the graph.

5. A double coated pile according to any preceding claim wherein the bituminous layer has a layer thickness of 3 mm or less.

6. A double coated pile according to claim 120



outer layer to satisfy, in association with the Young's modulus, the following relation:

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