

May 20, 1958

P. MONNET
TERRESTRIAL OR HYDRAULIC CONSTRUCTION
CONSTITUTED BY APERTURED ELEMENTS

2,835,112

Filed Jan. 21, 1953

3 Sheets-Sheet 1

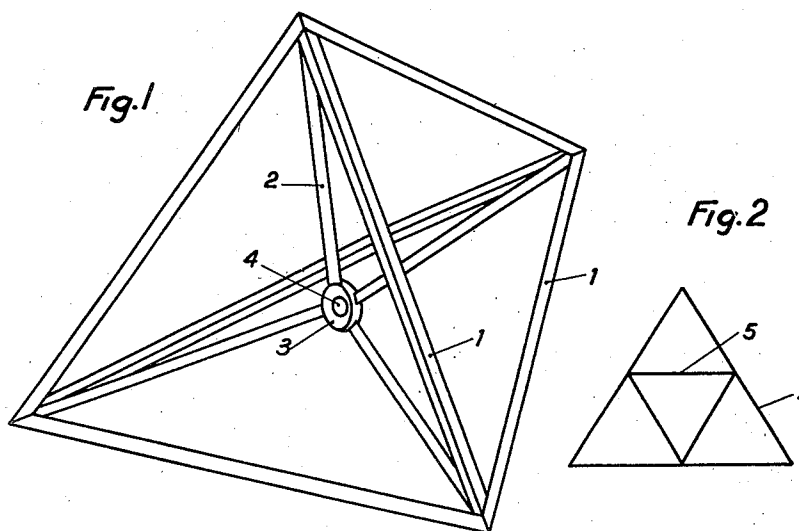


Fig. 3

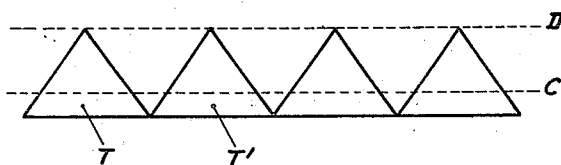
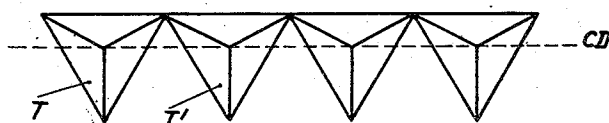


Fig. 4



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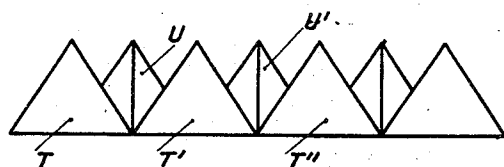


Fig. 5

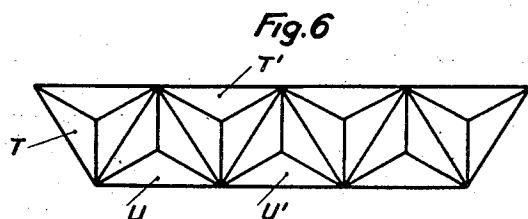


Fig. 6

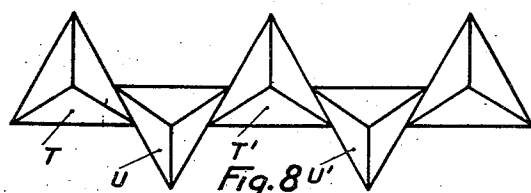


Fig. 7

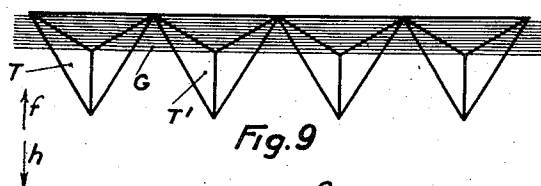


Fig. 8

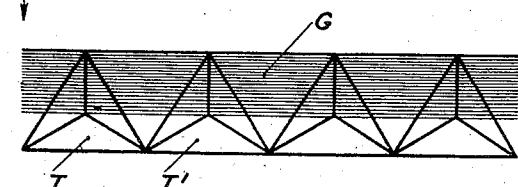


Fig. 9

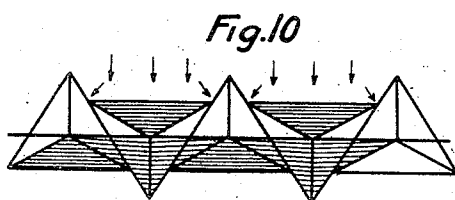


Fig. 10

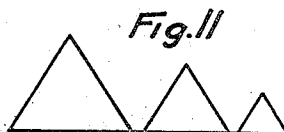


Fig. 11

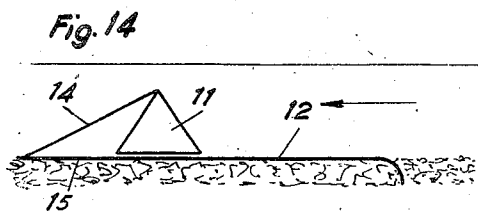
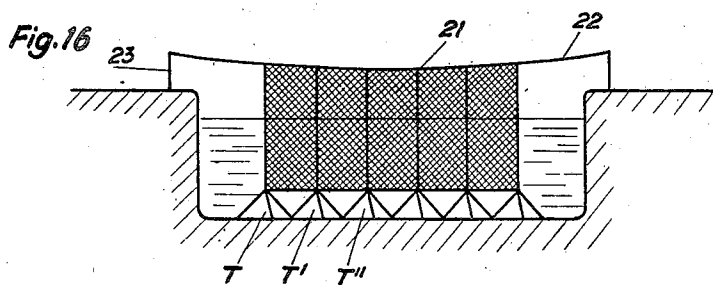
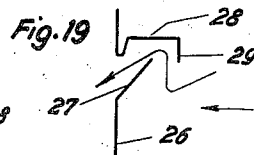
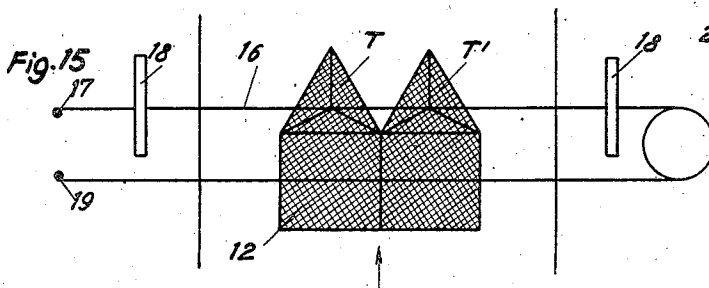
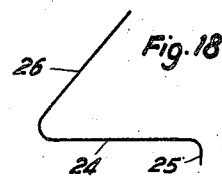
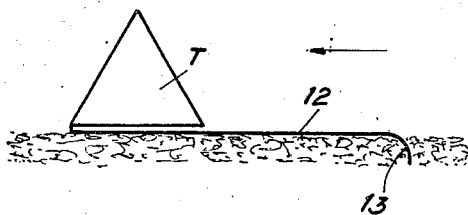
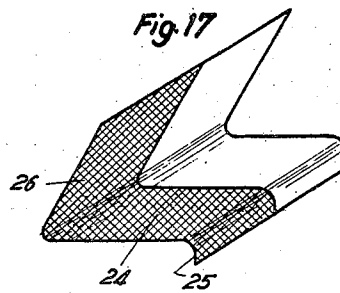
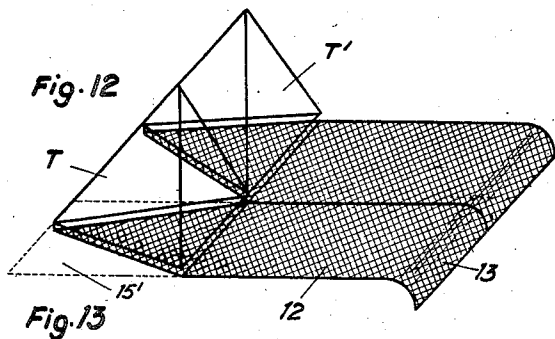
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TERRESTRIAL OR HYDRAULIC CONSTRUCTION CONSTITUTED BY APERTURED ELEMENTS

Pierre Monnet, Gap, France

Application January 21, 1953, Serial No. 334,208

5 Claims. (Cl. 61—3)

The present invention relates to terrestrial and hydraulic constructions such as defense dams on a sea front, constructions intended to stabilize earths or materials in movement, sunk or half-sunk constructions intended to collect materials carried by a stream, submersible dams, etc., the characteristic of these constructions being to be constituted by interconnected apertured obstacles.

To this end, use may be made of apertured tetrahedrons, these tetrahedrons having their apexes in juxtaposed relationship so that their faces are in the same plane. They may form in the horizontal plane a continuous or discontinuous front. In the inner spaces between the tetrahedrons of a same line other tetrahedrons may be placed, all combinations being, however, possible. The interconnection of the tetrahedrons may be ensured by cables passing through their centers of gravity or their apexes. Furthermore, the apertured obstacles of the construction may serve to support fabrics or nets made of textile fibers or metallic wires, to improve the retaining effect of the obstacles on the materials, and to permit the retention on a continuous front, whatever the distance between them. These fabrics or nets may cover certain faces of the obstacles, or interconnected the obstacles, or accommodate both these uses.

The apertured tetrahedrons whose edges are made of reinforced concrete or of shaped steel, are already known per se, having been employed in hydraulic constructions, for example as obstacles or retarders.

The present invention aims also to improve these tetrahedrons with a view to rendering them more rigid and more suitable for the constructions according to the present invention. To this end, according to the invention, use is made of regular tetrahedrons provided with a system of reinforcement constituted by braces connecting the common point of meeting of the three heights of tetrahedrons to the three apexes. To facilitate the use of these tetrahedrons in the construction, it may be expedient to manage in the meeting point of the interconnection-braces—which is at the same time the center of gravity of the tetrahedron—an eye or opening whose orientation may be that of the edge, parallelly to which must be effected the connection of the tetrahedrons by a common cable passing through their centers of gravity.

It has been found experimentally that the tetrahedrons tended, under certain conditions, to tip either under the action of earth bottom fall or under the action of stream itself or else under the action of Archimedean thrust. In order to eliminate the first named risk, it has been devised to place the tetrahedrons not directly upon the bottom but upon a grid-like sole adapted to protrude upstream and presenting mooring elements on the bottom. In order to eliminate the second named risk, it has been devised to provide the tetrahedron, downstream, with a counterventing element inclined and secured to a sole. In order to avoid the third named risk, it has been devised to maintain the tetrahedrons upon the sole by means of a cable directed along the construction and

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which, passing through the series of tetrahedrons, prevents these tetrahedrons from rising from the sole and eventually prevents the sole from rising from the bottom. By employing a line of tetrahedrons forming a chain of fixed points at the bottom of the bed, a further improvement consists in utilizing these tetrahedrons for fixing the lower ends of nets, curtains, grids or the like attached, on the other hand, to one or several cables maintained in place by means secured to the shore. It is thus possible to raise considerably the dam constituted by the tetrahedrons themselves.

A modification consists in employing, in lieu of tetrahedrons, other apertured obstacles, these obstacles being subject to the condition of being able to catch materials carried by the stream or cast into the water stream slightly upstream from the obstacles. A particularly advantageous form of these apertured obstacles consists in giving them the contour substantially similar to that of the ensemble constituted by the tetrahedrons and the sole supporting the same, that is to say that the said apertured obstacles will comprise, in a single piece, a sole provided with mooring elements at the bottom and an inclined or even vertical part playing the role of the sides of the tetrahedrons provided with a grating.

Finally, the various constructions according to the invention are foreseen to be utilized as having a better profile, long rectilinear, convex or concave, so as to correspond to the various conditions occurring in practice.

Several modes of execution of the arrangements according to the present invention will be described hereinafter by way of example, with reference to the accompanying drawings in which:

Fig. 1 shows in perspective a tetrahedron provided with a bracing system according to the present invention;

Fig. 2 shows in elevation the face of a tetrahedron provided with an additional bracing device;

Fig. 3 shows in elevation a construction composed of a line of tetrahedrons touching one another by one or their apexes;

Fig. 4 is a plane view corresponding to Fig. 3;

Figs. 5 and 6 show respectively in elevation and in plan a construction wherein, into inward angles of the lines of tetrahedrons of Fig. 3, there is placed a line of other tetrahedrons in a manner to form a continuous front on the two faces of the construction; the tetrahedrons are, in this disposition, in contact by an edge;

Fig. 7 shows the same general disposition of the tetrahedrons, in contact by an edge, but this contact takes place only along a portion of said edge; the construction then presents redans;

Figs. 8, 9, 10 show in plan constructions composed of tetrahedrons whereon fabrics or nets have been stretched;

Fig. 11 shows a line of tetrahedrons of decreasing dimensions, this disposition having for its effect to impart by raising to the bottom a water stream the maximum depth at the point selected;

Fig. 12 is a perspective view showing the tetrahedrons positioned upon mooring soles;

Fig. 13 is an elevational view showing one of these tetrahedrons;

Fig. 14 schematically shows in elevation a tetrahedron provided with a downstream counterventing element;

Fig. 15 is a plan view showing a mode of maintaining the tetrahedrons upon their sole to avoid their rising;

Fig. 16 shows a raised line of tetrahedrons resting on the bottom, by means of curtains or nets permitting of barring the water stream;

Fig. 17 is a perspective view showing an apertured obstacle employable in lieu of tetrahedrons;

Fig. 18 is an elevation thereof; and

Fig. 19 schematically shows how to constitute, in case

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of water stream carrying small materials such as sand, the apertured obstacles.

Shown in Fig. 1 is a regular tetrahedron whose edges 1 are, in a known way, constituted by steel shapes. In order to interbrace such tetrahedron, use is made, according to the present invention, of the well known property of the regular tetrahedron, according to which the four medians, joining each vertex with the center of gravity of the opposite face, meet in a point which is the center of gravity of the tetrahedron and which is $\frac{3}{4}$ of the way from any vertex to the center of gravity of the opposite face. Consequently, there are disposed, within the tetrahedron bracing rods 2 connecting a central body 3, disposed at the meeting point, to the vertexes of the tetrahedron. Since, as it will be seen later, the tetrahedrons of the construction may be interconnected by a metal cable passing through the centers of gravity, the body 3 may have an opening or eye 4 preferably oriented according to the direction that will be that of the connection cable, that is to say in principle according to a direction parallel to one of the tetrahedron edges. Clearly, any additional bracing system may be employed for reinforcing the aforesaid system. For example, in Fig. 2 the sides of the equilateral triangle forming each of the faces are interconnected by rods 5 constituting an inner equilateral triangle. It will be noted that these tetrahedrons being, according to the invention, generally intended to retain materials, this effect of retention is, of course, improved by the braces.

Shown in Figs. 3 and 4 is a construction constituted by a line of tetrahedrons T, T' . . . that touch one another by one of their vertexes and rest on a horizontal plane without any break in the plane. Such construction will be placed for example in a dam across the bed of a river and will retain materials in suspension. The tetrahedrons T, T' . . . are interconnected by a cable, for example a metallic cable such as C that passes through the openings manages, as above stated, in the center of gravity. Such system is balanced about an axis of gravity. However, since the center of the thrust exerted on the faces of the tetrahedron (supposed to be filled and which will be so, more or less, for example when the tetrahedron will have been more or less filled with the materials carried along) tends to rise as the depth increases, in the case of swelling for example, it may be more advantageous, in case of this kind, to suspend these tetrahedrons from a cable D passing in the upper vertex.

In the case of Figs. 5 and 6, between the tetrahedrons T, T' . . . there are placed other tetrahedrons U, U' forming another line so as to have successively, according to a horizontal, a face and an edge. Thus there will be continuity as regards the faces, and discontinuity as regards the vertexes. It is further possible (Fig. 7) to place the tetrahedrons T, T' at a certain distance therefrom, and to interpose between the tetrahedrons U, U' so as to obtain redans. Of course, the tetrahedrons U, U' will be interconnected by a cable in the same way as the tetrahedrons T, T'. But the redan has for its dimension $\frac{1}{3}$ the thickness of the construction, the centers of gravity and the upper vertexes of the tetrahedrons T and T' and U and U' are in straight line, so that the two groups of tetrahedrons may be interconnected by a single cable.

According to the present invention, it has been devised to combine the constructions formed of tetrahedrons with fabrics, for example with loosely woven gabion-type canvass or with metallic fabrics or nets, or the like. One or more faces of the tetrahedrons may be fitted with such fabrics or nets. It is further possible to employ the tetrahedrons as supports for these fabrics or nets, the tetrahedrons being disposed either in contact with one another or from distance to distance along the construction. It is clear that the fabrics or nets will be disposed, according to the cases under consideration, in a manner to obtain the desired effect. For example, in

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Fig. 8 there has been proposed to stabilize a mass of earth or materials in movement coming in the direction *f*. In this case, the interior of the tetrahedrons T, T' placed in line and interconnected according to the present invention should be filled with materials coming from upstream without becoming empty downstream. There will therefore be placed a gabion fabric upon the downstream face, either singly or in conjunction with other elements lining the faces of tetrahedrons and elements interconnecting the same.

In the case of Figs. 9 and 10 it has been supposed that the construction, constituted by the tetrahedrons T, T', was placed into a stream flowing in the direction of the arrow *h*, and whose dragged materials it was desired to collect.

The fabric or net will then be placed preferably on the upstream end of the construction so that the materials deposited present an inclination toward the downstream end. In Fig. 9, the tetrahedrons are disposed in conformable positions, while in Fig. 10 they are in reversed position. In this case, the retention front between two consecutive tetrahedrons contacting by a base edge is constituted by a trapezoidal fabric or net element whose horizontally disposed bases have a dimension equal respectively to $\frac{2}{3}$ and $\frac{1}{3}$ of the tetrahedrons' edge and whose sides are equal to this edge. The larger base serves to interconnect the upper vertexes, while the smaller base serves to interconnect the vertexes situated in the seat plane of the construction. The larger base and the two trapezium sides may be constituted by a rigid frame stretching the fabric or net; the trapezium sides are applied against the edges of the tetrahedrons to be interconnected and strongly secured to these edges. As the edges are not in a same plane, the absence of the fourth rigid side in the quadrangle permits its warping, without detrimentally affecting the comportment of the fabric stretched out.

In Fig. 12 each of the tetrahedrons T, T', which are interconnected as shown precedingly, rests on a horizontal grid-like sole presenting towards the upstream end a square-like extension 12 provided at its end with a vertical mooring apron 13 plunging to the bottom.

In order to avoid overturning of the tetrahedron in the downstream direction by the shock of a large element dragged along with the stream, the tetrahedron is provided with a brace 14 one end of which is secured, for example, to the vertex of downstream edge of the tetrahedron, while the other end thereof comes to apply against a downstream extension 15 of the sole 12. In lieu of securing this end to a downstream extension of the sole, there may be employed a downstream sole entirely independent from the upstream sole and secured to the latter by a series of clamps. To this end, the upstream sole, in lieu of having a triangular form in its downstream portion, may be rectangular, so that the built-up soles jutting out beyond the tetrahedrons be in juxtaposed relationship. This disposition has the advantage of decreasing the dimensions of the elements employed. It is indicated by dotted line in Fig. 12 and is denoted by reference 15'.

Furthermore, in some cases the tetrahedrons tend to rise under the floating effect, particularly when the mass in movement, as this often occurs in torrents, has a pasty consistence. This shortcoming will be remedied for example in the following way:

A cable 16 (Fig. 15), strongly moored in a steady point 17 of one of the shores of a water stream, passes across the tetrahedrons, for example through the eye managed, as above stated, in the point of meeting of the heights. This cable passes below rods or rolls 18 secured to the two shores and, after crossing the water stream, returns to be secured at a stationary point 19. It is clear that in this way the tetrahedrons T, T' are applied against the soles 12 which cannot rise.

When the tetrahedrons are provided with countervents, the return leaf may also interconnect these countervents.

Fig. 16 shows how a line of tetrahedrons T, T' may be employed interconnected and fixed to the bottom, as shown, to form a chain of fixed points serving to moor one or more retention nets or curtains 21 whose upper edge constituted by a transversal cable 22 stretched between two posts 23 secured to the two shores. It is clear that the cable 23, in lieu of being placed as shown in Fig. 16 above the water stream level, may also be placed below this level so as to constitute a kind of overflow dam. It may also be advantageous not to place the retention net vertically but to incline the same from the chain of tetrahedrons upstream thereof. Finally, in some cases it will be advantageous to place the line of tetrahedrons and the net not transversely in respect to the water stream but obliquely in respect to the water current. In Figs. 17 and 18 the tetrahedrons are replaced by other apertured obstacles of suitable form. In these figures the obstacles assume a form which is fairly analogous to that of the apparent contour of the tetrahedrons and its mooring sole. They comprise a sole 24 intended to apply against the bottom and provided with a plunging apron 25 and a partition 26 raised at an appropriate angle, all in a single piece. The obstacles may be provided with openings or eyes for passing the cables therethrough.

When the retention is concerned with small elements, for example with sand, use will be made, in lieu of a grid-like surface, preferably of a continuous surface such as metal plate pierced with a convenient number of orifices. In Fig. 19, there is shown in section one of these orifices managed in such way that the water passes through the baffled obstacle so as to avoid the passage of the small elements dragged along by the stream. To this end, the wall 26 has its upper portion bent upstream from the orifice so as to form the lower baffle 27, whereas the upper portion of the orifice takes the form of a sort of roof 28 extended downwardly as at 29 so as to mask normally the flow passage thus arranged.

There will now be indicated the various applications of the constructions obtained according to the present invention.

The stable stop line obtained perpendicularly to the water current may be, in a vertical plane, rectilinear, convex or concave.

The convex form will cause sloping piles of dragged materials, apt to play the role of protection for the construction such as a bridge pier that will be included therein.

The concave form will fix "ne varietur" (without variation) the point of maximum depth of the stream. It will canalize the flow of the latter and will permit the overflow only on a reduced depth. Thus, there may be advantageously replaced by a transversal construction a longitudinal construction of protection, such as a dam built up parallelly to the current direction.

The system also permits of fixing the bed of a fluctuating river according to a rectified axis. The bed being barred transversely throughout its width, the point of minimum level adopted for the system is that for which will finally take place the flow of the current after stowage of the hollow parts up to the level fixed in advance for each of the points of profile across.

What is claimed is:

1. Apparatus of the class described comprising a plurality of skeleton tetrahedrons each having four triangular open faces defined by rigid bars permanently joined at the apices of the tetrahedron and each tetrahedron having a connecting element located approximately at the center of gravity of the tetrahedron, and four rigid brace bars extending inwardly from the four apices of the tetrahedron to the connecting element, the several tetrahedrons being disposed with their centers of gravity in alignment, a cable uniting the connecting elements of the several tetrahedrons and means anchoring the opposite ends of the cable thereby to maintain the tetrahedrons in alignment, the several tetrahedrons forming a line extending transversely across a stream bed, and a sole upon which each respective tetrahedron rests, each sole resting upon the stream bed and extending from its tetrahedron in the up-stream direction thereby to prevent the tetrahedron from upsetting in the upstream direction.

2. Apparatus according to claim 1, wherein the sole is of grid formation and has its up-stream end portion deflected downwardly into the stream bed.

3. Apparatus according to claim 1, wherein the sole also extends downstream beyond the bottom face of the tetrahedron and a brace extends from the downstream end of the sole to the upper apex of the tetrahedron.

4. Apparatus according to claim 1, wherein a net is attached to the bars which define one of the side faces of each of the respective tetrahedrons.

5. A flow-obstructing device for use in the hydraulic building of jetties or the like, said device being a skeleton tetrahedron having four equi-lateral triangular faces each defined by rigid bars permanently joined at the apices of the tetrahedron and four rigid brace bars extending inwardly from the four apices of the tetrahedron to a connecting element located approximately at the center of gravity of the tetrahedron, said central member having therein an opening designed to receive a cable for anchoring the device at the point of use.

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