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(54) Pile, in particular an anchor pile.

(57) A pile having high resistance to dragging when utilised as an anchor for horizontal or near-horizontal leading. The pile has an elongated hollow body with a cross-sectional profile in the form of a closed figure which is asymmetric about at least one axis, and is preferably triangular, particularly an isosceles triangle whose equal angles are in the range 20° - 45°. The pile body is preferably constructed of plate material (6A, 8A, 6B, 8B, 6C, 8C, 10), with at least the lower end being open, for ease of driving into the supporting material (e.g. the sea-bed). A beam-like strengthening member (2) preferably extends across the interior of the pile body, for the full vertical length of the pile body, to strengthen the pile against bending when used for anchoring. A connecting member (20), such as an eger or hook, is located on the pile, preferably on one edge of the strenghtening beam. In the preferred forms of pile, the vertical strengthening beam (2) forms the apex (16) of an isosceles triangle between its equal sides and with 35° equal angles, and the connecting member (20) is on the apex (16) at about mid-length of the pile. Also described are heavy-duty marine anchoring systems employing the piles.

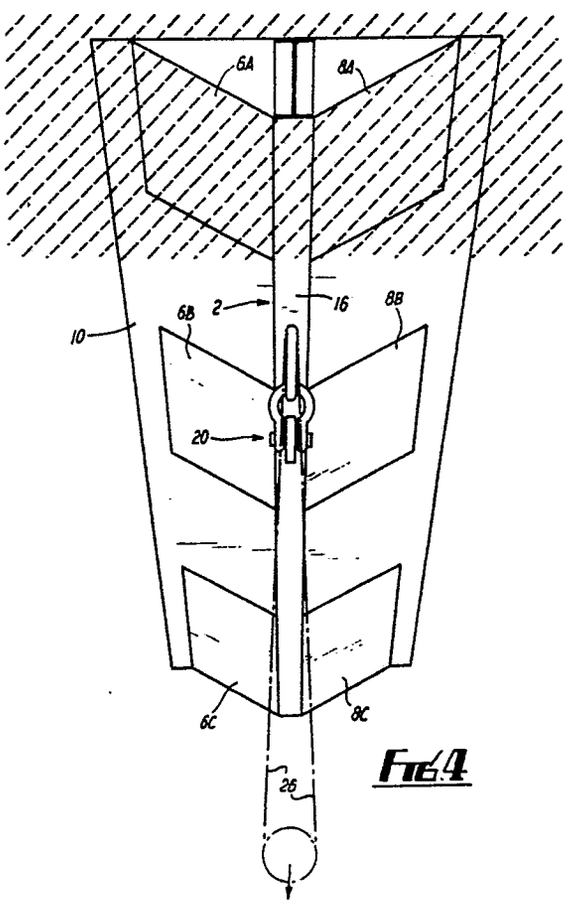

FIG.4

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Piles

This invention relates to piles, and more particularly but not exclusively to piles for anchoring against horizontal or near-horizontal loads.

Various forms of sea-anchor are known but are liable to drag (undergo unwanted horizontal movement) under high loads and/or in weak soil such as soft mud. Anchor piles are sometimes employed, but tend to be large, heavy, difficult to handle and drive, and relatively expensive when designed for withstanding higher horizontal loads.

It is therefore an object of the invention to provide a pile suitable for use as an anchor pile, and which obviates or mitigates these disadvantages.

According to a first aspect of the present invention there is provided a pile having an elongated hollow body for embedment in supporting material, connecting means on the pile for the connection of an anchoring linkage, at least a substantial fraction of the overall length of the pile body having a cross-sectional profile in the form of a closed figure which is asymmetric about at least one axis.

The asymmetric cross-sectional profile is preferably generally triangular, and more preferably generally in the form of an isosceles triangle. Where the profile is triangular, the connecting means is preferably located on an apex of the triangle but may alternatively be located on a side of the triangle, in dependence on the nature and direction of the load to be exerted on the pile in use. In the case of an isosceles triangular profile, the two equal sides are preferably the sides defining the apex on which the connecting means is located, and are preferably shorter than the third side. The triangular profile is preferably such that two internal angles of the triangle are in the range 20° - 45°, most preferably 35°.

One or more sides of the triangular or other asymmetric form of the pile body may be discontinuous along the length of the pile, and extension sections may be fitted to the body at either end or at both ends.

A strengthening member may extend laterally across the interior of the closed figure defining the cross-sectional profile of the pile body, and preferably for substantially the full vertical length of the pile body. The strengthening member preferably extends to the point of attachment of the connecting means to the pile. The strengthening member may take the form of a plate, beam, tube, or other beam-like structure.

The connecting means is preferably located at a point on the pile such that dragging resistance from supporting material in which the pile is substantially totally buried is substantially equal above and below the connecting means. The connecting means may be in the form of a padeye or other apertured or hooked member for the attachment of an anchoring linkage in the form of a chain, cable, or other flexible elongate anchoring linkage. Alternatively or additionally, the connecting means may be in the form of a latch or other rigid member for direct engagement with an object or a structure to be anchored by the pile.

The pile body is preferably constructed of plate material which may be relatively thin, with at least the lower end being open, to drive the pile a relatively low resistance to being driven into the supporting material for embedment therein. Such plate material may be reinforced in the vicinity of the connecting means.

According to a second aspect of the invention there is provided a method of anchoring an object or a structure, said method comprising the steps of driving at least one pile according to the first aspect of the invention into the ground, sea-bed, or other supporting material, and coupling an anchoring linkage between the object or structure and the connecting means on the pile.

Said method may comprise the steps of driving two piles according to the first aspect of the invention into the supporting material at a relatively short distance apart, and coupling a relatively long length of flexible elongate anchoring linkage at either end to a respective connecting means, and directly or indirectly to the object or structure at a point intermediate these ends by way of a runner, pulley, or other tension balancing means.

Piles in accordance with the invention may be used on the sea-bed, or on land.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings wherein:

Fig. 1 is a perspective view of a first embodiment of pile in accordance with the present invention;

Fig. 2 is a plan view from above of the first embodiment of Fig. 1;

Fig. 3 is a plan view from above of a second embodiment of pile;

Fig. 4 is a perspective view of a third embodiment of pile;

Fig. 5 is a perspective view of an anchoring method employing two piles of the third embodiment of Fig. 4; and

Fig. 6 is a perspective view of the anchoring method of Fig. 5 employing two piles in accordance with a fourth embodiment.

Referring first to Fig. 1, a pile in accordance with the first embodiment of the invention has an elongate body 4 made of thin steel plate providing a generally triangular cross-sectional profile for the body 4. This triangular profile is made up of side plates 6, 8 of equal length and a back plate 10 which is 2 metres wide, the angle A between each side plate 6, 8 and the back plate 10 being 35°.

The back plate 10 extends laterally beyond the side plates 6 and 8 to form side flanges 12 and 14, thereby providing the effect of increasing the width of the body 4 without unduly increasing the required amount of material in the overall pile.

An I-beam 2 which is 610 x 229 mm in size is welded between the centre of the back plate 10 and the apex 16 of the side plates 6, 8, so that the apex 16 is flattened to correspond with the end flange of the beam 2.

A padeye 20 is welded to the flattened apex 16 about one-third of the distance along its length, and web stiffeners 22 (Fig. 2) are provided on each side of the central web 24 of the I-beam 2 in the area of the padeye 20 to provide local buttressing. In use, the pile is driven into the sea-bed until its upper end is flush with the mudline, and the padeye 20 provides a connecting means for the connection of an anchoring linkage in the form of a mooring stable 26 between the pile and a structure to be anchored. (In Fig. 1, the pile end of the mooring cable 26 lies above the padeye 20 because of the perspective angle and because these parts are buried in mud which bends the anchoring linkage upwards).

Referring now to Fig. 3, the pile of this second embodiment is a fabricated structure in which the I-beam 2 of Figs. 1 and 2 is substituted by a plate 30 welded between the centre of the back plate 10 and the apex 16 of the side plates 6, 8. This allows the apex 16 to form a ridge instead of being flattened, and also allows the body 4 to be made in sizes other than those using standard I-beams. In other respects the pile of Fig 3 is similar in structure and function to that of Figs. 1 and 2.

The piles of these first and second embodiments are especially but not exclusively designed for use in subsea environments. Maximum restraint against loads applied through the mooring cable 26 is achieved by disposing the padeye 20 at or near the centre of horizontal soil pressure on the plates 6, 8 to minimise compressive buckling. However, if it was required to apply the load at the mudline, rather than below the mudline, the padeye would more effectively be located on the back plate 10 instead of the apex 16 to minimise compressive buckling. The asymmetric construction of the body about line B-B in Fig 2 means that the peak bending stresses at the apex of the side plates 6, 8 will be greater than the peak bending stresses in the back plate 10. The padeye 20 can be located at any selected position to ensure maximum bending stresses are taken in tension, thereby minimising compressive stresses or buckling, thus allowing thin plate construction of the body 4.

The point load applied to the padeye 20 in service is distributed into the soil through the open triangulated plates 6, 8, 10 surrounding the central I-beam web 2, which minimises resistance to passed of the pile into the soil during installation.

The piles of these embodiments therefore provide maximum horizontal restraint under load with minimum vertical resistance during driving, combined with good structural integrity to distribute the applied point load over an area of weak soil.

Modifications and improvements can be made without departing from the scope of the invention; for example, holes may be formed in the plates 6, 8, 10, and void formers, stiffeners and/or shear keys attached to the body 4. Further, a latch mechanism such as that described in our co-pending European Patent Application EP-0,268,387-A may be used in conjunction with the piles of the present invention, as an alternative or addition to the padeye 20 (which is given as merely one example of an anchor linkage connection).

Referring now to Fig. 4, this shows a third embodiment of pile which is generally similar to the first embodiment shown in Fig. 1, but which differs in respect of the side plates 6 and 8. In contrast to the first embodiment, the third embodiment has the side plates discontinuous along the vertical length of the pile, the side plates being divided into upper end portions 6A and 8A, central portions 6B and 8B, and lower end portions 6C and 8C. This results in a lighter structure consuming less plate metal, but having a generally similar performance (size for size) as the first embodiment of Fig. 1.

Fig 5 shows an anchoring method employing two of the Fig. 4 piles. The piles are driven vertically or near-vertically into the sea-bed until flush with the mudline, at a suitable mutual separation such as 26 metres or 43 metres. The padeyes on both piles are shackled to opposite ends of a 200 metre long anchor chain 27 which is looped across the sea-bed towards the structure (not shown) which is to be anchored by the piles, and thereby the chain 27 extends by about 100 metres towards the structure. Next, the centre of the chain 27 is passed through a chain runner (not illustrated) which allows the chain 27 to pass relatively freely through it to equalise the tensions in the two 100-metre legs of chain. Finally, the chain runner is connected by a further 300 metres of anchor chain (not shown) to the structure to provide the equivalent of one heavy anchor system utilising a conventional single heavy anchor pile, but actually

employing two much lighter piles with mutually balanced loadings. Thus the anchoring method schematically illustrated in Fig. 5 is suitable for providing one of the distributed multiple anchorages for a floating semi-submersible oil rig in 150 metres of water, with an anchor line length of about four times water depth.

In the above embodiments of pile in accordance with the invention, the characteristic ratio of vertical length to maximum lateral width is in the range 2-5 to 1, whereas conventional piles typically have a length to width ratio of 20-40 to 1.

Fig 6 shows a similar anchoring method to that of Fig. 5, but with a pair of piles in accordance with a fourth embodiment of the invention. The fourth embodiment of pile has a structure generally similar to the first embodiment of Fig 1, but in place of the I-beam 2 is a tubular pile 28, which reinforces a triangular plate structure 29 against bending as did the I-beam 2. The pile 28 extends below the triangular plate structure 30 at least as far as the vertical length of the triangular plate structure 29 to drive deep penetration of the sea-bed. The triangular plate structure 29 gives enhanced resistance against dragging of the pile in the upper reaches of the sea-bed up to the mudline where lesser compaction of the sea-bed material might be expected to provide a reduced resistance to dragging. In the fourth embodiment of Fig. 6, the ends of the anchor chain 27 are attached to each pile near the lower end of the triangular plate structure 29 approximately at a point where overall dragging resistance above and below the chain attachment is about equal. From the attachment point, the chain cuts through the sea-bed material in an upwardly curving path until the chain emerges from the mudline.

While certain modifications and variations have been described above, the invention is not restricted thereto, and other modifications and variations can be adopted without departing from the scope of the invention. For example, by welding a cover or other suitable member over the top of the pile (but with the provision of resting to ensure unimpeded pile driving), any of the embodiments of pile of the invention can be utilised for vertical support or vertical anchoring as an alternative or addition to the horizontal or near-horizontal anchoring function previously described.

Claims

. A pile having an elongated hollow body for embedment in supporting material, connecting means on the pile for the connection of an anchoring linkage, at least a substantial fraction of the overall length of the pile body having a cross-sectional profile in the form of a closed figure which is asymmetric about at least one axis.

2. A pile as claimed in Claim 1, wherein the asymmetric cross-sectional profile is generally triangular.

3. A pile as claimed in Claim 2, wherein the asymmetric cross-sectional profile is generally in the form of an isosceles triangle.

4. A pile as claimed in Claim 3, wherein the two equal internal angles of the isosceles triangle are in the range 20° - 45°.

5. A pile as claimed in any preceding Claim, wherein a beam-like strengthening member extends across the interior of the closed figure defining the cross-sectional profile of the pile body for substantially the full vertical length of the pile body.

6. A pile as claimed in Claim 5 as dependent on Claim 3, wherein the beam-like strengthening member extends from the apex defined by the two equal sides of the isosceles triangle to the midpoint of the third side of the triangle.

7. A pile as claimed in Claim 6, wherein the connecting means is located on the apex of the triangle in the vicinity of the middle of the vertical length of the pile.

8. A pile as claimed in any preceding Claim, wherein the pile body is constructed of plate material with at least the lower end of the pile body being open.

9. A method of anchoring an object or a structure, said method comprising the steps of driving at least one pile according to any one of Claims 1 to 8 into the ground, sea-bed, or other supporting material, and coupling an anchoring linkage between the object or structure and the connecting means on the pile.

10. A method as claimed in Claim 9 comprising the steps of driving two piles according to any of Claims 1 to 8 into the supporting material at a relatively short distance apart, and coupling a relatively long length of flexible elongate anchoring linkage at either end to a respective connecting means, and directly or indirectly to the object or structure at a point intermediate these ends by way of a runner, pulley, or other tension balancing means.

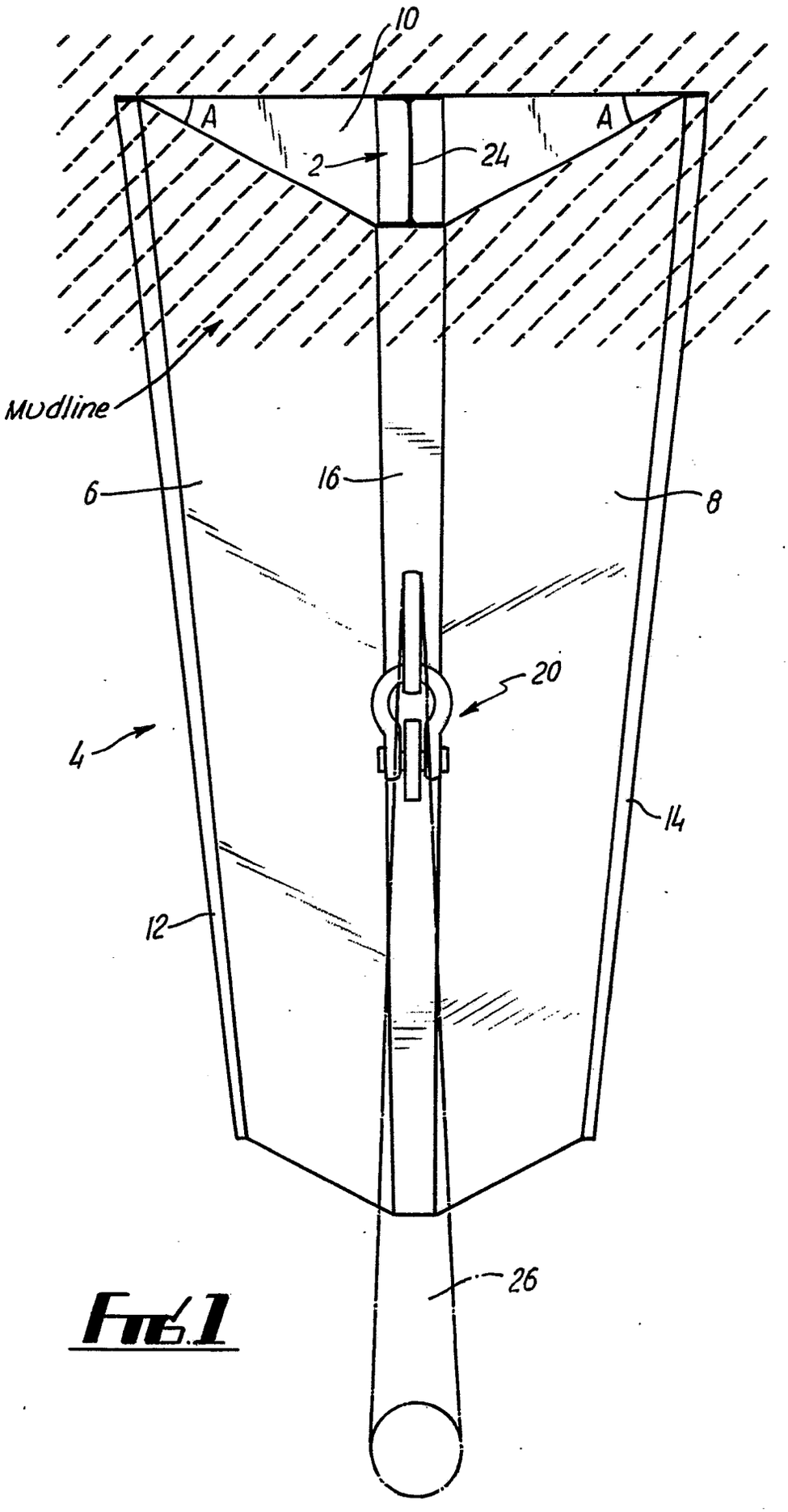

FIG.1

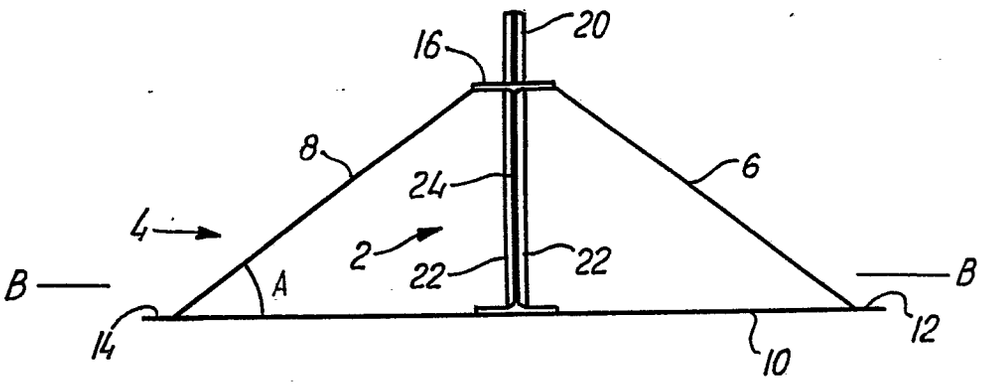

FIG.2

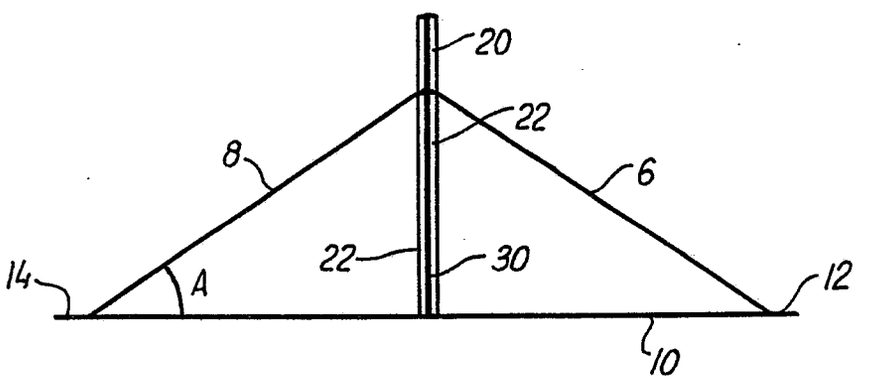

FIG.3

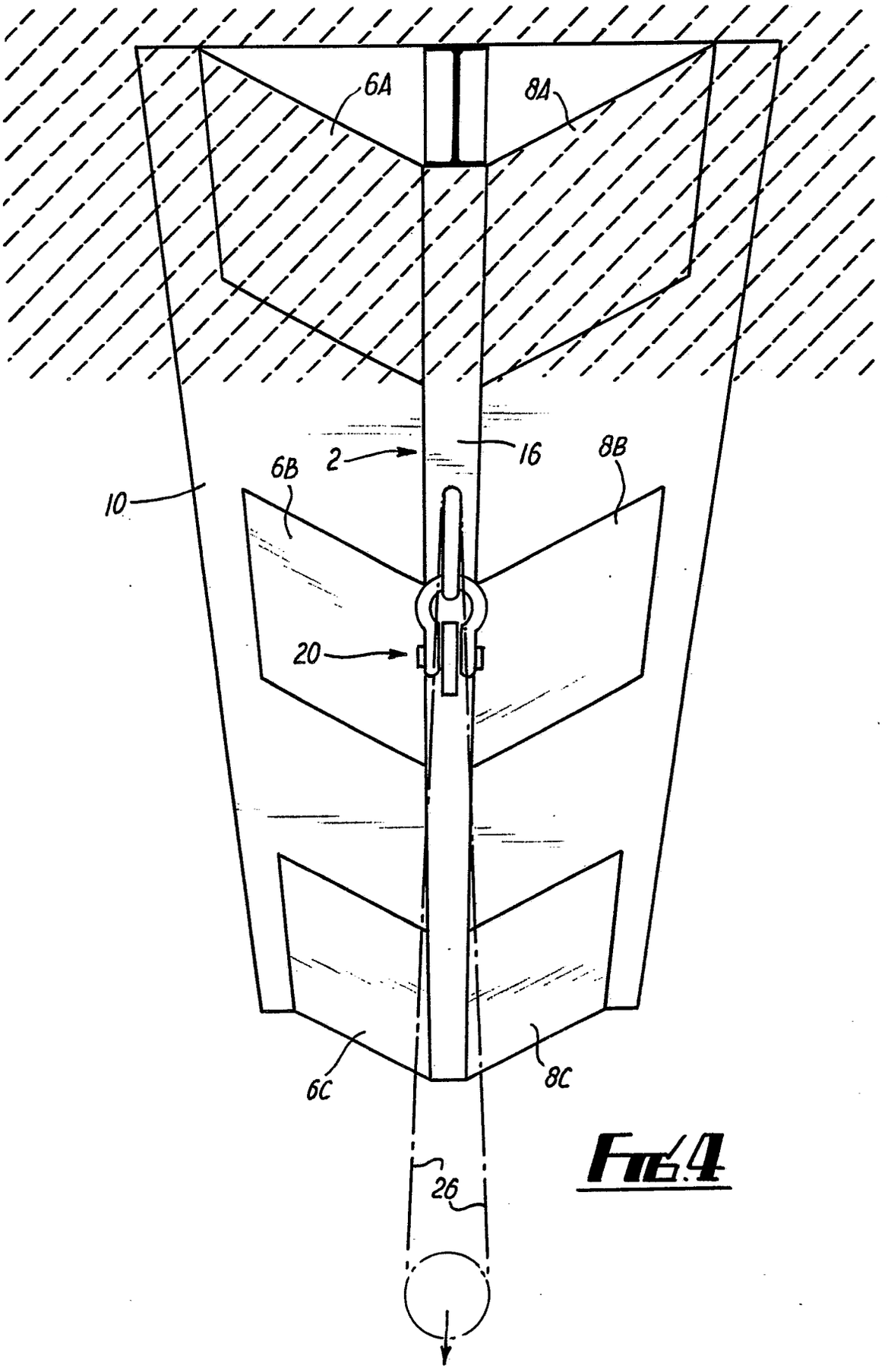

FIG.4

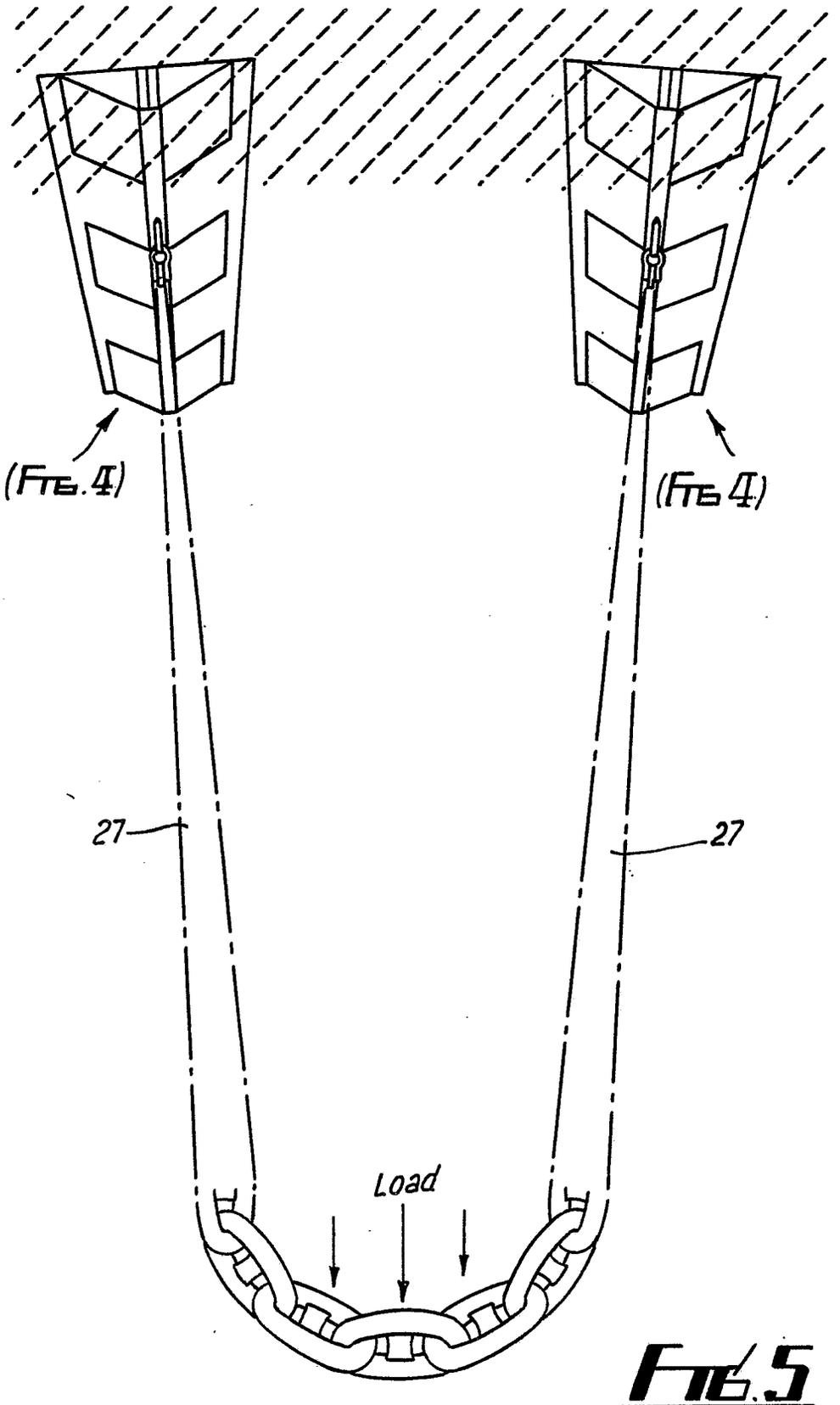

FIG. 5

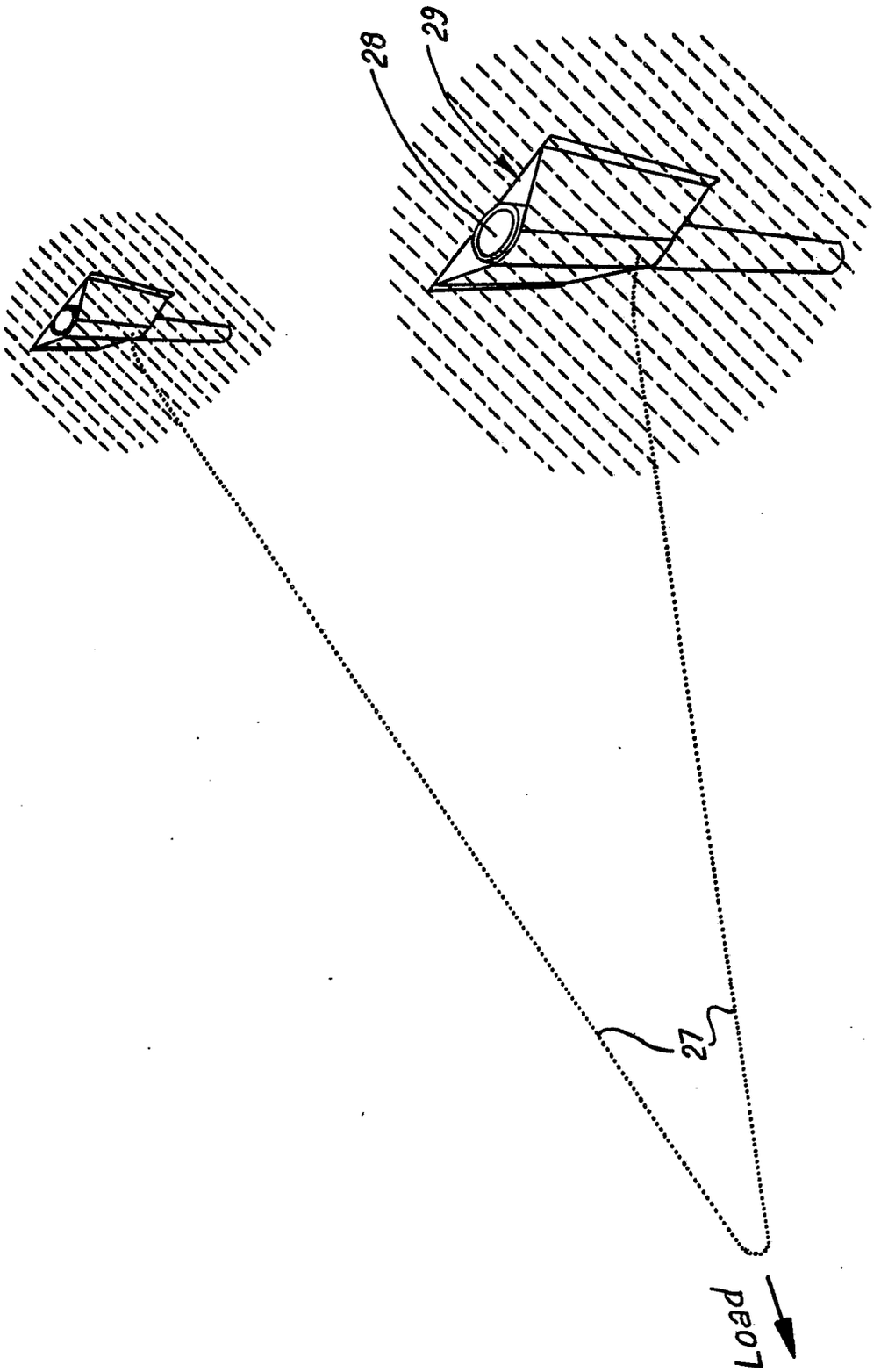

FIG 6

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EUROPEAN SEARCH REPORT

. Application number

EP 88307661.4

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	DE - B2 - 2 405 238 (ECHTLER) * Fig. 1,2 * --	1	B 63 B 21/00 E 02 D 5/54
A	DE - C - 806 234 (DORTMUND-HOERDER HÜTTENVEREIN AG.) * * Fig. 1 * ----	1,2	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

B 63 B
E 02 B
E 02 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	18-11-1988	SCHMICKL

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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