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(54) Underwater wall construction.

(57) A wall is constructed underwater by successively filling buoyant shells which define courses of the wall. The shells may be integral, concertina-folds of a polymer plastics bag which is initially secured to the bed on which the wall is to rest, or polymer concrete boxes which are interconnected laterally and which float on the surface before filling. The shells are preferably filled with a hydraulic fill material which is pumped into it.

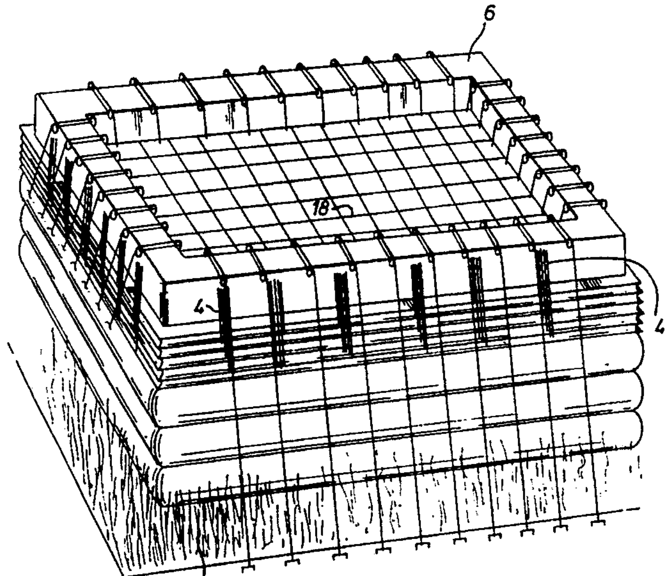

Fig.1.

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The present invention relates to the construction of retaining walls underwater.

Retaining walls are required to be constructed underwater for various purposes, for example, in carrying out land reclamation, barrage and bridge construction, as well as in coastal protection work. Such walls may be straight sections or may be constructed so as to enclose a volume in order to create an artificial island.

Conventional techniques for underwater wall building include sheet piling, the construction of a concrete wall, or creating a mound of rocks. It has also been proposed in GB-A-2 205 883 to construct an underwater wall with a retaining face of blocks or panels which is held in position by horizontal ties extending rearwardly into a volume of hydraulic fill material behind the wall. All of these methods suffer from the disadvantage that they require extensive underwater operations by divers, which considerably increases the cost of construction. Moreover, where concrete or rock is used, it is necessary to import large quantities of material into the site. Since these materials are heavy, transport costs can make a significant contribution to the overall cost of the wall.

GB-A-2 205 883 also proposes a method of constructing a wall whereby a polymer material sleeve is wrapped round a ring of guidelines. Each of the lines is weighted and the polymer material is fixed to each line so that, as the lines are lowered, the polymer material defines a retaining face for the final wall. This technique suffers from the disadvantage that the prevailing currents in the water tend to cause the guidelines to be dragged out of vertical due to the lightness of the assembly being lowered. This limits the applicability of this technique to small constructions or to use in relatively calm waters.

In order to overcome the technical problems of providing a construction technique for producing an underwater wall which will provide the basis of a durable structure at relatively low cost and without requiring extensive underwater operations by divers or the importation of large quantities of construction materials, the present invention provides a method of constructing an underwater wall which is built up in courses, each course being created in a buoyant shell, the shell of each course being connected to the shell of the next uppermost course. Using this method it is possible to control the construction from the surface.

Several embodiments of the method will be described.

In one embodiment the shells for the courses are successive, integral, folds of a concertina-folded bag of plastics material. The bag is secured to the bed on which the wall is to rest and each fold released and filled to develop each course in succession from the bottom of the wall upwardly. Alternatively the bag can be allowed to submerge as each fold is filled to produce a course of the wall.

In another embodiment, the shells for the separate courses are defined by buoyant - eg polymer concrete-boxes with open top and bottom faces, which are capable of being secured to each other laterally to create a course of any length. The boxes also interconnect vertically. The shell of each course can be assembled from boxes at the surface and then filled with hydraulic fill material. Before the course is totally submerged, the shell of the next course is connected to it. Because of the greater rigidity of the structure the wall tends to remain vertical as it is submerged.

In all cases, the material used to weight the shells of the courses is preferably hydraulic fill material consisting of dredged material derived from the local area where the wall is being constructed which is pumped in a suspension in water into the shell. Other filling materials may be employed.

Since the materials used in constructing this type of wall are relatively inexpensive, and there is no requirement to transport heavy construction materials to the site, extremely durable retaining walls can be constructed for a cost which is significantly less than known construction techniques such as sheet piling, concrete walls or rock walls.

Some methods of wall construction embodying the present invention will now be described, by way of example only, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a perspective view showing an intermediate stage in the construction of a wall using a polymer plastics bag;

Figure 2 shows a section through the wall constructed using a bag of the type shown in Figure 1;

Figure 3 shows a transverse section through a completed retaining wall using the construction method described with reference to Figures 1 and 2;

Figure 4 is a perspective view showing a course built up from connected polymer concrete boxes in accordance with a second embodiment;

Figure 5 shows a vertical section through a portion of a wall constructed from boxes as shown in Figure 4 illustrating the manner in which the boxes are connected to horizontal ties;

Figure 6A and 6B show two stages in the construction of a wall using the polymer concrete box method;

Figure 7A to 7D shows stages in the construction of a wall using an alternative construction method using the polymer plastics bag; and

Figures 8A and 8B show a cross-section and plan of a bag being filled in the method illustrated in Figure 7.

In the following description, the construction methods of the present invention will be described with reference to the construction of an artificial island. In this case the wall to be produced is a closed annular wall. However, it will be appreciated that the construction methods are equally applicable to the construction of elongate walls for coastal protection works or similar. The methods may also be used for the construction of a support as for a bridge pier. For this purpose, a single bag, as described in more detail with reference to Figures 1 - 3 may be employed.

The first method of construction will now be described with references to Figures 1 - 3. This method makes use of a single concertina-folded polymer plastics bag to define the shells of vertically adjacent courses of a portion of the wall. A number of such bags are used adjacent one another to form an elongate wall with the spaces between adjacent bags closed by the lateral earth pressure exerted by the filling of the bags. A single bag with three filled shells defining three courses of a wall is illustrated in Figure 1. The bag 2 is made of a strong polymer plastics material which is porous or perforate to allow water to pass through it as it sinks, or as material is added to its interior. The bag 2 initially has its side walls concertina-folded with each fold being secured by a series of colour-coded twine straps 4 around the periphery of the bag. The neck of the bag is defined by a buoyant rim 6. This rim is preferably a glass-reinforced concrete (GRC) sprayed polystyrene rim. However, an inflatable rim or a rim constructed of polymer concrete having a specific gravity of approximately 0.8 may be employed instead. The base of the bag 2 is surrounded by a flange of matting 8 which carries artificial seaweed fronds 10.

The rim 6 provides pulley supports 12 for a series of ties 14 which have sections extending into the interior of the bag and outside the bag. Each end of each tie 14 is anchored to the bed by a pin 16, which is preferably driven into the bed by means of a launcher driven by the pressure of compressed air. For example, an air launcher as promoted by Ryan International for use in the "soil nailing" technique may be employed. Additional pins 16 may be used to secure the matting 8 to the bed. The use of such pins provides a secure foundation for the wall. The pinning of the bag to the bed may be carried out from the surface by lowering the launchers on a winch rope closer to the bed.

The wall of the bag 2 may be double skinned as shown in Figure 2 in order to provide a cavity into which concrete may be pumped as the bag is filled in order to provide a more durable retaining surface to the filled bag on completion of the wall construction.

As the bag 2 is filled geogrids 18 may be incorporated into the interior of the bag and, optionally, secured to the interior of the bag by ties. Alternatively, the geogrids may be formed in the bag during manufacture. The geogrids are preferably made of polymer material such as polyethylene or polypropylene or other geotextile such as TENSAR. A high strength metal mesh could also be employed as a reinforcing geogrid 18. However, geotextiles are cheaper and are more conveniently incorporated on site as the material is available in rolls.

The technique of filling the bag is referred to as "pulling up" as the bag is extended fold by fold upwardly as it is filled to define each course of the wall. In order to construct an artificial island using the bags as described, pairs of diametrically opposed bags are "pulled up" together. For example the bags 2A and 2B as shown in Figure 3 could be pulled up simultaneously. Or, if more surface help were available, all of the bags 2A to 2H could be pulled up at the same time with intermediate bags 2 pulled up subsequently to fill the gaps between the bags 2A to 2H. Each bag which is to be pulled up is first towed out to the required position and secured on the bed. The bottom of the bag can be forced onto the bed by placing a heavy weight such as a concrete block in the bag when it is in position. Where the waters are tidal, towing into position is preferably done at low tide. The height of the rim 6 must be sufficient to allow the upper edge of the rim to float above the surface of the water while the base of the bag 2 is anchored to the bed by means of the ties 14 and anchor pins 16. Once the bag is in position the ties 4 securing the lowermost fold of the bag are released and hydraulic fill material pumped into the interior of the bag. A geogrid 18 may then be inserted. However, it is not necessary to incorporate a geogrid at every level. Successive courses of the wall are built up by repeating the preceding steps. As the height of the wall under water increases, the rim 6 can be dismantled so that it does not project too far above the surface. Figure 2 shows an intermediate stage in the pulling up of the bag 2 in which two courses have been completed. In Figure 1 three completed courses are shown. Once the wall has been completed to the required height concrete may be pumped into the space between the double skinned walls of the bag.

Once a complete, annular retaining wall has been built up as shown in Figure 3 from retaining bags, the interior space may be filled with hydraulic or other fill material and reinforced with geogrids. The geogrids provides horizontal ties, either across the whole width of the island as shown in

Figure 3 or tying the walls back to a distance sufficient to resist the shear forces exerted by water pressure on the retaining face of the wall as described in GB-A-2 205 883. Reference may be made to this earlier application for a discussion of additional ways in which the filling material within the wall may be reinforced by the use of mats. The filling of the island may take place at the same time as the courses of the wall are being built up.

For stability the bags should not be too tall in relation to their cross-section. Where the water is deep a wall may be built up by placing bags one on top of another. The structure may be completed by driving piles through it into the bed. This is facilitated by the fact that the pile driver can rest on a solid structure.

The described technique of building the wall in courses using a concertina-folded bag may still require a certain amount of diving assistance in some circumstances, particularly to secure the base of the bag to the bed in the first instance. The technique described with reference to Figures 4 - 6 overcomes this disadvantage since, although the wall is constructed from the bottom up as before, the courses are each created at the surface. Therefore, this second method is more appropriate for walls which are required to have greater height, or where the water depth is not shallow at low tide.

As shown in Figure 4, each course is constructed from polymer concrete boxes 30. Polymer concrete is chosen because it can be produced with a specific gravity of 0.8, that is lighter than water so that it will float. Polymer concrete is made from polymers derived from vegetable or fish oils. The concrete is a mixture of the selected polymer and a filler such as sand or fly ash. The resulting concrete can be cast by pouring and the boxes 30 can be produced relatively cheaply. The concrete is impermeable and has a tensile capacity of approximately 28N/m^2. Its compressive strength is equal to that of high strength concrete. The concrete also has high insulation values and can be reinforced with fibre to increase allowable stress.

The proposed concrete boxes 30 shown in Figure 4 are simple fabrications of 4 polymer concrete panels provided with fixing means 32 whereby the boxes can be interconnected laterally and vertically. The fixing means may comprise coupling ties 32 which slot into receiving holes in adjacent faces of the boxes. The boxes may also be bolted together through adjacent side walls as shown at 34 in Figure 4 and 36 in Figure 5 where adjacent courses are interconnected vertically. It is preferred that the fixing means for vertical interconnection allow a push-fit type of connection so that the courses can readily be assembled together at the surface from a vessel. The adjacent courses of boxes are staggered relative to one another in order to produce a conventional type of bonding so that there is no continuous vertical joint extending up the entire height of the wall.

The boxes 30 in the lowermost course of a wall each has attached to its base a polymer plastics bag 36, which provides a closure at its open base.

In order to construct a wall using boxes of this type, a series of boxes are interconnected laterally in order to produce a single course of the wall of the required length. If an island is to be produced then the ends of the course are connected together to produce a ring. The initial course is constructed from boxes each having a bag secured to the lower open end. Since the empty boxes have a specific gravity of 0.8, the assembled course will float on the surface of the water. Once assembled the boxes are filled by pumping in hydraulic fill material. This material first fills the bags and then the boxes. Before the open top ends of the boxes are submerged, a subsequent course of boxes is connected to them and the filling process continues with the wall being submerged towards the bed one course at a time. Since the boxes provide a rigid outer structure for the wall, the wall descends in a substantially vertical path. The purpose of the bags 36 can be seen in Figure 6B which shows the manner in which the bags compensate for variations in the depth of the bed over the length of the wall. If surveys show that sea bed fluctuates in depth to a greater extent than can be accommodated by the use of bags 36, it may be necessary for the initial courses to be of staggered length in order that subsequent courses remain horizontal.

As shown in Figure 5 the polymer boxes may be secured to geogrids 38 by connectors 40. The geogrids are used to reinforce the filling material placed behind the retaining wall. In the case of an island, the grids may extend horizontally across the entire island or, alternatively, they may be secured to an internal wall at a sufficient distance behind the retaining face of the wall to resist the shear forces of the water.

A flange of matting 42 carrying artificial seaweed can be connected to the boxes or polymer bags 36 at the base of the lowermost course of the wall. The matting can be anchored by pins as described with reference to the first embodiment. The purpose of the artificial seaweed is to entrap debris in the water and provide a protective mound of polymer reinforced earth around the base of the wall. This mound serves to reduce the velocity of water striking the wall and thereby protects the base of the wall from erosion damage.

Ties may be used to secure the wall to the bed during construction in order to minimise drifting, particularly during the early stages of construction. It will be noted that the stiffness of the wall increases as each course is added. With this method of construction, it is possible to partially construct the wall away from its intended site and then tow it into position before completion of the final courses.

Instead of polymer concrete, any other lightweight material may be used to define the shells for the courses. For example boxes may be made of glass reinforced concrete or even of steel provided with some buoyant material to give an equivalent specific gravity of around 0.8. However, room must be left to allow the units to be filled with the hydraulic fill or other filling material.

The principle of submerging the wall as the courses are added as employed in the method described with reference to Figures 4-6 can also be employed using a concertina-folded polymer plastics bag of the type used in the first described method. This method will now be described with reference to Figures 7 and 8. The main difference between this method and the method described with reference to Figures 1-3 is that the bag is not first secured to the bed before filling commences. Each bag 2 to be filled is provided with a buoyant rim 50. As previously, each fold is tied independently to the rim by means of a series of peripheral ties. Initially the ties for the first fold are released and the hydraulic fill material is pumped in as shown in Figure 7B. A horizontal tie 52 is used to anchor the bag laterally. As each course is formed by filling a fold of the bag, the next fold is released until eventually the base of the bag rests on the bed. During this filling process, it may be necessary to increase the buoyancy of the rim 50 in order to support the weight of the submerging wall. The rim may be an inflatable structure in which additional compartments may be inflated to increase the buoyancy.

An alternative rim structure is illustrated in Figure 8A. In this case a buoyant section 56 of the rim supports the neck of the bag above it so that the submerging courses are given lateral stability by their engagement with the edges of the buoyant rim 56. Such a rim may be made of GRC coated polystyrene. In order to provide additional vertical reinforcement, geogrids 58 may extend in a vertical plane through the bag. Preferably such grids are incorporated during the manufacture of the bag and, being flexible, will fold up internally when the bag is concertina folded. The geogrids 58 are visible in the plan view of Figure 8B and are shown tying opposing walls of the bag to one another. Horizontal ties 52 to tie the wall back into the interior fill material are preferably secured to the bag at the same locations as the internal vertical geogrids.

With any of the described methods of wall construction, the upper surface of the wall may be protected by precast concrete edging sections in order to prevent damage from erosion.

Claims

1. A method of constructing an underwater wall which is built up in courses, each course being created in a buoyant shell, the shell of each course being connected to the shell of the next uppermost course, and comprising the filling of the shells of each course in succession.

2. A method as claimed in claim 1, wherein each course is defined by a successive fold of a concertina-folded bag.

3. A method according to claim 1, wherein the shell for each course is defined by boxes with open top and bottom faces, which are capable of being connected to each other laterally and vertically.

4. A method according to claim 3, wherein the boxes of the first course are each provided with a bag to close the lower face thereof.

5. A method according to claim 3 or 4, wherein a course of boxes is floated on the surface of the water and then filled to partially submerge the course before a subsequent course of boxes is connected to the partially submerged course before filling is continued.

6. A method as claimed in any one of the preceding claims, further comprising the use of ties anchored to the bed in order to maintain the position of the wall during construction.

7. A method according to claim 2, wherein the bag is connected to a buoyant rim.

8. A method according to claim 2 or 7, wherein the bag has a double-skinned outer wall, the method further comprising the step of filling the space between the two skins with concrete after the bag has been at least partially filled.

9. A method as claimed in any one of claims 2, 7 or 8, comprising holding the base of the bag on the bed before filling commences.

10. A method of wall construction substantially as herein described with reference to Figures 1 - 3 or Figures 4 - 6 or Figures 7-8 of the accompanying drawings.

11. A buoyant shell for defining one or more courses of a wall to be constructed in accordance with the method as claimed in any one of the preceding claims.

12. A shell according to claim 11, comprising a plastics bag initially concertina-folded with each pleat secured to the rim of the bag by a series of ties around the periphery thereof, each fold being intended to define a course of the wall.

13. An open ended box provided with connecting means for connected it laterally and vertically to similar boxes, the box having a specific gravity such that it floats.

14. A box according to claim 13, having a specific gravity of 0.8.

15. A box according to claim 13 or 14, comprising polymer concrete panels.

16. A box according to any one of claims 13 - 15, having a plastics bag connected to it in order to close the open base of the box.

17. A bag for use in constructing an underwater wall substantially as herein described with reference to Figures 1 - 3 or 7 - 8 of the accompanying drawings.

18. A box for use in constructing an underwater wall substantially as herein described with reference to Figures 4 - 6 of the accompanying drawings.

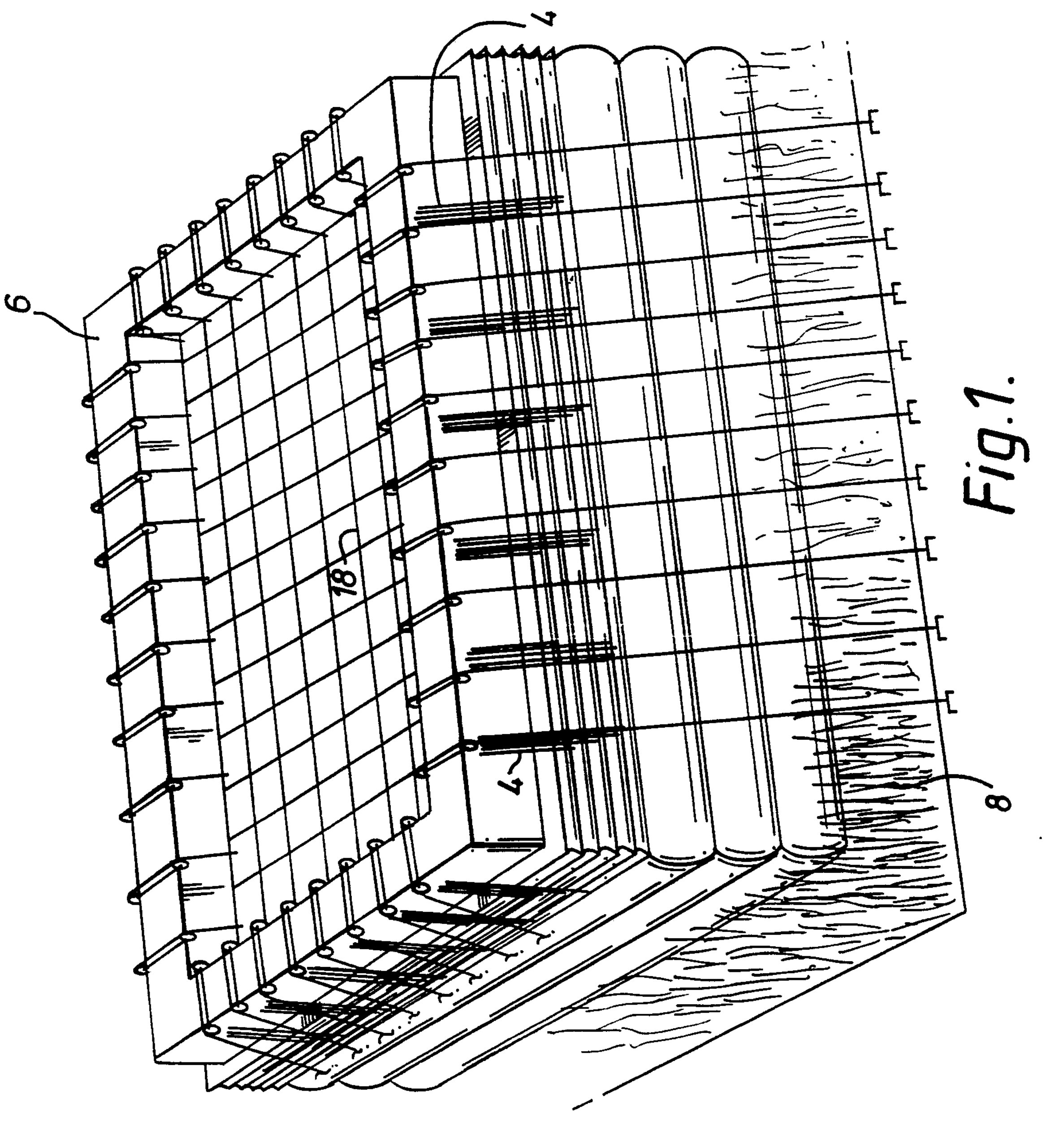

Fig.1.

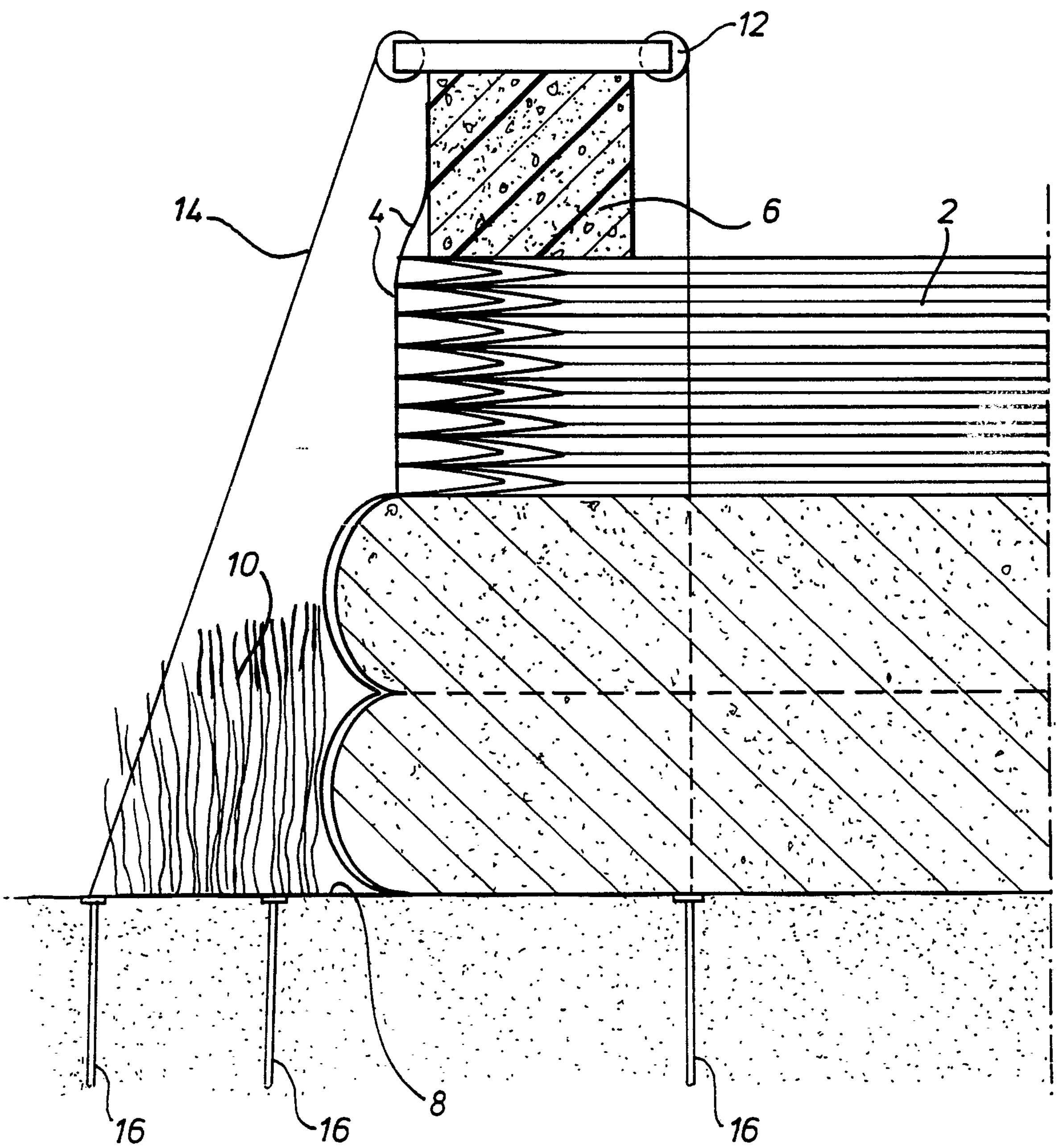

Fig.2.

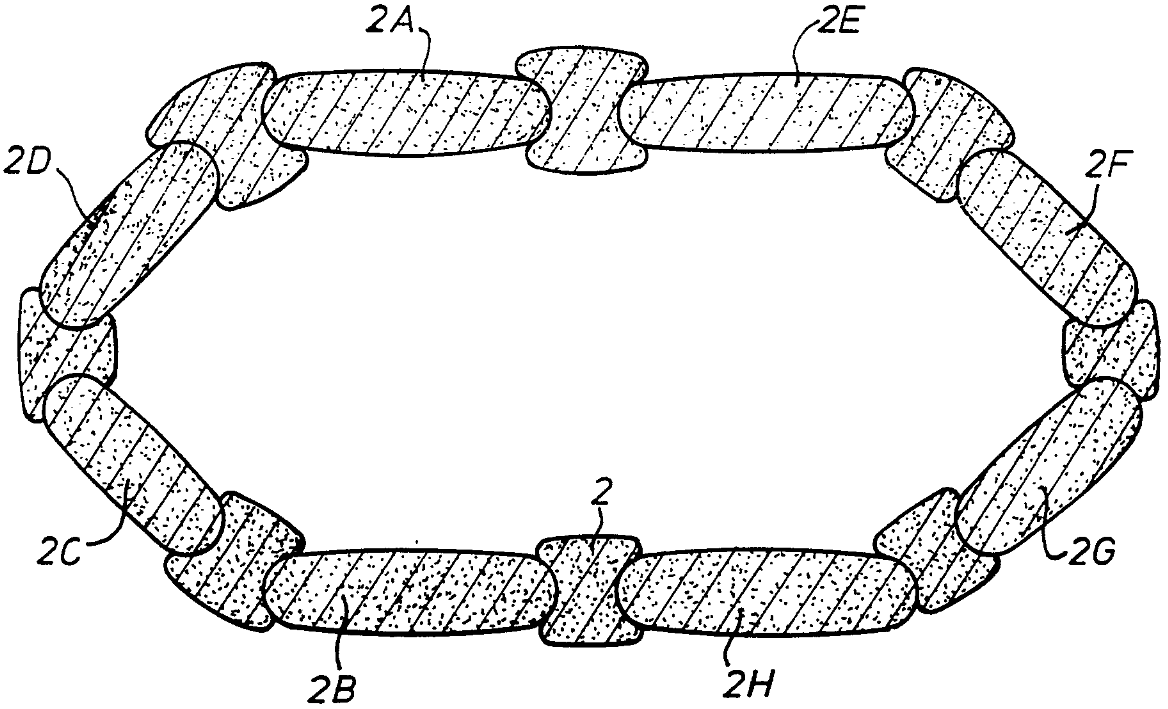

Fig. 3.

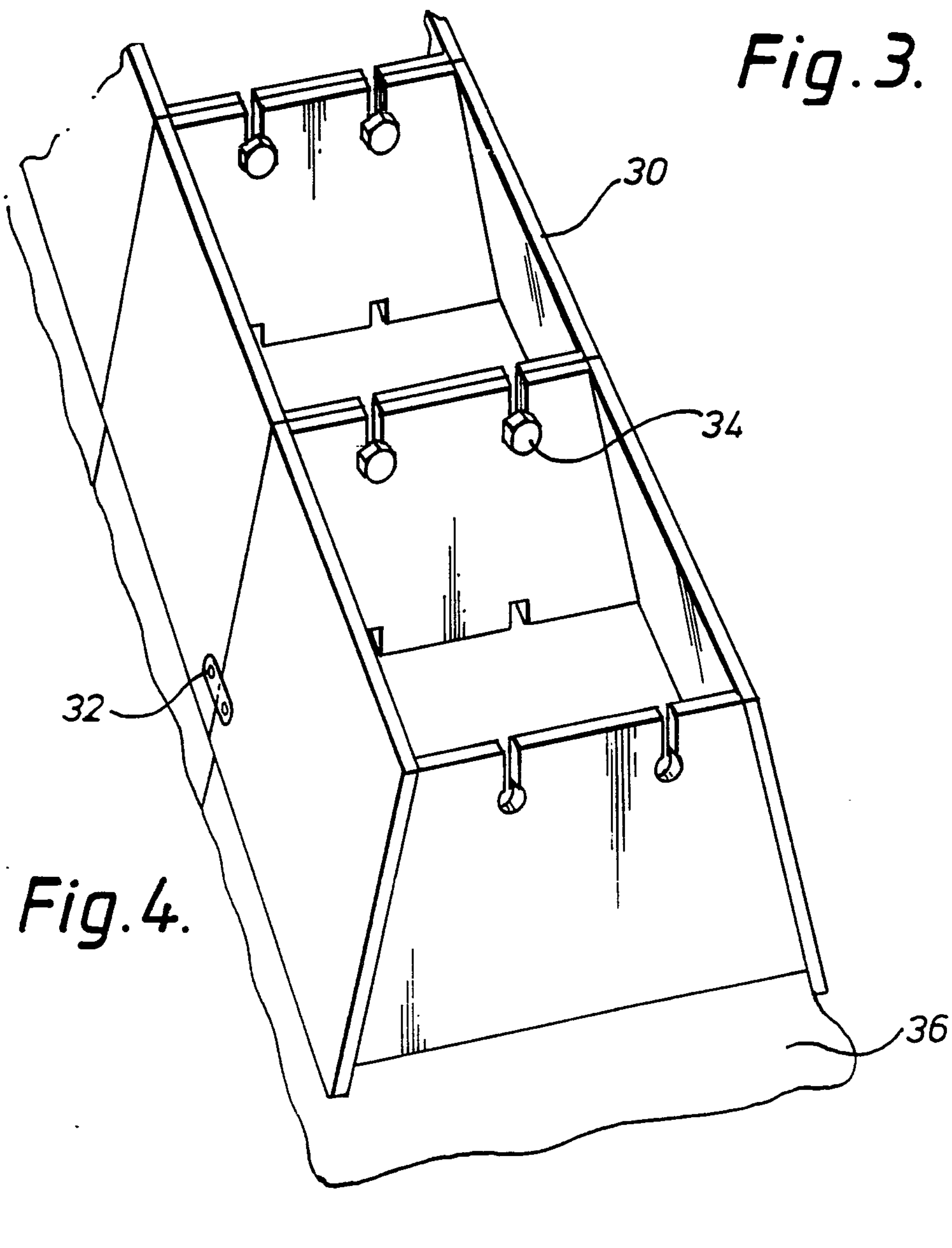

Fig. 4.

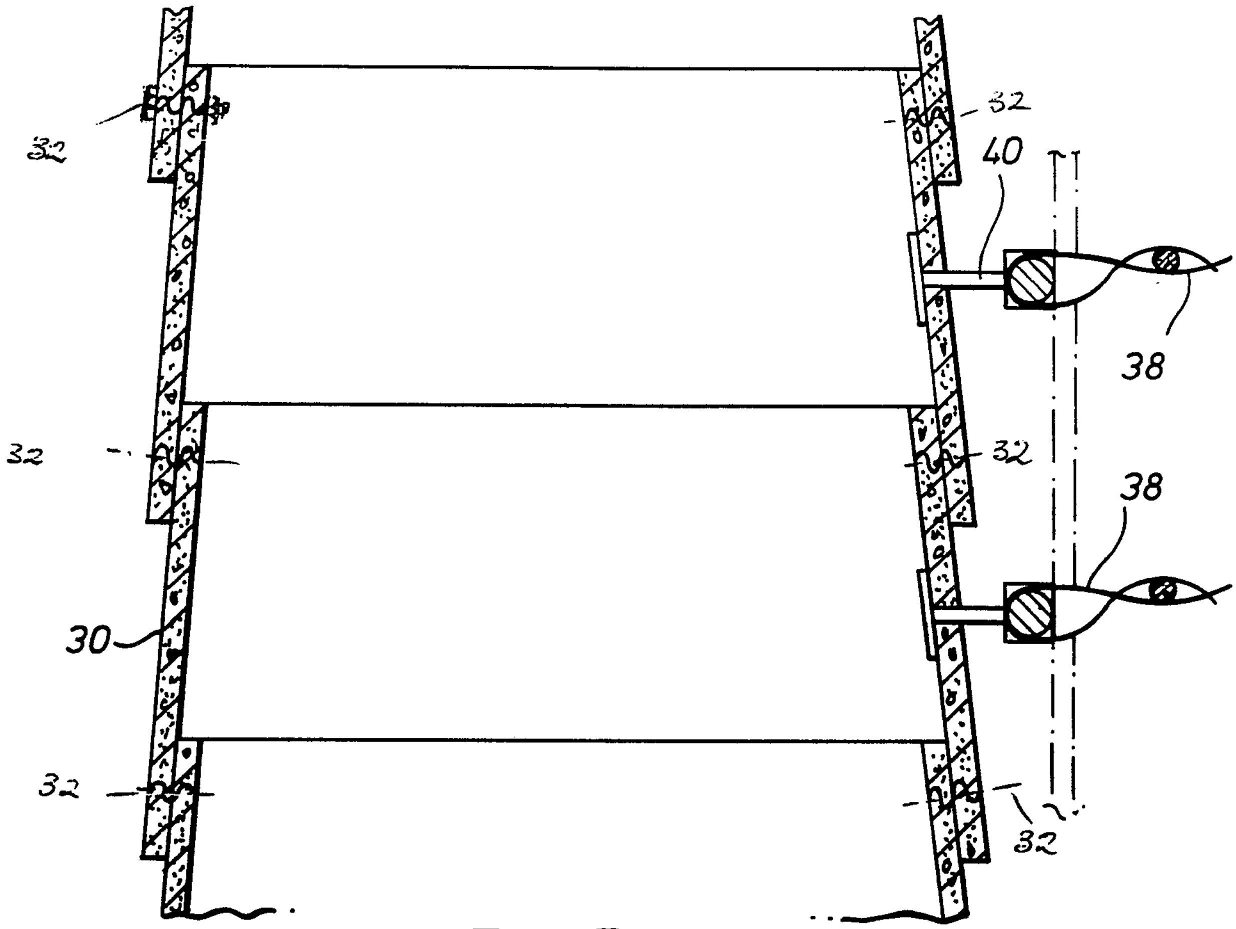

Fig.5.

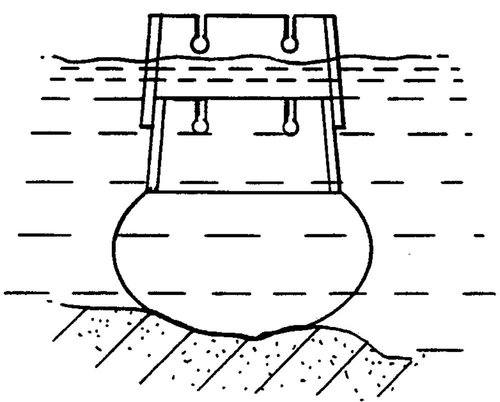

Fig.6A.

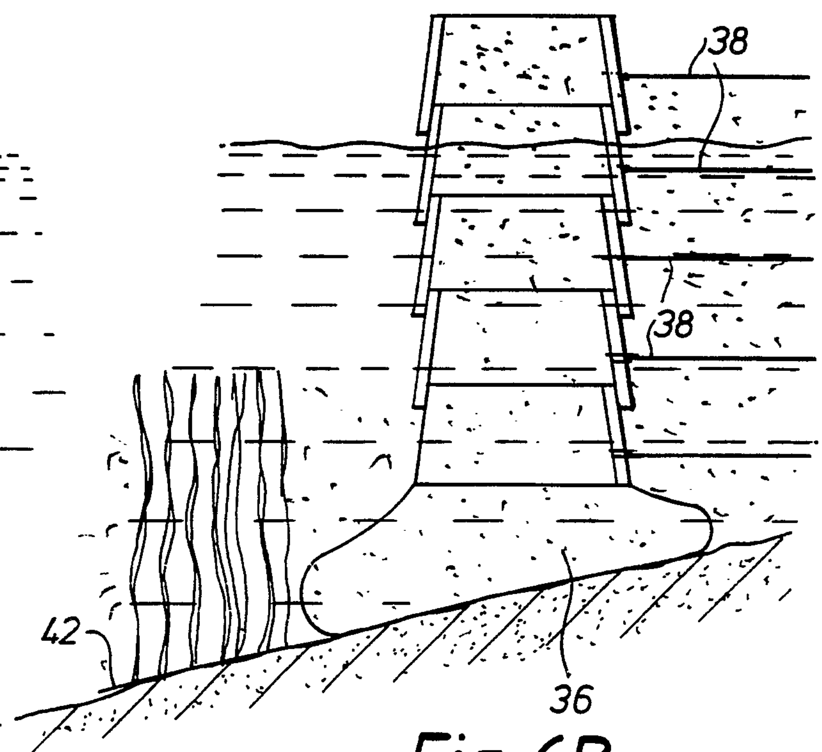

Fig.6B.

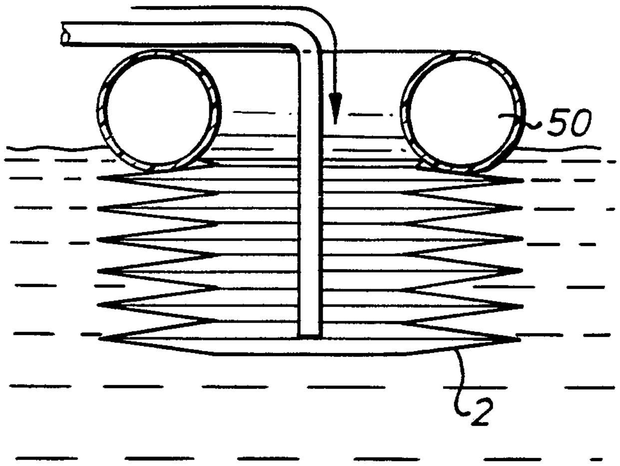

Fig.7A.

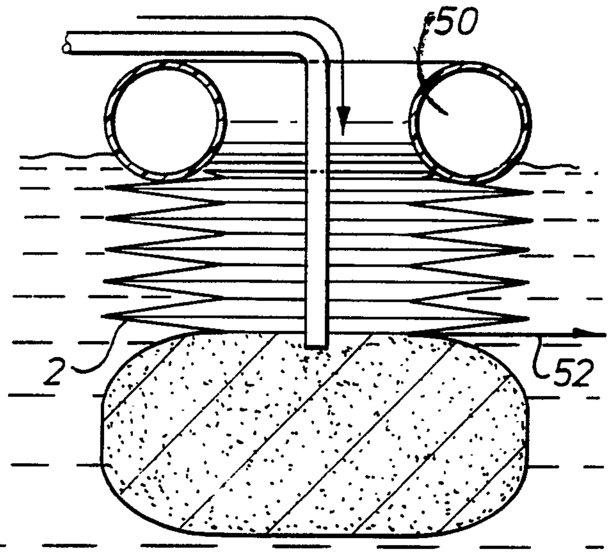

Fig.7B.

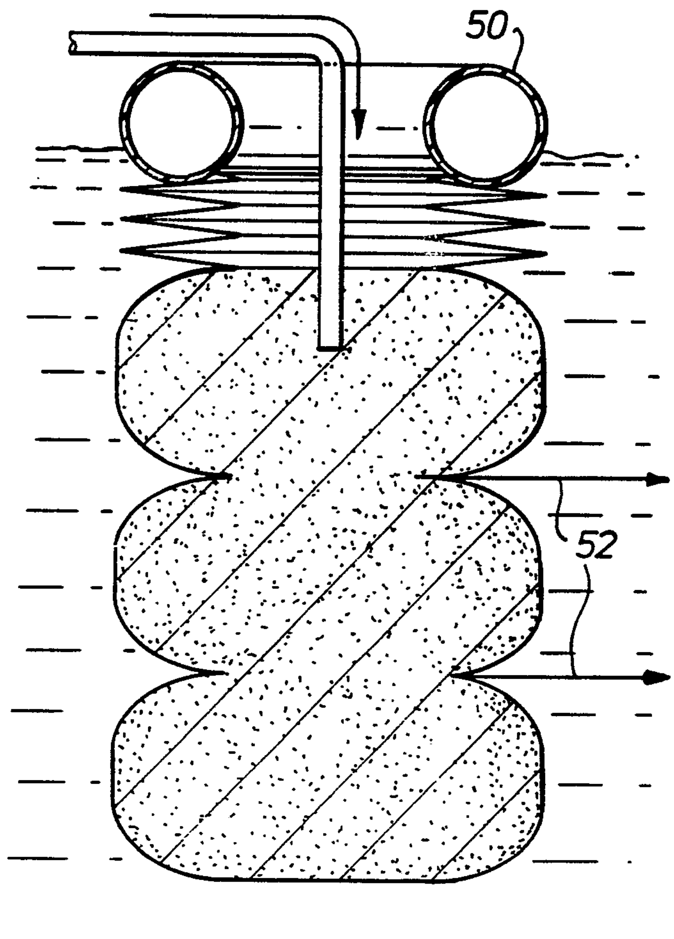

Fig.7C.

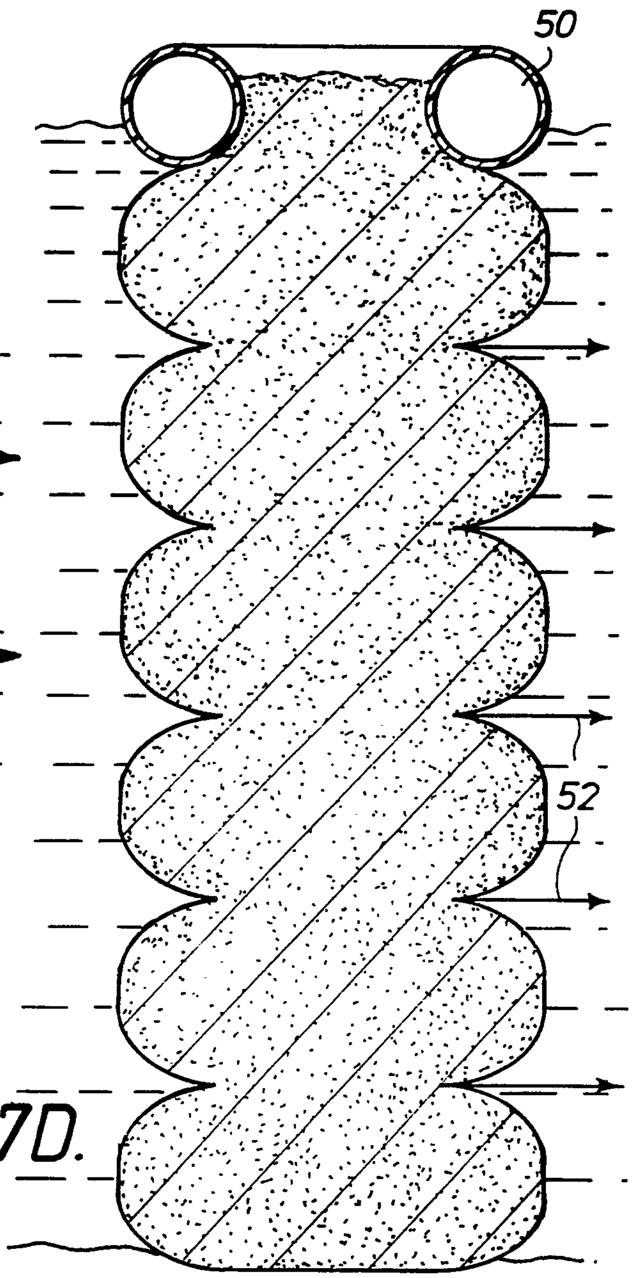

Fig.7D.

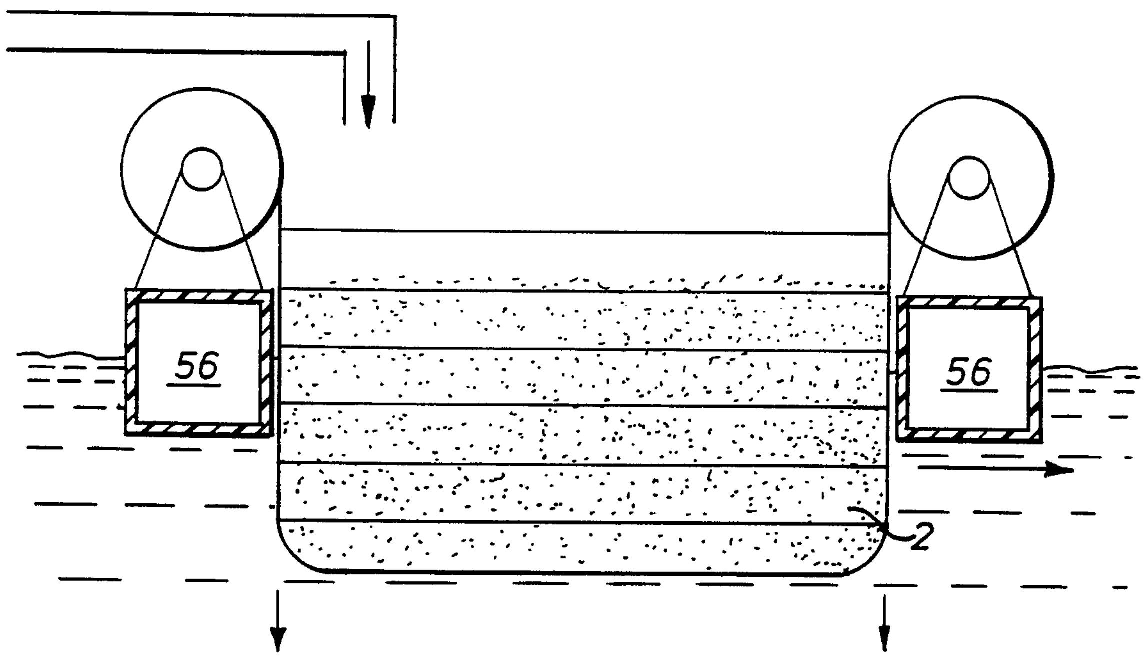

Fig.8A.

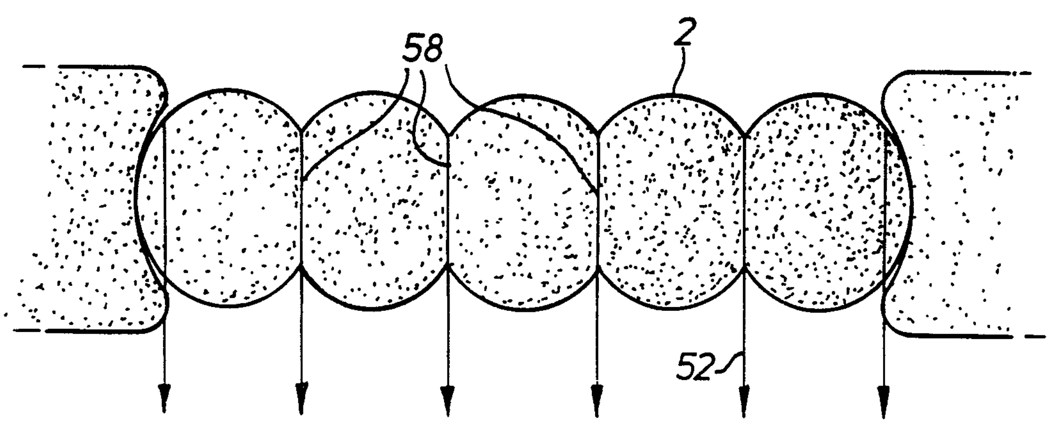

Fig.8B.