

- [54] **METHOD FOR BUILDING IMMERSED STRUCTURES AND A DEVICE FOR CARRYING OUT SAID METHOD**
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- [52] U.S. Cl.**61/46, 61/22, 61/25, 61/30, 61/49, 61/50, 61/52**
- [51] Int. Cl.**E02b 3/06, E02b 7/00, E02d 27/20, E02d 29/06**
- [58] Field of Search.....**61/50, 52, 46, 22, 49, 30; 14/27; 114/5 F**

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- Primary Examiner—Jacob Shapiro*
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[57] **ABSTRACT**

A method and device for the construction of dams or dikes either in rivers or in the sea. A wall of sheet piles is set in position by embedding in the bottom, a row of projecting elements is placed alongside said wall in substantially parallel relation thereto, the space formed between said projecting elements is packed with filling material, a prefabricated raft which is supported on the sheet-pile wall and on the row of elements is set in position underwater on the bottom which has thus been prepared, grout is injected into at least part of the foundation mass, whereupon the raft is anchored relative to the mass.

19 Claims, 30 Drawing Figures

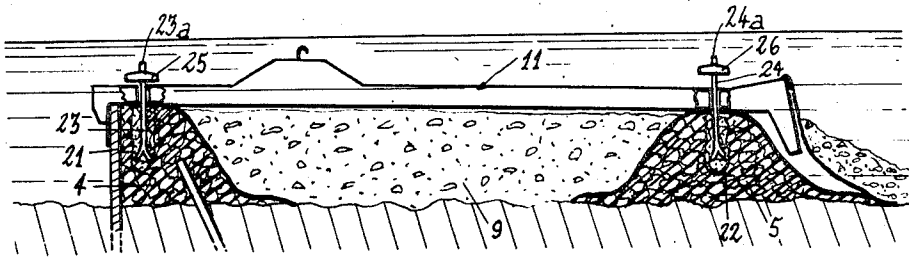


Fig. 5

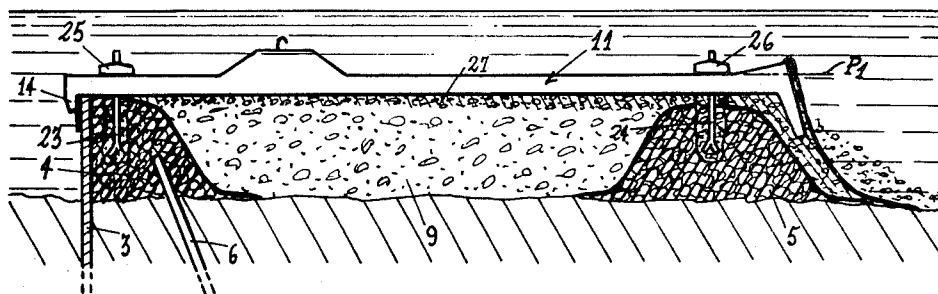


Fig. 8

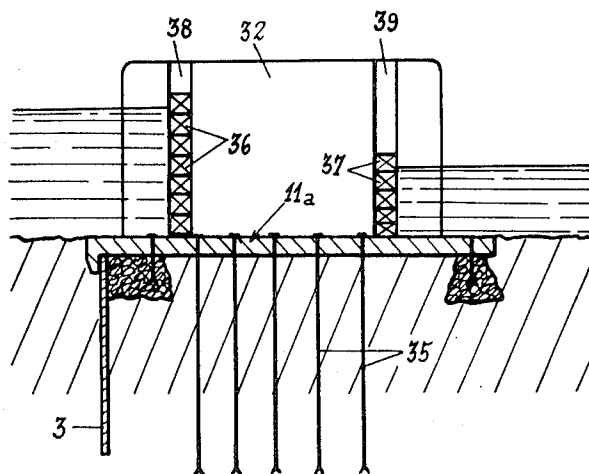
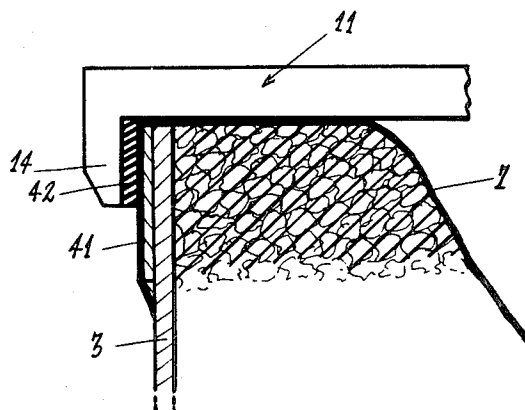


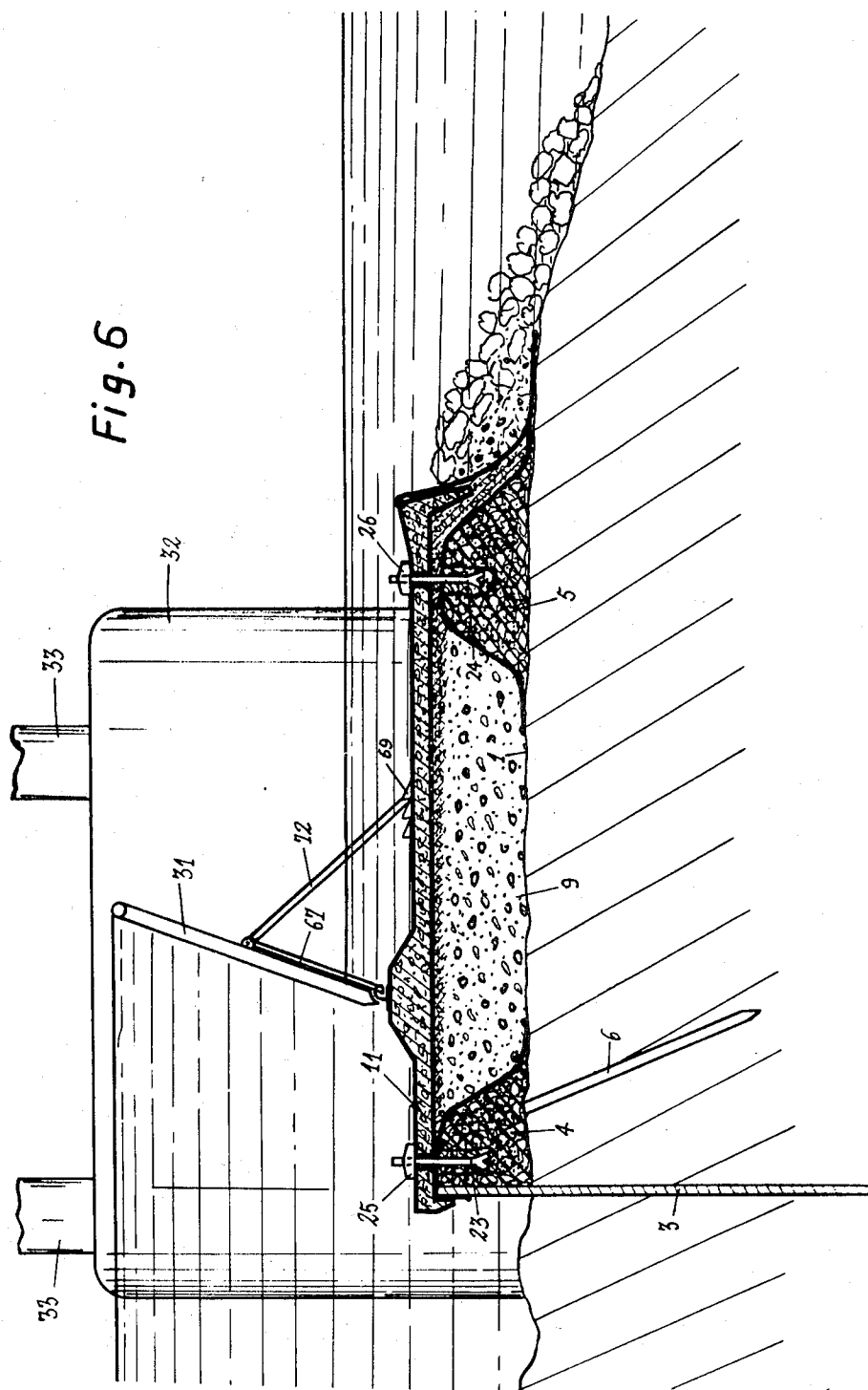
Fig. 9



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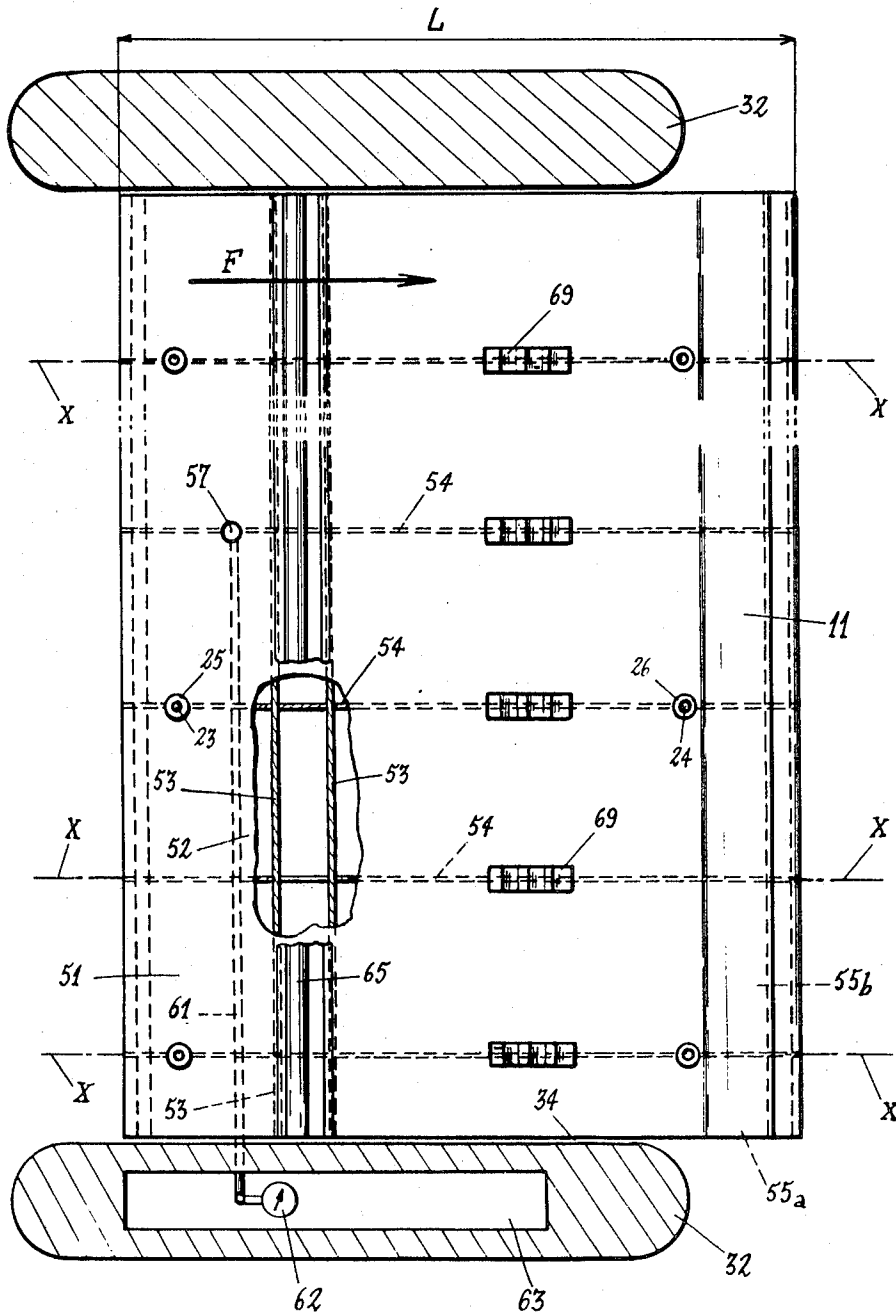
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Fig. 7



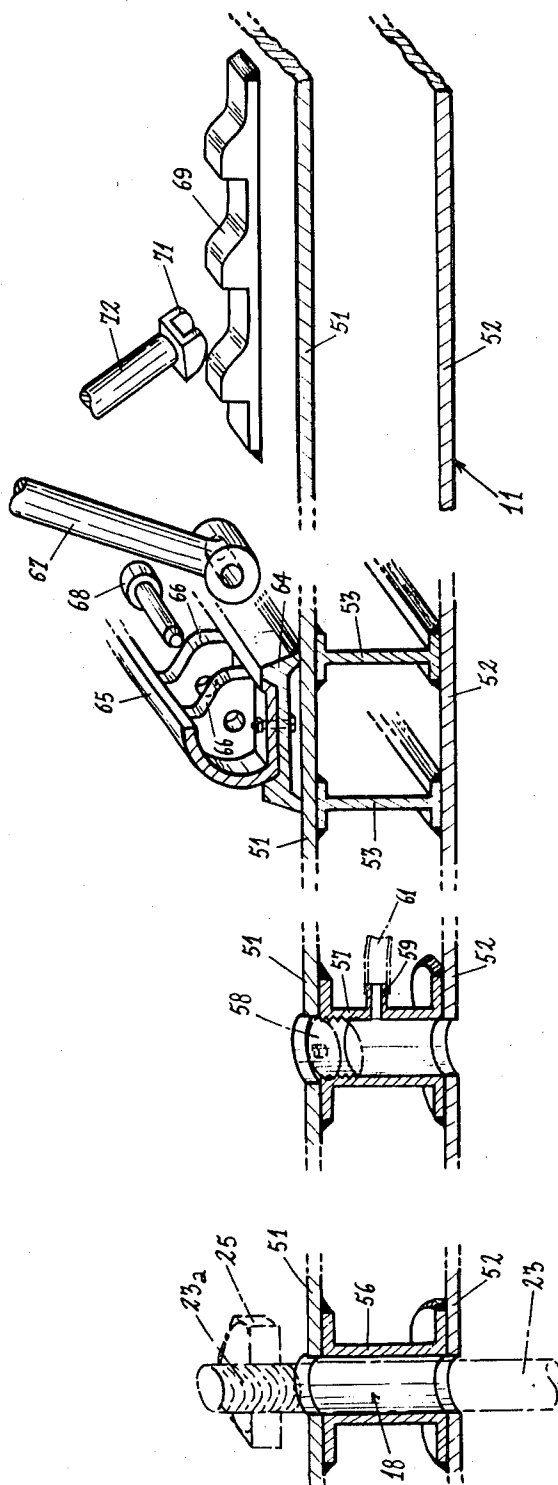
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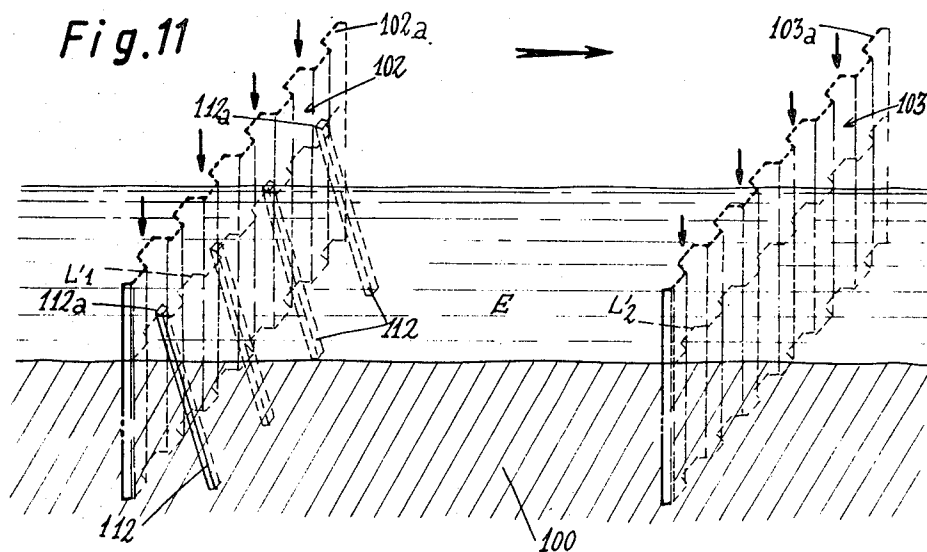
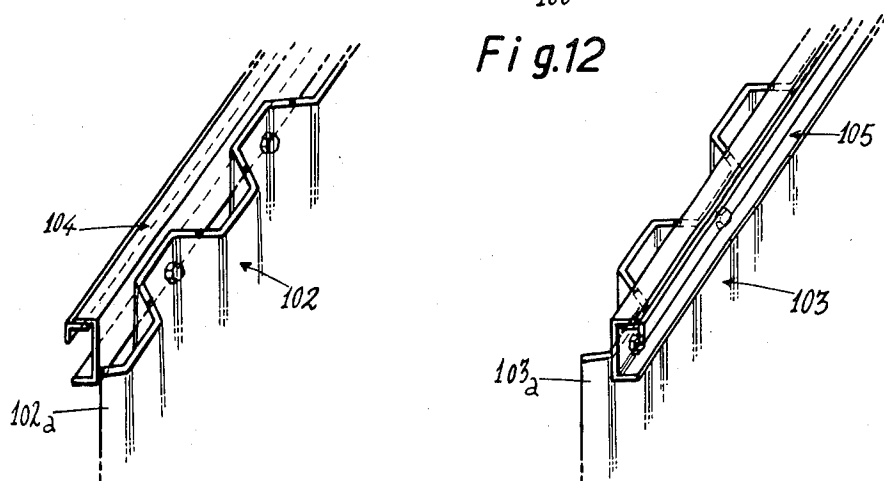
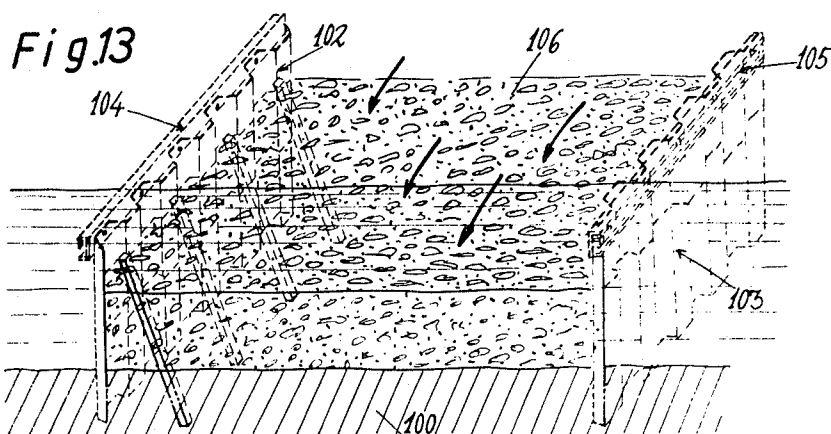
Fig. 10



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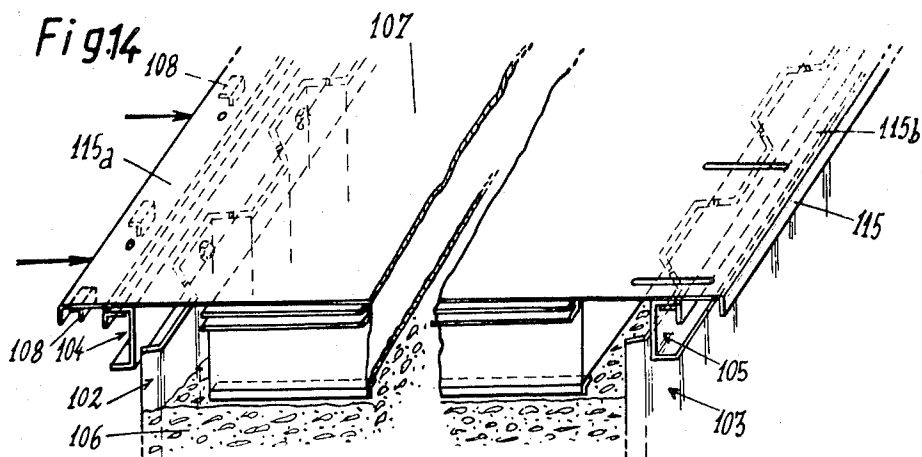
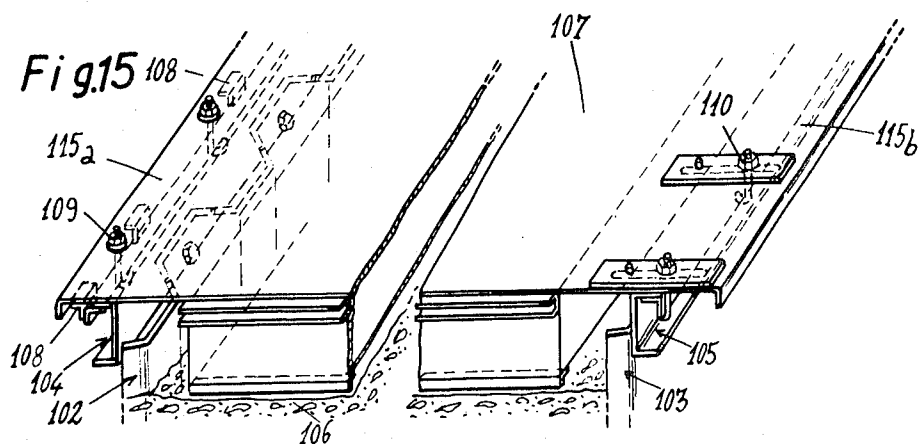
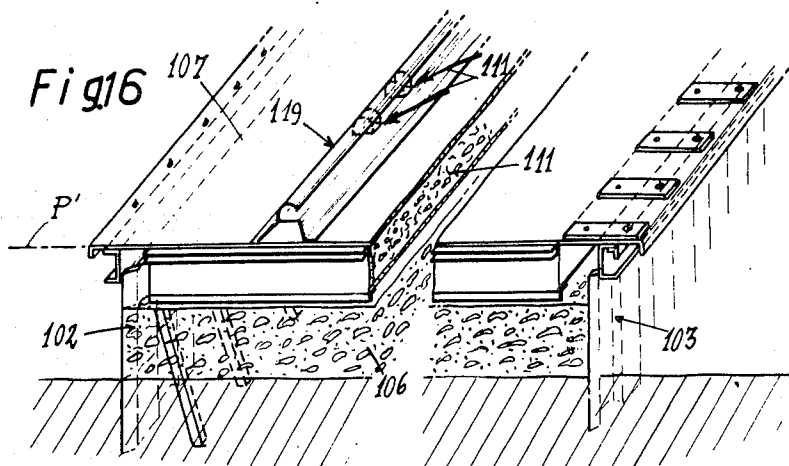
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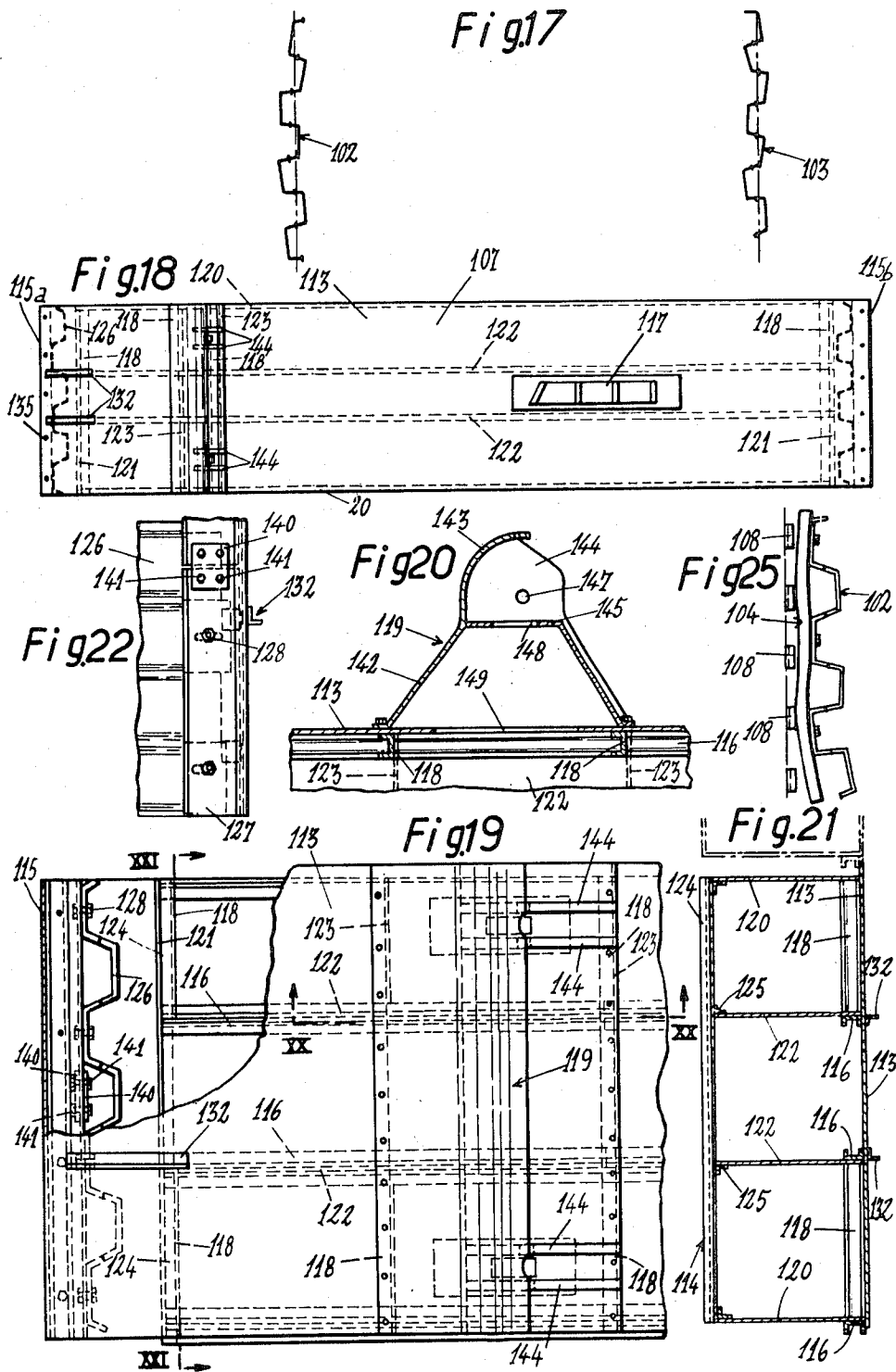
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Fig. 23 XXIV

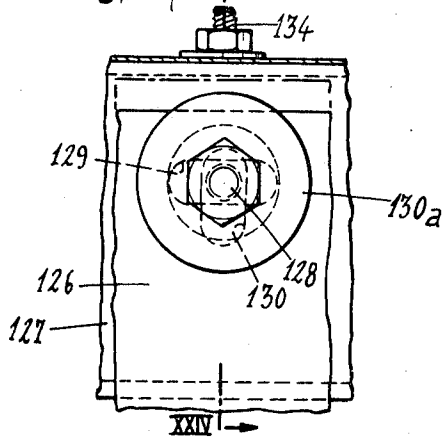


Fig. 24

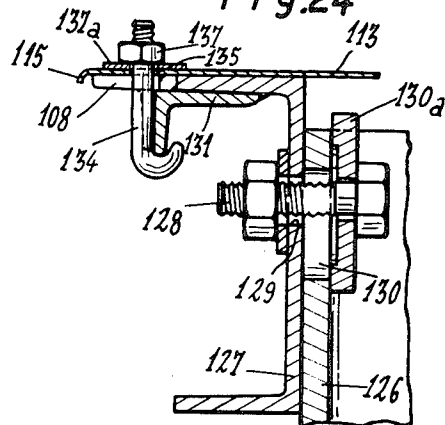


Fig. 26

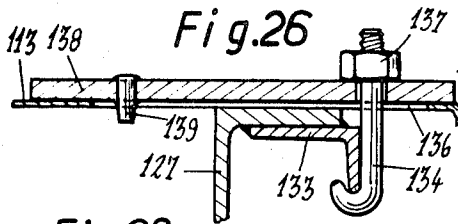


Fig. 27

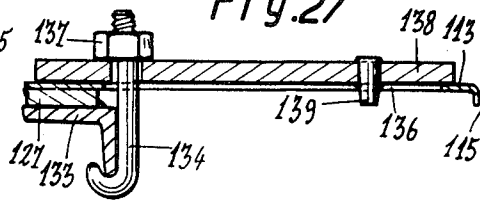


Fig. 28

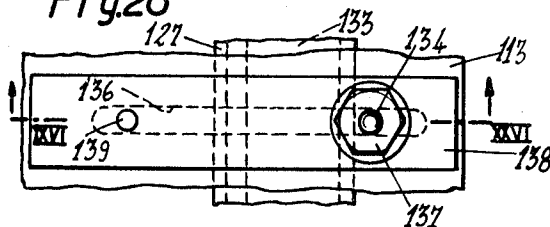


Fig. 29

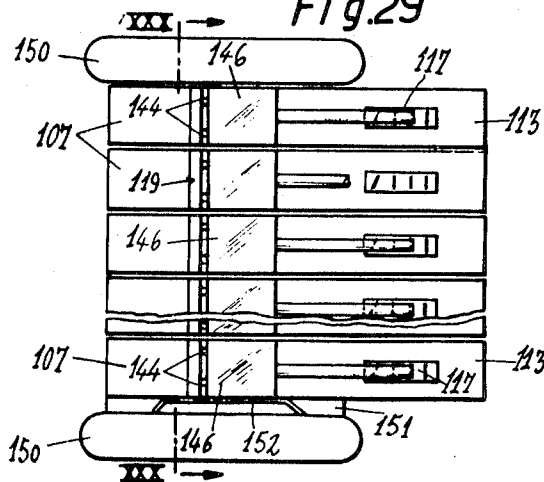
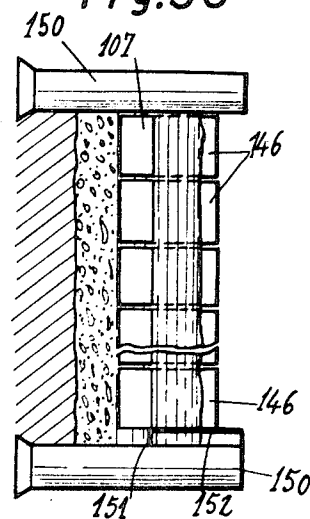


Fig. 30



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METHOD FOR BUILDING IMMersed STRUCTURES AND A DEVICE FOR CARRYING OUT SAID METHOD

This invention relates to a method which is intended to be employed for building immersed structures such as embankments or dams, especially movable dams either in rivers or in the sea and for underwater construction of foundations without any preliminary unwatering of the site.

It is customary practice to build river or sea structures by temporary unwatering of the foundation ground, this being carried out by isolating a given area within an enclosure formed by walls of steel sheet-piling or earth embankments. The water contained in the enclosure as thus constructed is removed by pumping. This makes it possible to work in the dry and thus to carry out any excavating work which may be necessary in order to free the surface of the bearing bed on which the structure is to be seated, then to build up the solid or hollow mass of masonry which constitutes the structure to be built.

Since methods of this type are sometimes costly and difficult to carry out in practice, recourse is also had to different methods which do not entail the need for preliminary unwatering. These methods involve the construction at a distance from the final site location of structures formed either of masonry or of metal which are brought into position either by floating or by means of lifting equipment.

These structures are then anchored to the foundation ground by means of one of the two following methods: either by sinking onto the foundation ground or onto a previously levelled rockfill bed; or by boring through the ground in order to lower the structure to the necessary depth and in order that said structure should rest on a bearing bed.

These methods of foundation without preliminary unwatering are attended by the following disadvantages: the degree of accuracy obtained at the time of positioning of the prefabricated structure is not sufficient to permit the possibility of anchoring to the structure at the moment of prefabrication of this latter the components which permit subsequent mounting of equipment such as sluice-gate systems of movable dams, hydroelectric generating sets or the like which are intended to complete the structure when this latter has been fixed in its final position after boring or sinking.

In accordance with the invention, in order to overcome the disadvantage and to permit rapid and very accurate positioning of the prefabricated structure on a foundation which has been prepared under water, the method for building immersed structures such as embankments or dams and especially movable dams either in rivers or in the sea and entailing underwater positioning on a prepared bottom without preliminary unwatering of a prefabricated structure which constitutes one constructional element is characterized in that a sheet-pile wall is driven along the location line selected for the structure, that a row of projecting elements is placed substantially parallel to the sheet-pile wall, that filling material is placed within the space thus formed, that a prefabricated foundation raft is immersed and lowered onto the bottom which has thus been prepared so as to bear on the one hand against the sheet-pile wall

and on the other hand against the row of projecting elements, that grout such as Colgrout is injected into at least part of the foundation mass which is provided for the raft, and that the raft is anchored with respect to said foundation mass. The upstream portion of the raft is preferably anchored to the sheet-pile wall, the effect of anchoring being to create a support which provides resistance against sliding of the raft in the downstream direction.

Preparation of the foundation mass is thus carried out after sinking of the prefabricated raft.

Injection of grout into the foundation mass beneath the raft is preferably carried out through the raft itself.

In a first embodiment of the invention, the row of projecting elements which is disposed parallel to the sheet-pile wall consists of a rockfill stringer whilst a second rockfill stringer is placed against the sheet-pile wall and along this latter. In this case, the grout is distributed beneath the raft and within the rockfill stringers which are thus transformed into hard concrete known as Colcrete.

In one advantageous embodiment, anchoring of the raft is carried out by passing through this latter rods which are sealed in the rockfill stringers after they have been transformed into Colcrete and which are provided with abutment members for limiting uplift of the raft.

In accordance with one advantageous form of construction in which the raft has been lowered underwater to a depth which is greater than the intended depth, the raft is partially raised until it comes up against the abutment members of the anchoring rods which have been placed in predetermined positions. The raft can thus be brought strictly to the desired height.

The operations to be performed in this first form of construction are therefore relatively numerous. Moreover, if the necessary operation of re-filling with rock material has not been performed owing to unforeseen circumstances, downstream undermining of the structure is liable to occur.

It is for this reason that, in a second embodiment of the invention, setting of the row of projecting elements in a position substantially parallel to the sheet-pile wall consists in driving along the location line of said row a second sheet-pile wall and the foundation raft is anchored to the two pile walls.

Said second sheet-pile wall has a triple function: to ensure more effective conservation of integrity of the raft in the event of downstream undermining or erosion which reduces the potential danger of downstream uplift of the structure; to serve as a support for the downstream end of the raft; and also to replace the rods which are sealed in the downstream rockfill stringer by serving as anchoring means to prevent uplift of the raft during grout injections.

Said pile wall also permits simplification of the operations to be performed by dispensing with the following steps:

placing of rockfill stringers and subsequent conversion to concrete by injection of grout and positioning of anchoring rods and abutment members for these latter.

In consequence, only two operations are performed within the space formed beneath the intended location of the foundation raft and between the two sheet-pile walls and these operations are as follows:

- placing of filling material within said space and
- injecting grout into the small enclosed space formed between the filling material and the underface of the raft and then into the space enclosed within the raft.

The method can thus be carried into effect within a much shorter period of time and at much lower cost.

However, the anchoring rods employed in the first embodiment have a double function, viz:

- on the one hand of affording resistance to the stresses which will tend to lift the raft during grout injections and
- on the other hand and by virtue of the abutment members which are adjustable of serving to place the foundation raft in a horizontal position with a degree of precision which could be of the order of a few millimeters if so desired.

In point of fact, it is known that a sheet-pile wall which is driven underwater may not exhibit perfect alignment; however, when efficient pile drivers are employed, the displacement of a sheet-pile head in a direction at right angles to the wall may be only of the order of one centimeter. Height variations are also liable to arise although the depth of penetration can usually be stopped to within a few millimeters and transverse displacements in the plane of the wall are inevitable.

For the reasons just given, in order to compensate for variations in alignment and in height and especially in the second embodiment of the invention, provision can also be made for a horizontal waling of each sheet-pile wall at the upper extremity of this latter. If the intended level or position-setting of the waling is accurately maintained and if the foundation raft is secured to the sheet-pile walls after waling of these latter, this waling operation readily permits the possibility of attaining both the objectives of anchoring rods as mentioned above.

The invention is also concerned with a device for carrying out the method under consideration, said method being characterized in that it comprises a sinkable foundation raft provided with means for injecting grout into the intended foundation mass.

In one particular embodiment which is of interest in the case of sluice-gate systems consisting of separate elements in juxtaposed relation such as rocking-shutters, the foundation raft extends to the full intended length of the dam between two piers of masonry and is constituted by a hollow sinkable pontoon reinforced by longitudinal and transverse tie-beams, said pontoon being provided with an upstream nose for attachment to the sheet-pile wall and with a downstream nose which is intended to be mounted astride the row of projecting elements consisting of the downstream rockfill stringer or the second sheet-pile wall. Said raft is preferably provided with a set of through-passages at the time of prefabrication (said passages being employed for injecting grout and, in the case of the first embodiment, for the insertion of anchoring rods), the sills of the shutters and the guides being intended for the abutting application of the shutter props.

In an advantageous embodiment of the device which is primarily employed in the second embodiment of the invention and intended to compensate for variations in alignment and in height, a horizontal wale can be secured, preferably by means of bolts, to each sheet-pile wall at the upper extremity thereof and on the side remote from the space formed between the two pile walls. In this case, the holes formed in the sheet piles for attachment of these latter can be vertical slots in order to compensate for variations in height.

Moreover, the sheet piles correspond in principle to a given mean height covered per element but there can exist in practice a variation of the order of 1 millimeter in the direction of the sheet-pile wall. The pile drivers can compensate for variations of this order during driving but it is preferable not to subject them to such a requirement by reason of the cost of labor. In the case of assembly by means of bolts, drilling of the wale can consequently be carried out either on site as a function of the actual position of the sheet piles or in the workshop, in which case provision is made for horizontal slots.

The following description is given by way of non-limitative example and is solely intended to provide a clear understanding of the manner in which the invention can be carried into effect, reference being made to the accompanying drawings, in which:

FIGS. 1 to 5 are explanatory diagrams in transverse cross-section showing the different stages of application of a first embodiment of the method according to the invention;

FIG. 6 is a view in elevation and in transverse cross-section showing a shutter dam which is placed in position in accordance with this form of construction;

FIG. 7 is a more detailed plan view showing a portion of the dam illustrated in FIG. 6;

FIG. 8 is a diagrammatic transverse cross-section showing another embodiment in the case of a dam having a single large sluice-gate element which extends from one pier to the next;

FIG. 9 is a detail view showing the method of attachment of the foundation raft;

FIG. 10 is a partial view in perspective and in transverse cross-section showing one embodiment of the foundation raft in the case of the dam of FIG. 7;

FIGS. 11 to 16 illustrate in sequence a number of successive operations involved in a method of construction according to a second embodiment contemplated by the invention; in these figures, FIGS. 14 to 16 are each broken away at the center and the two portions thus defined have been brought together whilst FIGS. 12, 14 and 15 are drawn to a larger scale;

FIG. 17 is a diagrammatic top view showing the two sheet-pile walls;

FIG. 18 is a plan view of a raft element which forms part of a device in accordance with a second embodiment of the invention and which is employed in the construction of a dam of the movable shutter type;

FIG. 19 is a plan view on a larger scale showing the upstream portion of said raft element, the top plate having been partially broken away;

FIGS. 20 and 21 are vertical sectional views of said raft element taken respectively along lines XX—XX and XXI—XXI of FIG. 9;

FIG. 22 is a partial left-hand view of the object of FIG. 19;

FIG. 23 is a downstream view in elevation and in transverse cross-section showing the raft element at the top upstream end thereof;

FIG. 24 is a left-hand view of the object of FIG. 23 and taken in cross-section along line XXIV—XXIV of said figure;

FIG. 25 shows diagrammatically the contact between the upstream portion of the raft element and the upstream waling;

FIGS. 26 and 27 are views in elevation and in longitudinal cross-section showing the raft element at the top downstream extremity, these views being taken along two separate planes;

FIG. 28 is a top view of the object of FIG. 26;

FIG. 29 is a top view showing a dam of the movable shutter type which is constructed in accordance with the second embodiment of the invention;

FIG. 30 is a left-hand view of the object of FIG. 29.

There will first be described a number of embodiments of the method which is contemplated by the invention followed by devices which are particularly well suited to the application of the method.

Referring now to FIG. 1 of the accompanying drawings, there can be seen at 1 the underwater bed or bottom which has previously been levelled by dredger and on which it is desired to build a dam of any type (shutter-type dam or a dam comprising a movable gate consisting of a single unit). The level of the water is shown at 2. The water tends to flow in the direction of the arrow F, thus defining the upstream end and downstream end. The initial operation consists in driving along a first bottom line L₁ on the upstream side a continuous wall 3 of steel sheet-piling which projects to a predetermined height *h* from the bottom. The wall 3 extends along the full intended length of the dam between two lateral supports (abutments or piers which are erected in the river bed).

Two rockfill banks or stringers are placed behind the wall 3, the first stringer 4 being applied against the wall 3 along the first bottom line L₁ and the second stringer 5 being placed further downstream along a second bottom line L₂ so that a trough A or space is formed between the stringers 4 and 5, the second stringer 5 being intended to constitute a row of projecting elements. The upstream stringer 4 is levelled down to the summit of the sheetpiling whilst the height of the stringer 5 is slightly smaller. There are shown in the upstream stringer 4 the heads of inclined piles 6 which have previously been driven and the presence of which is useful for ensuring subsequent resistance against sliding of the dam structure as a whole.

Protective plastic sheets 7 and 8 are placed over the two oppositely-facing rockfill banks in order to prevent any deposition of sand between the stringer elements. As thus arranged, the channel may be abandoned if the water level is not favorable and operations may be resumed at any suitable time without any attendant danger of filling of the spaces between the rockfill banks with sand since this would be liable to hinder any subsequent injection of Colgrout.

As shown in FIG. 2, the trough which is formed between the stringers 4 and 5 is then filled with alluvial or like filling material 9 (especially sand), the level of which corresponds substantially to that of the stringer 5. Said alluvial material does not penetrate into the stringers 4 and 5 by reason of the protective sheets 7 and 8.

One or a number of prefabricated foundation rafts or structures 11 are brought either by floating or land transportation by means of lifting equipment and placed in position above the foundation mass which has thus been prepared. If the distance between two piers (not shown) is substantial, it may in fact prove an advantage to replace the single element 11 by a plurality of juxtaposed elements.

The foundation raft 11, a certain number of structural characteristics of which will be described hereinafter, essentially comprises a body 12 having a top surface which carries the components 13 for attaching and/or pivotally mounting the sluice-gate elements, said body being extended by an upstream nose 14 and by a downstream nose 15.

If the foundation raft 11 is brought into position by floating, said raft is of hollow construction with pluggable orifices for filling with water, orifices for evacuation of air and passages for injecting air or grout of the type known as Colgrout (cement-base colloidal mortar which is not miscible with water).

The raft 11 is immersed and lowered to a depth P₂ which is smaller than the final depth P₁ and secured to the sheet-pile wall 3 while allowing the water to drive out the air which is present within the interior of the raft. Steps are taken at the time of immersion to ensure that the upstream nose 14 engages with the edge of the sheet-pile wall 3. Since the distance between the stringers 4 and 5 is slightly smaller than the distance between the noses 14 and 15, said nose 15 extends slightly beyond the stringer 5. The raft 11 is slightly inclined towards the downstream end (as shown in FIG. 3). A sheet of flexible plastic material 16 is unrolled along the nose 15 and fixed in position by depositing alluvial material 17. Thereupon, the foundation raft 11 can be left in position for any desired period of time.

Colgrout g), grout C is then injected through passages such as 18, 19 which extend through the raft 11, thus piercing the sheets 7 and 8 at suitable locations (as shown by the arrow 9 the intended function of said sheets being to prevent the Colgrout from spreading beyond the stringers).

After setting of the Colgrout which has transformed the stringers 4 and 5 into Colcrete without bonding the raft 11 by virtue of the sheets 7 and 8, holes 21, 22 are bored in said stringers through the raft 11 and use is accordingly made, for example, of the above-mentioned passages 18 and 19 (as shown in FIG. 4). Anchoring rods 23, 24 are anchored in said holes and provided with adjustable abutment members 25, 26 which can be fixed at predetermined levels on the upper extremities 23a, 24a of the rods with as high a degree of accuracy as may be necessary. These operations can be carried out at low water or underwater by making use of graduated rules with the aid of frogmen or helmet divers.

In the example herein described, it is intended that the foundation raft 11 should be finally placed in the horizontal position so that the abutment member 26 should be located at the same level as the abutment member 25 and above the raft 11.

As a result of injection of compressed air into the raft 11, the water contained therein is driven out, with the result that said raft rises along the anchoring rods 23, 24 while pivoting about the front portion thereof, the nose 14 being applied against the sheet-pile wall 3.

When the raft 11 is applied against the abutment members 25, 26 which are fixed on the anchoring rods, said members are displaced if necessary (especially by screwing or unscrewing) in order to ensure a degree of horizontality of the raft 11 which is as perfect as may be desired at the requisite depth P_1 and Colgrout is again injected into the free space 27 which is located beneath the underface of said raft in order to fill all the spaces and to bond said raft to the Colcrete masses formed by the stringers 4 and 5 and to the mass 9. Finally, all the internal spaces of the raft are filled with Colgrout.

It then only remains to mount the stationary or movable shutter element or elements by supporting these latter on the raft 11 and taking advantage if necessary although not essentially of a low-water period (as shown in FIG. 5).

The method contemplated by the invention offers in particular the following advantages:

while operations are in progress, the river bed is wholly clear and is not obstructed by any cofferdam

reduction in volume of masonry

very substantial reduction in cost price

possibility of interrupting operations several times.

In FIGS. 6 and 7, there is shown a dam which is equipped with rocking shutters 31 or so-called Aubert shutters which are constructed by means of the method according to the invention. Two or more piers 32 are built in the river bed and support a runway (only the substructure 33 of which is illustrated) along which the carriage for operating the shutters 31 is intended to move. The raft 11 has been placed in position with a small clearance 34 (as shown in FIG. 7) which is subsequently filled within the entire space located between the piers 32.

In the case of a dam having a single large gate element which extends from one pier to the other (as shown in FIG. 8), the foundation raft 11a is advantageously attached to the subjacent ground by means of anchoring rods 35 or by means of piles which are driven into the ground and added to the anchoring means mentioned above. In this embodiment, the top face of the raft 11a is flat and the gate system which is not shown and consists of a vertical lift shutter, taintor gate or like system can be constructed or repaired under dry conditions by virtue of the protection afforded by movable cofferdams as shown in FIG. 8. Said cofferdams are constituted by two stacks 36 and 37 of girders, the extremities of which are engaged in grooves 38 and 39 formed in the opposite walls of the piers 32.

A mode of connection between the nose 14 of the raft 11 and the sheet-pile wall 3 is shown in FIG. 9. A wale 41 is placed over said wall and in turn covered by a plate 42 of lead or neoprene which serves to take up any play of the raft 11 at the time of position-setting as has been explained in the foregoing.

There will now be described with reference to FIGS. 7 and 10 certain arrangements of a sinkable floating raft for carrying out the method, said raft being fitted with movable shutters.

The foundation raft 11 is constructed in the same manner as a pontoon by means of two plates 51, 52 which are braced by vertical longitudinal-stiffening beams 53 located at right angles to the direction F of the current and by transverse-stiffening beams 54

located parallel to the current which provide cross-bracing and divide the raft 11 into a certain number of juxtaposed compartments 55a, 55b and so forth, said compartments being leak-tight or capable of communicating with each other through pluggable openings.

For the sake of simplification, the beams 54 have not been shown in FIG. 10. The beams 54 are preferably disposed along the axes of the shutters 31, said axes being represented in FIG. 7 by lines X—X.

As shown in FIG. 10, passages 18, 19 consisting of tubes 56 welded to the top plate 51 and bottom plate 52 which constitutes the raft are provided at intervals corresponding to alternate shutters and in the vicinity of the beams 54, for example. Said passages serve to inject sand or Colgrout beneath the raft and then, when the two rockfill stringers have been transformed into Colcrete, to bore holes in which the anchoring rods 23, 24 are sealed.

An anchoring rod of this type is illustrated in chain-dotted lines. The upper extremity 23a of the rod which is anchored beneath the raft is threaded, thereby permitting the possibility of adjusting the level of the bearing nut and of securing said rod at the proper height. The tubes 56 are located at intervals corresponding to alternate shutters, for example, whilst provision can be made for additional tubes which serve simply as vents.

The foundation raft 11 is also provided with a number of orifices such as the orifice 57 for taking pressure measurements. The orifice 57 is closed by a plug 58 and provided with a nipple 59 for connecting a pipe 61 terminating in a pressure gage 62 which is housed, for example, within a recess 63 of the pier 32.

By removing the plug 58, it is possible by means of a crow-bar to pierce the layer which bonds the raft to the subjacent sand and thus to permit subsequent measurement of the pressure within the sand when the structure is in service.

A knowledge of the pressures which exist beneath the foundation raft permits accurate determination of the safety coefficient of resistance to sliding of the entire raft structure towards the downstream end when the sluice-gate system is closed and when the water level upstream of this latter is thus substantially higher than the downstream level.

The sill-bearing unit 64 (FIG. 10) of the shutters 31 is mounted directly above the longitudinal beams 53 and adapted to accommodate the rounded sill 65. Said sill is stiffened by means of cheeks 66 which serve as bearing-brackets for a hinged tie-bar 67 of the shutter 31, said tie-bar being secured by means of a detachable pin 68.

The guides 69 for adjusting the angle of tilt of the shutters are mounted on the downstream side and directly above the transverse beam 54. The shoes 71 of the back-struts or props 72 of said shutters are applied against said guides. The shutters 31 can be mounted on the foundation raft 11 without difficulty after immersion of this latter but the raft can also be fitted with the shutters at the outset.

In the case of very large gates or shutters, the top surface of the raft can be completely flat and this latter thus constitutes a kind of apron. In the event that the raft is of the pontoon type, this latter can be provided with water-tight compartments in which the ballasting is remote-controlled.

The method which is illustrated in FIGS. 11 to 16 must permit positioning of a prefabricated foundation raft on a submerged bottom 100. It will be assumed that the bottom referred-to is the bed of a watercourse since this will permit reference to the concept of an upstream side (left-hand side of the accompanying figures), a downstream side (right-hand side), a longitudinal direction (direction of flow) and a transverse direction (across the width of the bed).

As shown in FIG. 11, the initial operation consists in driving two vertical sheet-pile walls 102 and 103 in parallel vertical planes elevated on a first line L'_1 and a second line L'_2 of the bottom while endeavoring to maintain constant spacing with the greatest possible degree of accuracy. As shown in FIG. 12, there is then carried out a horizontal waling 104 or 105 of the upstream sheet-pile wall 102 and of the downstream wall 103 at the upper extremities 102a or 103a of these latter while taking the necessary steps to ensure that the wales 104 and 105 are as horizontal as possible and that the intended level of these latter is carefully maintained. As shown in FIG. 13, the space E shown in FIG. 11 and formed between the two sheet-pile walls 102 and 103 is then packed with a fill 106 such as alluvial material up to a level which is slightly lower than the intended level of the bottom plane of the foundation raft after sinking of this latter.

A prefabricated foundation raft or raft element or prefabricated structure 107 is then brought by flotation and positioned above the two sheet-pile walls in order that the upstream edge e should be located slightly further upstream than in the final position. As shown in FIG. 14, the raft is then sunk so as to rest on the wales 104 and 105 of the two sheet-pile walls, the precision anticipated in regard to the maintenance of level of bearing surfaces being within a tolerance range of the order of a few centimeters. The raft is then shifted towards the downstream end until the bearing members 108 provided on its upstream edge come into contact with the upstream wale 108 as shown in FIG. 15 and the raft is then anchored to the two wales 104 and 105 by means of suitable fixing means 109 and 110. All the spaces remaining within the raft and beneath this latter are then filled by injecting mortar 111 which is not miscible with water through the raft as shown in FIG. 16. Finally, the sluice-gate system of the dam is placed in position under the conditions laid down in the first embodiment. The raft is thus fixed in the desired stationary position P'.

In this initial embodiment, inclined piles were provided as an optional feature. Should it be deemed useful to retain this feature in the second embodiment under consideration, said piles 112 are driven before placing the raft in position while taking steps to leave a free space between the pile heads 112a and the pile wall as shown especially in FIG. 11; under these conditions, the space thus formed will be filled with injected grout which will form a coating around the pile; the greater bulk of said mass ensures more effective transmission of stresses than would have been possible by means of the pile alone.

FIG. 17 clearly shows that the two sheet-pile walls can be maintained in parallel relation at the time of driving of the walls since the alignment is defined from the river bank by a surveyor who is equipped with a

sighting telescope but it can be seen that each wall describes a sinusoid of very small amplitude.

The raft element which is illustrated in FIGS. 18 to 22 comprises an apron 113 beneath which is fixed a floating unit 114, the apron being intended to rest on the wales of the two sheet-pile walls whilst the floating unit is intended to be housed between these latter and above the alluvial fill as shown in FIGS. 14 and 16.

As will become apparent hereinafter, the foundation raft of a dam is constituted by juxtaposed elements which are welded to each other. An element as shown in FIGS. 18 to 22 corresponding in this example to only one shutter (it could also correspond to a plurality of shutters).

An apron element is constituted by a flat horizontal steel plate 113 of substantial length compared with its width, said plate being endowed with rigidity on the one hand by downward bending of the two transfer edges 115 of said plate as shown in FIG. 14 and on the other hand by means of three longitudinal channel-iron members 116; said channel-iron members are welded beneath the plate in one case along the edge in order to provide a joint with the adjacent element whilst the two other members are spaced along the width but preferably concentrated in the central portion of the plate at the point corresponding to the location of the welded guide 117 which serves to support the foot of the shutter prop and therefore accommodates stresses of considerable magnitude; provision is also made for four other transverse channel-iron members 118 which are welded underneath the plate beneath the longitudinal members 116; two of said members 118 are located in the vicinity of the upstream and downstream portions of the sill 119 of the shutter which accommodates the stresses transmitted by the prop and transfers these latter to the raft; the two other transverse members are located in the vicinity of the upstream and downstream ends of the plate 113 at the extremities of the members 116.

The floating unit 114 comprises a certain number of caissons which are all open at the bottom portions thereof. Said caissons are constituted by the plate 113 and by vertical longitudinal and transverse partition walls which are attached to the underface of said plate. Provision is also made for four longitudinal partition walls 120 and 122 which are fixed along the whole length of the four members 116 and for four transverse partition walls 123 which are attached along the four channel-iron members 118 but only on each side of the two central members 116. Three separate caissons are thus defined on each of the two edges of the element whilst the central portion is not partitioned. Transverse and longitudinal angle-iron members 124 and 125 respectively serve as stiffeners for the lower portion of the different vertical plates.

In order to ensure flotation of the raft element, compressed air is delivered beneath the raft plate 113 into the six caissons while preferably leaving the central compartment filled with water, thereby ensuring good stability both in the transverse and longitudinal directions. Taking into account the weight distribution of the element, it will be necessary to regulate the air pressures within the different compartments in order to ensure progressive downward movement of the element without any danger of dislocation; it is therefore

recommended practice to provide a pressure gage on each compartment.

The two sheet-pile walls which are provided with walings onto which said raft element is lowered are vertical steel sheet-pilings 126 having a cross-section in the shape of a trapezium without the large base and juxtaposed with alternately oriented concave portions, the crest level being lower than the water level. Each sheet-pile wall is joined at the top and along the upstream face in the case of the upstream wall or along the downstream face in the case of the downstream wall by means of a horizontal channel-iron member 127 which serves as a wale and the top flange of which is located at a higher level than that of all the sheet piles.

As shown in FIGS. 23 and 24, the wale is attached to each sheet pile at the point of convexity which is directed towards the wale by means of high-tensile bolts 128 which pass through holes 129 formed at a constant height in the wale and holes 130, one of which is formed in each sheet pile; said holes are intended to be punched in the workshop since on-site work is costly and are provided in the form of slots which are horizontal on the wale and vertical on the sheet piles; the first holes mentioned serve to compensate for driving variations in transverse inclination and the second holes serve to compensate for height variations. The slots 130 formed in the sheet piles are each covered by a pressure washer 130a of the dished type which is placed on the side remote from the wale. However, it is possible to contemplate on-site formation of the holes which can in that case be round holes inasmuch as the exact position of fixation of each sheet pile can be determined in situ.

In order to lower the raft element onto the wales of the sheet-pile walls, said element is correctly positioned by means of angle-iron pieces constituting the bearing member 108 which are provided as shown in FIG. 14 and welded to the underface of the plate 113 in proximity to the upstream flanged edge 115 of this latter in order that the vertical flanges of said bearing members should materialize a plane which is parallel to said edge; during shifting of the raft as contemplated in FIG. 14, said bearing members 108 will be brought against the vertical flange of a continuous angle-iron member 131 which is welded to the underface of the upstream wale 127 and projects to a slight extent with respect to this latter. A possible alternative to the use of bearing members 108 consists in accurately fixing the position in plan of the raft element when this latter is still located at a distance of a few centimeters above its final sinking level in order that the hooked bolts should be correctly placed relative to the waling of the sheet-pile wall, this operation being carried out by means of rods which are inserted in some of the holes of the plate. Assuming that the element is located slightly too far upstream, said rods would accordingly be brought in contact with the angle-iron member 131 which is welded to the wale by displacing the element over a short distance. Since the waling and therefore the angle-iron member 131 is not wholly rectilinear as a result of errors in spacing at the time of driving, only a certain number of the bearing members 108 come into contact with the angle-iron member as shown in FIG. 25 whilst the other bearing members remain in more or less correct alignment.

At the upstream end, the longitudinal stiffeners 116 can extend beneath the plate 113 up to the point at which the sheet-pile wall is intended to be placed in the final position; in order that the shifting operation may be carried out without incident, this nevertheless makes it necessary to ensure that the extremities of the stiffeners correspond in fact to the concave portions of the sheet-pile wall. It is for this reason that, in order to remove this requirement of coincidence, said extremities are preferably stopped at a sufficient distance from the upstream flanged edge 115; the portion of the plate 113 which is thus freed is nevertheless stiffened by means of angle-iron members 132 which are welded to the top face of said plate in the planes of the stiffeners 116.

In order to fix the raft element on the sheet-pile walls, provision is also made on the downstream wale 127 for an angle-iron member 133 which is identical with the member 131 and fixed in the same manner but on the downstream side. The plate 113 is accordingly secured at both the upstream and downstream ends and as near as possible to the flanged edges 115 by means of hooked bolts 134, the stems of which traverse the plate through perfectly aligned round holes 135 on the upstream side and longitudinal slots 136 on the downstream side; the hooks of said bolts which are directed downwards are intended to engage beneath the vertical flanges of the angle-iron members 131 and 133 and the upwardly directed threaded ends of said hooks are fitted with nuts 137 which are tightened against the plate, there being interposed between said nuts and said plate on the upstream side pressure-distributing washers 137a and on the downstream side longitudinal sealing plates 138 which are intended to cover the slots 136 and pierced by two holes, one hole being intended for the hooked bolt and the other hole being intended to receive a conical pin 139 which is driven-in with a hammer in order to prevent the plate 138 from rotating while the nut is being tightened.

The slots 136 are intended to take into account any errors in spacing between the two sheet-pile walls; the bolts pass through the slots at the downstream end at a point corresponding to the greatest distance between the wall 103 and the wall 102 and at the upstream end at a point corresponding to the shortest distance between said walls, as shown respectively in FIGS. 26 and 27; the length of the slots is such as to correspond to the maximum spacing error which can be expected and which is of the order of one decimeter. Also in order to take spacing errors into account, the stiffeners 116 are stopped at the downstream ends at a distance from the flanged edge which is greater than on the upstream side by at least the length of the slots.

In order to apply the wales against each other in end-to-end relation, each wale extremity is provided with two holes and the two abutting wales are clamped between two fish-plates 140 by means of bolts 141 which are passed through the assembly as shown in FIGS. 19 and 22.

From FIGS. 19 and 20, it is apparent that the sill 119 consists of a transverse plate which extends over the entire width of the raft element and is bent in such a manner as to have a flat bottom portion 142 which is inclined downwards towards the upstream side and a top portion 143 having a cross-section which describes

approximately one-quarter of a circle, the concave portion of which is directed downwards and towards the downstream side. At the level of the two stiffeners 116, provision is made beneath said plate and above the plate 113 for two pairs of longitudinal vertical cheeks 144, the edges of which are also inclined downwards in the downstream direction at the bottom portions thereof. Each pair of cheeks is separated by a transverse plate 145 having a horizontal portion at the level which separates the top and bottom portions of the plate 119 and a portion which follows the downwardly inclined downstream edge of the cheeks 144. All said plates are welded to each other and the assembly is bolted to the raft plate directly above the central channel-iron members 118. A shutter 146 which is not illustrated in FIGS. 19 and 20 but appears in FIGS. 29 and 30 is mounted on said sill; the upright members of the hinged tie-bar of said shutter are pivotally mounted on the cheeks 144, the top portions of which are provided for this purpose with bores 147. Finally, recesses 148 and 149 are formed on the one hand in the horizontal portion of the plate 145 of the sill and on the other hand in the plate 113 of the raft element beneath the position occupied by the sill; filling of the element beneath the plate which covers this latter and the interior of the sill with concrete such as concrete of the type designated by the trade name "Prepakt" or the like could thus be wholly continuous.

For the construction of a complete dam which covers a river bed between two piers 150 as shown by way of example in FIGS. 29 and 30, the foundation raft is constituted by a plurality of juxtaposed elements 107. The sluiceway system for which the raft is intended to serve as a support is constituted by a plurality of metallic shutters 146, the width of each shutter being intended to correspond to the width of one raft element. The conditions of assembly of the raft elements depend on local circumstances: for example, two adjacent elements can be floated side by side, for example, and joined together temporarily before being assembled by welding (the plate 113 of one element is accordingly mounted astride the lateral stiffener 116 of the adjacent element as shown in FIG. 21); during assembly, special attention must be given to alignment of the holes 135 of the upstream end of the raft. The sills and guides are fixed on the raft prior to sinking of this latter.

If one of the edges of the raft is located at a distance from the pier, there is welded to the nearest plate 113 a horizontal plate 151 which extends right up to the face of the pier; in order to ensure full retention, the vertical plane swept by the extreme edge of the nearest shutter is materialized by a vertical plate 152 which covers at least all the stationary positions of the shutters and which is joined to the pier face by means of a concrete packing.

The invention could also be applied to structures other than dams of the movable shutter type and could accordingly extend by way of example to a dam having a movable gate formed in one piece.

Moreover, the second sheet-pile wall could be also considered as useful in the first embodiment since it also provides enhanced safety in the event of downstream undermining. Provision would in that case be made for two rockfill stringers placed against two

sheet-pile walls, namely along said walls and against the opposite faces of these latter.

What I claim is:

1. In a method for the construction of an immersed structure on a bottom and entailing underwater positioning of a prefabricated structure on a prepared foundation mass without preliminary unwatering of said bottom between a first line of said bottom and a second line of said bottom which is substantially parallel to said first line, the improvement wherein a first sheet-pile wall is driven on said first line, a row of projecting elements is laid on said second line, said first sheet-pile wall and said row of projecting elements being such as to delimit a space which is packed with filling material, said first sheet-pile wall, said row of projecting elements and said space which is packed with said filling material being such as to form part of said foundation mass which is prepared without preliminary unwatering, a prefabricated foundation raft forming part of said prefabricated structure is immersed and lowered onto said foundation mass, said prefabricated raft being supported on the one hand on said first sheet-pile wall and on the other hand on said row of projecting elements, grout is injected into at least part of said foundation mass and said prefabricated raft is anchored relative to said foundation mass.

2. A method according to claim 1, wherein said grout is injected into said foundation mass through said raft itself.

3. A method according to claim 1, wherein said laying of said row of projecting elements consists in placing a first rockfill stringer on said second line and a second rockfill stringer is placed on said bottom against said first sheet-pile wall and along said wall.

4. A method according to claim 3, wherein said grout is injected beneath said prefabricated raft and into said first and second rockfill stringers.

5. A method according to claim 3, wherein said prefabricated raft is anchored by passing rods through said raft and the upper extremity of each rod is provided with an abutment member, and said anchoring rods are sealed in said first and second rockfill stringers.

6. A method according to claim 5, wherein said prefabricated raft is intended to be located at a first depth in the final position of construction and said underwater positioning of said prefabricated raft on said foundation mass comprises the steps of lowering said prefabricated raft to a second depth which is greater than said first depth, placing said abutment members on said anchoring rods in position such that if said prefabricated raft is applied against said abutment members which are placed in said positions said raft is located substantially at said first depth, causing the upward return of said prefabricated raft until said raft is applied against said abutment members so as to free a space beneath said prefabricated raft and filling said free space with grout.

7. A method according to claim 6 wherein, after upward return of said prefabricated raft until said raft is applied against said abutment members, said abutment members are displaced along said anchoring rods until said prefabricated raft is located exactly at said first depth.

8. A method according to claim 6, wherein said prefabricated raft has an upstream portion and a downstream portion and said underwater positioning of said raft at said second depth is carried out in such a manner as to ensure that said prefabricated raft is placed in an inclined position in which said downstream portion is lower than said upstream portion and said upward return of the raft is carried out by injection of compressed air until said raft is applied against said abutment members which are displaced along said anchoring rods after said upward return of the prefabricated raft until said raft is located exactly at said first depth, thereby providing a free space beneath said prefabricated raft and said free space is filled with grout.

9. A method according to claim 8, wherein, prior to said upward return of the raft, said upstream portion of the raft is anchored to said first sheet-pile wall along an anchoring zone and said upward return of the raft is carried out with pivotal motion of said prefabricated raft with respect to said anchoring zone.

10. A method according to claim 1, wherein said laying of said row of projecting elements consists in driving along said second line a second sheet-pile wall and said anchoring of said prefabricated raft is carried out on said first and second sheet-pile walls.

11. A method according to claim 10, wherein each of said first and second sheet-pile walls has an upper extremity and is provided prior to said underwater positioning of the raft with a horizontal waling of each of said first and second sheet-pile walls at said upper extremities and said prefabricated raft is anchored to said walings.

12. A method according to claim 11, wherein said prefabricated raft is intended to be placed in a predetermined position in the final position of construction, said underwater positioning of the raft being carried out with a slight relative horizontal displacement in the direction at right angles to said first and second sheet-pile walls with respect to said position so that said prefabricated raft has one extremity located on the side corresponding to said relative displacement, said displacement being carried out on the side corresponding to one of the first and second sheet-pile walls, said prefabricated raft is brought into said position by moving said extremity which is located on the side corresponding to the relative displacement until said raft is applied against said waling of one of said first and second sheet-pile walls towards which the relative displacement is carried out.

13. A sinkable raft for use in the construction of a structure immersed on a foundation mass prepared without preliminary unwatering, said raft having a hooking nose for engaging a sheet-pile wall, said raft also having a plurality of through passages for injecting grout and for the insertion of anchoring rods, tapping means carried by said raft for taking pressure measurements within said foundation mass, said raft having an upstream extremity with means for securement to a

first sheet-pile wall and a downstream extremity with means for securement to a second sheet-pile wall, said raft having over the whole of its surface a substantially horizontal plate having two edges which correspond each to one of said first and second sheet-pile walls, and means for fixing said edges on substantially horizontal walings on said sheet-pile walls comprising hooked bolts engageable over substantially vertical flanges of said walings.

14. A raft according to claim 13, one of said edges of said plate having passages for said bolts, said passages comprising slots at right angles to said first and second sheet-pile walls.

15. A raft according to claim 13, said raft comprising at least one flotation caisson which is fixed under said horizontal plate.

16. A raft according to claim 15, and stiffeners beneath said horizontal plate, said stiffeners being oriented in two substantially horizontal directions respectively perpendicular to said first and second sheet-pile walls and parallel to said walls, said stiffeners which are oriented at right angles to said sheet-pile walls stopping at a distance from said edges of said plate in stopping zones, said stopping zones delimiting with said edges of said plate a remaining portion of said plate which has a top face and said plate carrying on said top face of said remaining portion a number of additional stiffeners.

17. A raft according to claim 15, said flotation caisson comprising substantially vertical plates having a bottom level and delimiting a plurality of juxtaposed compartments in said two horizontal directions, and stiffeners at said bottom level of said vertical plates.

18. A raft according to claim 13 for the construction of a dam of the rocking-shutter type, said raft having passages for injecting grout, said passages extending on the one hand through a shutter sill which is fixed on said horizontal plate and on the other hand in said plate beneath said sill.

19. A device comprising a plurality of sinkable rafts for the construction of a dam of the rocking-shutter type between two piers, each said raft having a hooking nose for engaging a sheet-pile wall, each said raft also having a plurality of through passages for injecting grout and for the insertion of anchoring rods, and tapping means carried by each said raft for taking pressure measurements within said foundation mass, each said raft having an upstream extremity with means for securement to a first sheet-pile wall and a downstream extremity with means for securement to a second sheet-pile wall, one of said rafts being disposed at a distance from one of said piers and comprising a substantially horizontal connecting plate which covers the gap between said raft and said adjacent pier, said one raft also comprising a substantially vertical sealing plate which is mounted above said connecting plate in a substantially vertical plane along said raft edge which is nearest said pier over the whole space swept by said shutters.

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