

This invention concerns a new type of anchorage device with an articulated element and a cranked shape for use in any type of ground, easy to install by means of known placing procedures (percussion, vibrodriving, propulsion, driving using a monitor and suction in the case of loose ground, etc.).

This technique is applicable for providing an anchorage in the ground and for providing fixed anchorage points in water, in particular, for port installations (marinas, mooring pontoons, etc.).

Patent FR 2.424.846 describes an anchorage system with free rotation of the point of attachment, this latter being situated in front of the centre of gravity relative to the leading end to be driven into the ground, the system being placed by a tractive force on the cable.

Patent US 3.282.002 describes an anchorage device provided with free rotation of the point of attachment and fitted with a flat plate capable of pivoting, the angular displacement of this plate being limited by a stop. However, this plate does not pivot of its own accord, it is necessary to use a spring or even an explosive charge, in order that it locks and secures the anchorage.

Patent US 3.888.057 describes a device which requires a tractive force to be exerted on the eye of a freely mobile part which is situated in the middle of the anchorage plate in order that a lug perpendicular to the plate and situated in the front part close to the leading end driven into the ground, straightens out and then permits the anchorage plate to pivot. Under these conditions and particularly in the case of hard ground the couple on the mobile part may be too small to allow the device to open and the plate will then drag at the rear without pivoting.

Patents GB-A-2.089.862 and FR-A-2.470.823, FR-A-1.453.190 and US-A-1.982.963 also describe prior art.

The problem to be resolved is therefore as follows :

It is necessary to obtain high resistance anchorage points on land and at sea which can reliably support a tractive force which is horizontal, inclined upwards and even vertically upwards, from one ton to approximately one hundred tons. While capable of being positioned accurately, the anchorage system must be suitable for all types of ground (for example : clay, sand, rocky ground).

Anchorage piles or, in general, groups of anchorage piles, normally resolve this type of problem but they have the disadvantage of being pulled out when the vertical force applied is too great.

Certain special anchoring systems based on a pivoting principle, due to the eccentric nature of the tractive force applied by a cable on the plate are very unreliable as the probability of correct functioning is very low.

The invention concerns an anchorage device comprising an anchorage element designed to penetrate into the ground under the action of penetrating forces, in particular, percussion, this anchorage element comprising at least one rigid principal body having at least one leading end to be driven into the ground, the said penetration forces being basically exerted in accordance with a plane of penetration passing through the said leading end driven into the ground and an axis of percussion or propulsion associated with the principal body, at least one articulated element connected so that it pivots on the said principal body and having a limited angular movement, at least one anchorage line connected to the said principal body by means of a flexible connection with at least one point of attachment located between the said leading end and the centre of gravity of the bearing surface of the principal body, the said point of attachment being in front of the centre of gravity, the said plane of penetration passing through the said centre of gravity, the said device providing the following combination :

a. A cranked shape forming the said articulated element, the said cranked

shape forming the said articulated element presenting a concave surface on the side opposite to the said leading end.

b. Location of the said centre of gravity (G) between the said point of attachment of the anchorage line and the articulation for the said articulated element, and

c. An offset relative to the plane of penetration (Δ) of the said point of attachment, this being fixed, and also the said articulation, this being positioned in accordance with an axis perpendicular to the said axis of percussion in the part opposite to the leading end driven into the ground, relative to the centre of gravity, so that the application of a tractive force on the anchorage line results in rotation of the articulated element and pivoting of the anchorage element.

The force applied, in particular, the percussion forces, impart energy to the anchorage element in order that it penetrates into the ground.

The above combination is capable of providing, when the tractive force T is exerted by the anchorage line, the best position for immobilising the anchorage device. It is designed so that it is displaced in the ground when it is subjected to these forces and is orientated in order to provide the maximum principal couple in order to make use of the optimum thrust exerted by the ground.

The term "principal couple" relates to the contour of the transversal sections at the axis of movement of the anchorage element.

The term "flexible connection" relates to a connection which does not basically apply any moment of rotation to the point of attachment on the plate, such as, a link obtained by means of a cable, chain, swivel joint or an articulated threaded rod.

The device is implanted in the ground by applying the penetration forces F_p by means of, for example, techniques such as percussion, vibrodriving,

propulsion, driving in using a monitor or even suction in the case of loose ground, these techniques all being known to persons skilled in the art. The choice will depend on the nature of the ground.

The angular movement of the cranked articulated element may be between 30° to 60° and, preferably, approximately 45° relative to the plane of penetration Δ .

Examples of producing the invention are given by the following appended Figures and diagrams, where :

- Figures 1 and 1A represent, schematically, a first type of anchorage element in accordance with the invention, viewed from above and from the side respectively
- Figures 2, 3, 4, 5, 6 and 7 illustrate the sequence for placing and immobilising the device in accordance with the invention, in different types of ground
- Figures 8 and 9 illustrate another method of producing the device in accordance with the invention and
- Figure 10 shows another method of producing the articulated element.

In accordance with Figure 1, the anchorage device designed to resist a tractive force T at any angle of use (horizontal, inclined and vertically upwards) is provided with at least one anchorage element, designated overall by the reference 1 and generally penetrates into the ground in a vertical position by means of one of its ends constituting the leading end 2 driven into the ground. An anchorage line 3 comprises, in particular, a cable, a chain or an articulated threaded rod, designed to transmit the required tractive force T by means of an axis subject to traction 11, attached to the said element by at least one point by means of a flexible connection 5, such as, for example, a swivel joint which does not basically introduce any bending moment or torsion to the said point of attachment on

the axis subject to the tractive force 11.

The position of this latter on the anchorage element is chosen so that the point of application of the tractive force to the said element is located in front of the barycentre, or centre of gravity G, of the bearing surface implanted in the ground, or the principal couple of the said anchorage element, in the direction of the said leading end 2. The anchorage element is characterised by a principal body which comprises a rigid dorsal part 6 on which is positioned a plate 4 fitted with deflectors 15 on the internal surface. This rigid dorsal part supports and transmits the energy of percussion up to the leading end 2.

This is initially transmitted onto the anvil 7 which is integral with the rigid part 6 and which is surmounted by a guide pin 8 designed to receive the element used to implant the device, this pin having a length h of two to six times its transversal dimension d. It is preferable to use a male pin in order to avoid any risk of the driving element sticking due to the hammering and bruising effects on impact with the anvil. This pin may have any shape (for example: square, rectangular, round, oval or lozenge).

In the part opposite to the leading end driven into the ground 2, the anchorage element is equipped with a cranked articulated element 9, this being provided with stiffeners 18 for the internal part facing the pin 8, this pivoting on an axis 10 perpendicular to the axis of the anchorage element in accordance with the plane of penetration Δ up to a maximum position determined by a stop 17 defining an angular movement α of 30° to 60° relative to the axis of the anchorage element which is in the plane of penetration Δ and which passes through the pin 8. The articulated element 9 has a plane surface on that part of the cranked element furthest from the said articulation 10. In accordance with another method of construction, illustrated in Figure 10, that part of the articulated element 9, furthest from the said axis of articulation 10, has a curved shape, the radius of curvature r being at least equal to the distance separating the said axis of articulation 10 from the leading edge driven into the ground 2.

The length of this articulated element which separates the articulation 10 from the free end 9a of the said element is between one-half and one-tenth of the total length of the anchorage element and particularly interesting results have been noted using a value basically equal to one-third of the total length of the anchorage element.

The articulated element is designed so that the cranked element, in the vertical position at the time of penetration, that is, a line along the plate 4 is within the field of action of the principal couple acting on the device, that is, the contour of the transversal sections at the axis of movement of the said anchorage element.

The distance from the leading end 2 to the axis of the tractive force 11 constituting the point of attachment of the anchorage line 3 is between one quarter and one half of the total length of the anchorage element. A good performance was obtained when the distance was preferably equal to one-third.

The ratio of the length of the anchorage element, defined in accordance with the plane of penetration (Δ) to the width of the said element, is between $1/3$ and 10 and, preferably, between 1 and 5.

It has been noted that the distance from the leading end 2 to the axis of the tractive force 11 or point of attachment is between one quarter and one half of the total length of the anchorage element and, preferably, equal to one third.

Good results have been recorded when the length of the articulated element 9, from the articulation 10 up to its free end 9a, including the distance separating the articulation 10 of the said element at the point of attachment 11 for the anchorage line 3 and the distance separating the said point of attachment 11 to the leading end 2 of the anchorage element 1, are each basically equal to one-third of the total length of the anchorage element 1.

The leading end driven into the ground may have a dissymmetrical form

relative to the plane of penetration (Figure 1A). It may also have a symmetrical form relative to the same plane of penetration (Figure 9).

It must also be symmetrical relative to a plane perpendicular to the plane of penetration passing through the axis of percussion. Its form may then be, for example, pointed, straight (Figure 8) or even trapezoidal, as shown in Figure 1.

The leading end is extended by means of an aerofoil section 16 which may, for example, be made of steel or a plastic material and which "protects" those vulnerable parts of the device, in particular, the cranked articulated element, the anchorage line and the flexible connection. This aerofoil section projects over the plate 4 in order to correctly guide the displacement of the anchorage element.

The anchorage device in accordance with the invention is applied by using a combination of the following stages :

a. Before driving in the anchorage element 1, the anchorage line 3 is attached to the said element, the diameter being less than the dimension of the said element, when considered as a plane perpendicular to the direction of application of the force of penetration and that portion of the said anchorage line in the vicinity of the point of attachment is attached along the element, on the side opposite to its leading end, in order that it may penetrate into the ground at the same time as the said element.

b. The anchorage element is designed so that the principal couple is as small as possible in order to take full advantage of the energy of percussion. It is preferable that it is positioned in front of all the articulated elements (cable 3 and articulated element 9) so that they are protected during the percussion stage as they are within the "field of action" of this principal couple.

c. After having driven in the said element to the required depth, a tractive force is applied, at the surface, to the anchorage line 3, at any height in an

upwards direction, this inducing a vertical upwards component which immediately and spontaneously pivots the articulated element 9 and the anchorage element 1.

Three inherent characteristics of the device in accordance with the invention enable this pivoting mechanism to be initiated when these characteristics are used in combination :

- the articulated element 9 has a cranked shape, the concave surface of this cranked element being on the side opposite to the said leading end 2. The end 12 of the articulated element 9 has a chamfer at its free end 9a, the thin edge being directed outwards
- the axes of the tractive force 11 and the pivoting force 10 of the articulated element 9 are offset (Figure 2) relative to the plane of penetration Δ passing through the centre of gravity g of the anchorage element. This offset assists in initiating the pivoting action of the anchorage element relative to a horizontal axis
- the position of the centre of gravity between the point of attachment on the axis of the tractive force 11 and the axis of pivoting 10 assists in establishing the motor couple due to traction on the anchorage line 3 and the pressure of the ground P on the articulated element 9. Figure 3 illustrates schematically, the commencement of the rotational action of the pivoting part.

This pivoting action stops (Figure 4) when the barycentric resultant R of the ground pressure against the principal couple on the anchorage element is in alignment with the tractive force T on the cable. In this case, T is less than R.

If the anchorage element has been positioned at a depth exceeding the critical depth (two to four times the largest dimension of the anchorage element), the conditions due to the thrust exerted by the ground are perfectly stable as there is a flow of the material comprising the ground,

from the side subject to compression M_c towards the side not subject to compression M_b . As a result, the static anchorage resistance or permanent anchorage resistance F_a is perfectly stable (Figure 5).

In the case of saturated ground (on the sea bed) (Figure 6), a tractive force applied rapidly relative to the flow of the interstitial water in the pores of the ground results in a suction effect F_b which, in addition to the static resistance F_a described above, resists the dynamic forces on the anchorage line.

This force F_b may be expressed as :

$$F_b = (P_1 - P_2) S$$

Where : S is the area of the anchorage element, P_1 and P_2 are the pressures due to the interstitial water in front of and at the rear of the anchorage element.

At a shallow depth (Figure 7), the anchorage resistance is limited by the dragging force F_a of a volume of ground with the approximate form of an inverted inclined cone positioned above the anchorage system (hatched zone).

If necessary, the device may be removed from the ground. For this purpose, it will be, for example, equipped with at least one extraction cable or any other known method of extraction, fixed to at least one point 13 on the articulated element 9 and which enables, if necessary, the anchorage element to be extracted from the ground, on applying, from the surface, a tractive force exerted vertically or at the rear.

A particularly advantageous method of constructing the anchorage device in accordance with the invention is illustrated in Figures 8 and 9. Its more compact form, the leading end 2 which is symmetrical relative to the plane of penetration and its principal body 6 produced in the form of an IPN or HPN profile section holding a larger anvil 7 means that the anchorage

device, due to the smaller principal couple involved, is more suitable for driving into hard ground or soft rock and ensures that it is correctly immobilised.

The types of anchorage device in accordance with the invention may be arranged in series or in parallel and may be connected together by anchorage lines. This device then increases the anchorage force.

Laboratory tests have been carried out using an anchorage device weighing 2.8 kg. This device was implanted, using a percussion method, in sand saturated with water, to a depth of 1.35 metres. The characteristics of the anchorage device were as follows :

- total length of the device	330 mm
- total width of the device	160 mm
- length of the articulated element L	100 mm
- width of the articulated element l	160 mm
- angle of the cranked section of the articulated element	125°
- angular movement	55°
- transversal dimension of the pin d	20 mm
- length of the pin h	50 mm
- distance between the axis of the tractive force and the axis of pivoting	95 mm
- distance between the axis of the tractive force and the leading end	135 mm

In accordance with these conditions, a horizontal tractive force of 3 tons and a vertical tractive force of 1.5 tons were exerted without the device being pulled out of the ground.

The device in accordance with the invention is suitable for work carried out at sea and provides a very high anchorage resistance for floating or semi-floating supports, irrespective of the ground encountered. It can hold a

structure strictly and accurately in position and also ensures that the anchorage has a long service life.



CLAIMS

1. Anchorage device comprising an anchorage element designed to penetrate into the ground under the action of penetrating forces, in particular, percussion, this anchorage element comprising at least one rigid principal body having at least one leading end to be driven into the ground, the said penetration forces being basically exerted in accordance with a plane of penetration passing through the said leading end driven into the ground and an axis of percussion or propulsion associated with the principal body, at least one articulated element (9) connected so that it pivots on the said principal body and having a limited angular movement, at least one anchorage line (3) connected to the said principal body by means of a flexible connection with at least one point of attachment (11) located between the said leading end (2) and the centre of gravity (G) of the bearing surface of the principal body, the said point of attachment (11) being in front of the centre of gravity (G), the said plane of penetration passing through the said centre of gravity (G), the said device providing the following combination :

a. A cranked shape forming the said articulated element (9), the said cranked shape forming the said articulated element (9) presenting a concave surface on the side opposite to the said leading end (2).

b. Location of the said centre of gravity (G) between the said point of attachment (11) of the anchorage line (3) and the articulation (10) for the said articulated element (9), and

c. An offset relative to the plane of penetration (Δ) of the said point of attachment (11), this being fixed and also the said articulation (10), this being positioned in accordance with an axis perpendicular to the said axis of percussion in the part opposite to the leading end driven into the ground, relative to the centre of gravity, so that the application of a tractive force on the anchorage line (3) results in rotation of the articulated element (9) and pivoting of the anchorage element.



2. Anchorage device in accordance with claim 1, characterised in that the element (9) includes an articulated plane surface on that part of the cranked element furthest from the said articulation (10).

3. Anchorage device in accordance with claim 1, characterised in that the part of the articulated element (9) furthest from the said axis of articulation (10) has a curved shape, the radius of curvature r being at least equal to the distance separating the said axis of articulation (10) from the leading end driven into the ground (2).

4. Anchorage device in accordance with any one of claims 1 to 3, characterised in that the articulated element (9) includes a chamfer (12) at its free end, its thin edge being directed outwards.

5. Anchorage device in accordance with any one of claims 1 to 4, characterised in that the angular movement of the said articulated element (9) relative to the plane of penetration ($\triangle$) is between 30° and 60° and is, preferably, approximately 45° .

6. Anchorage device in accordance with any one of claims 1 to 5, characterised in that the length of the articulated element (9) separating the articulation (10) from the free end (9a) of the said element (9) is between one-half and one-tenth of the total length of the anchorage element.

7. Anchorage device in accordance with any one of claims 1 to 6, characterised in that the anchorage element (1) includes a means of guidance (8) for the penetration forces, this means of guidance (8) having a length (h) of between two and six times its transversal dimension (d).

8. Anchorage device in accordance with any one of claims 1 to 7, characterised in that the leading end driven into the ground (2) and forming part of the anchorage element (1) has a dissymmetrical form relative to the plane of penetration ($\triangle$).



9. Anchorage device in accordance with any one of claims 1 to 7, characterised in that the leading end driven into the ground (2) and forming part of the anchorage element (1) has a symmetrical form relative to the plane of penetration (Δ).

10. Anchorage device in accordance with claim 1, characterised in that the length of the articulated element (9), measured from the articulation (10) up to its free end (9a), the distance separating the articulation (10) of the said element at the point of attachment (11) from the anchorage line (3) and the distance separating the said point of attachment (11) at the leading end driven into the ground (2) from the anchorage element (1) are each basically equal to one-third of the total length of the anchorage element (1).

11. Anchorage device in accordance with claim 1, characterised in that the ratio of the length of the anchorage element, measured in accordance with the plane of penetration (Δ), to the width of the said element is between 1/3 and 10 and, preferably, between 1 and 5.