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(54) **Submarine construction for tsunami and flooding protection, for fish farming, and for protection of buildings in the sea**

(57) Gabion walls (4,30) built into the sea as tsunami barriers, extending at least 50m up to 4km below sea level. Vertical walls extending above sea level, preferably protected with hanging triangular structures as surge stoppers (41), with stabilization landward (18), to replace conventional dikes and levees and to save land areas. Vertical walls of fences (31, 32) extending above sea level, which are circular and filled with rocks, surround pillars to protect off-shore platforms, windpower plants, bridge pillars and other submarine structures.

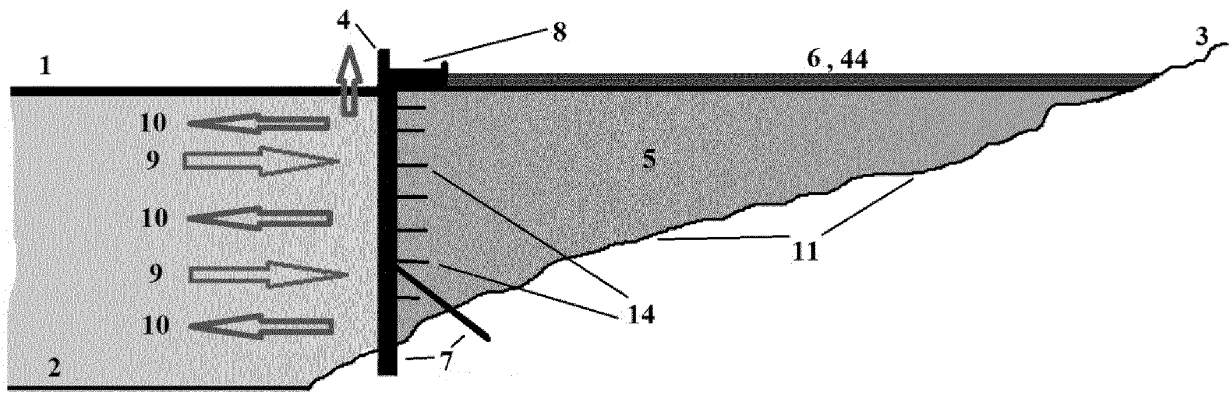

Fig. 1

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Description

Field of invention

[0001] The present invention relates to the protection against Tsunami waves, against high sea waves, against flooding from storms, and also presents a novel technology for submarine architecture. The seawater reservoirs separated by the Tsunami barriers can be used for fish/tuna and seafood production and partially can be filled up to gain new land.

Cross-References to Related Applications

[0002] The entire disclosure of the following patent applications is incorporated herein by reference:

- PCT/IB2012/054543 filed on September 03, 2012 in the name of Hans SCHEEL
- PCT/IB2012/057458 filed on December 19, 2012 in the name of Hans SCHEEL
- Japan Patent Application No. 2013-23131 filed on February 8, 2013 (English version) and March 26, 2013 (Japanese translation) in the name of Hans J. SCHEEL

Background

[0003] Many coastal areas have the risk of high Tsunami sea waves which may cause the death of coastal inhabitants and huge damage to cities and industrial and cultural buildings and infrastructure. The largest recent Tsunami catastrophes have been 2004 Sumatra and 8 countries with 231'000, and 11.3.2011 Tohoku, Japan with >19'000 casualties and the Fukushima catastrophe. According to Bryant (2008) many large cities like Tokyo and New York and hundreds of km coastline are threatened with future Tsunami, especially in case of a Mega-Tsunami.

[0004] Tsunami waves are formed from sudden vertical displacements of the ocean bottom related to earthquakes, from land slides, from underwater vulcanic eruptions, or the waves are initiated from falling meteorites or from man-made explosions. Their initial wavelength is much longer than the typical depth of the ocean of 4km, the initial amplitude (height of the wave) is limited to a few tens of centimeters and rarely exceeds 1m, and the travelling speed is about 700 km/h.

[0005] The catastrophic Tsunami sea waves of typically 4 to 10 m height are formed when the gravitation waves reach the decreasing water depth at the coast. The long wavelength of the pressure wave is then reduced and compensated by increased amplitude, or in other words the kinetic energy of the pressure wave is transformed to potential energy by increasing the height of the Tsunami sea wave. Wave heights up to 38 m and higher are formed when the coast has a funnel-shaped structure which concentrates the energy. Observations of such extreme waves have been observed and confirmed by computer simulations.

[0006] Expensive Tsunami warning systems have been developed which often are too late for coastal inhabitants and which anyhow cannot prevent huge material, housing and infrastructure damages. In USA the National Oceanic and Atmosphere Administration NOAA is coordinating Tsunami warning and protection efforts, and has an archive of Tsunami conferences and workshops.

[0007] Annunziato et al.(2012) have discussed the improvements of the Global Disasters Alerts and Coordination System (GDACS) with the analysis of the Tohoku earthquake and Tsunami of 11 March 2011, and Kawai et al.(2012) reported on measurements using GPS buoys and other gauges after the 2011 Tohoku earthquake.

[0008] In the area of the North Atlantic, global warming may firstly cause a destabilization of gas hydrates on the ocean ground, and secondly a basic weight shift caused by melting ice sheets, and these may cause massive landslides and earthquakes which then generate pressure waves (Berndt et al. 2009). In other areas shock waves can be triggered by underwater landslides (Hornbach et al. 2007, 2008) whereby the topography of the seafloor plays a role.

Earlier proposals to reduce the Tsunami risks include the following:

[0009]

- Researchers at Iowa State University, at the request of the UN Food and Agriculture Organization (FAO), have proposed coastal forests as 'Bioshield' (Science Daily 16.4.2007).
- The former Japanese Prime Minister Naoto Kan in 2011 had proposed that the reconstruction of villages is allowed only at higher land levels, which means for fishermen a longer route to the port.
- Japanese patent application JP 7113219 discloses several breakwaters, which successively reduce the energy of the "overtopping" Tsunami wave so that it is hoped that the dam on the land will hold up the residual Tsunami wave. The efficiency of this structure is depending on the sea bottom slope in front of the first breakwater; on the height of the first breakwater versus the height from the bottom of the sea and the distance from the coastline; on the height of the submerged breakwater versus the sealevel at the arrival of the tsunami shock wave; and on the slope and height of the bottom structure, the reduction of the Tsunami pressure wave is small. The main effect of the structure disclosed in JP 7113219 is to fight against the Tsunami wave and its energy whereby it is hoped that the breakwater dam on the land will stop the reduced Tsunami wave and will survive the Tsunami wave. Disadvantage is that the sea of the harbour is sectioned so that its use is limited. One should either preserve the harbour region,

or transform it to very valuable land or to fishing farms as discussed below.

- Chinese patent application CN 1804224 discloses the use of a large water bag filled with composite material 50 to 80 m from the coast and a second floating bag partially filled with water and partially with gas, both fixed to the seabed. This may reduce the Tsunami wave somewhat, but would not prevent the formation of the catastrophic Tsunami wave, see discussion of Fig.2 below.
- British patent 987271 proposes tread-riser/terrace structures, extending along the coast, which are 3 to 5 metres high and claim that "since the riser is well submerged only small waves can pass over it" (?). "The deepest riser should be spaced far enough from the shore to permit navigation of small boats along the coast". Only a very minor effect of this invention on breaking sea waves can be expected, and the effect on Tsunami waves will be negligible.
- US patent 6050745 proposes wave breaker steps at the base or toe of breakwaters like bulkheads and seawalls in order to prevent undercutting. This invention does not conflict with our invention, but such terraced structures at the base of our Tsunami barriers may have a certain local protective effect on the barrier's lifetime.

[0010] Breakwaters and dams are widely applied but give only marginal protection against high Tsunami waves as shown in Kamaishi, Japan. The Ports and Harbours Bureau of Japan Ministry of Land, Infrastructure, Transport and Tourism has proposed a combination of "Submerged Breakwater, Artificial Beach Nourishment and Gentle Slope-type levee" as an "integrated shore protection system" which was realized at the Kamaishi Port, Iwate Prefecture, Japan: From 1978 to March 2009 (in 31 years!) this Tsunami Protection breakwater has been built at cost of 1.5 billion USD and was celebrated on Monday September 27, 2010 as worldwide deepest breakwater for the Guinness Book of World Records. However, with its length of 1960 m and depth of 63 m it could not protect the harbour and city of Kamaishi, so that the March 2011 Earthquake and Tsunami killed about 1000 people and partially destroyed the breakwater. Similarly, the fishing village Taro north of Kamaishi was destroyed with 100 fatalities, although population believed in their double sea walls. The journalist Norimitsu Onishi was critical in New York Times March 31, 2011 of Japan's use of seawalls.

By knowledge of the present invention and realization of the novel technology, these catastrophs could have been prevented, because the coastal structure of Kamaishi Bay causes a funnel effect and thus further increases the Tsunami waves which for 63 m water depth have already been several meters high (see Fig.2 below). Instead of repairing this breakwater the Tsunami Barrier described below of 200 m height should be built.

[0011] A general description of Tsunamis has been published by Bryant (2008), and the propagation of a Tsunami in the ocean and its interaction with the coast by Levin and Nosov (2009). In a PhD thesis A. Strusinska (2010, 2011) simulated the development of Tsunami sea waves using the Coulwave programme of Lynett (2002; Lynett and Liu 2002) and reviewed the protection attempts trying to reduce the effect of the already formed Tsunami sea waves. Murty et al. (2006) analyzed in depth the Indian Ocean Tsunami 2004 and could explain the catastrophic effects in eight countries effected.

Deeply immersed Tsunami barrier are needed which reflect most of the pressure waves.

Deep-sea construction using conventional concrete technology is in principle possible in view of behavior studies of concrete in marine environment (Al-Amoudi 2002; Mehta 1991; Stark 1995). However the challenge increases significantly with increasing depth of the sea. There is therefore a need for a novel approach for barrier construction and to find a solution to eliminate or at least reduce the Tsunami risks, to prevent the formation of harmful Tsunami waves when the pressure waves reach reduced water depth at the coast.

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[0012]

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[0013] **Please note:** In most Figures the open sea is on the left side, except for Figures 2 and 11 the sea is on the right side.

General description of the Invention

[0014] The principle of the invention is shown with a cross section in Fig.1 with the pressure waves (9) from earthquakes or landslides reflected (10) at the stable vertical wall and with release of some pressure energy by upward motion of water in front of the barrier. The vertical submerged wall is facing reduced shear flow and no impact from high sea waves, whereas the vertical concrete wall on top of the Tsunami barrier (4), and the vertical front of the dike or levee are protected above sea level by the invented hanging inclined/triangular structures ("surge stoppers" or "wave deflectors") which can be replaced.

[0015] The present invention provides vertical stable walls at modest costs and at relatively high production rates by a novel submarine architecture technology. To this effect, it relates to a protection barrier as defined in the claims. At the same time, by filling the gap (5) between the Tsunami barrier and the shore (3), new land can be gained the value of which could compensate all or at least a large fraction of the construction costs.

[0016] The gap encloses huge seawater reservoirs which can alternatively be used for large-scale farming for tuna and other fish or seafood, or which can be filled up with rocks, gravel, debbries, sand and covered by a soil layer to gain new land.

[0017] Fig. 1 represents a schematic cross section of a vertical barrier (e.g. a Tsunami barrier) reflecting the gravitational waves from earthquakes or landslides. In this idealized case the vertical barrier extends to the bottom of the ocean (2), typically 4 km, and thus totally reflects the Tsunami pressure wave. However, if one considers the variation of the wave velocity and the related amplitude development during the movement towards the coast, that is during experiencing reduced water depth, one realizes that the high Tsunami sea waves are developing only at water depth less than about 500 m or even 200 m. Their velocity c is given in a first approximation (Levin and Nosov 2009 Ch.1.1 and Ch.5.1) by

$$c = \sqrt{(\mathrm{g \ x \ h})}$$

with g gravitation and h the water depth, and the product of the amplitude or wave height A squared times velocity c is constant:

$$A^2 \ \mathrm{x} \ c \ = \ \mathbf{constant.}$$

[0018] These relations are shown in the combined Fig. 2 with the parameters c = 713 km/h at a water depth of 4000 m for two typical examples of wave heights of I= 0.3 m and II= 1.0 m at h = - 4000 m . The lower part of the figure shows the velocity c as function of water height h with an idealized picture of the slope of the continental shelf the slope of which is increasing near the "break". The upper part of the figure shows the wave height A as a function of water depth h. The Tsunami wave heights are increasing slightly until water depth is less than about 500 m, and only at water depth around 200 m the wave heights increase above 2 m for initial wave heights of 0.3 m and 1.0 m at 4 km depth. The consequence is that the Tsunami barrier can be erected at water depth between 50 m to 500 m which normally is still on the continental shelf. With a Tsunami barrier up to 3 m above sea level at high tide and a top concrete wall extending 6 to 8 m above the top of the Tsunami barrier, depending on highest expected waves from Tsunami and storms, the combined submerged Tsunami barrier and the top concrete wall with the surge stopper should be effective to protect the coast. In contrast to prior-art breakwaters the present invention prevents formation of high Tsunami waves whereas prior art breakwaters try to reduce the catastrophic effect of high Tsunami waves near the coast after these waves have been formed. The prominent example is the Kamaishi breakwater discussed above.

[0019] Also it should be considered that deviations from the straight coastline like bays or fjords may lead to a funnel effect which can multiply the heights of Tsunami waves reaching the coast. This was described in case of the March 11, 2011 Tohoku Tsunami for the Bay of Kamaishi. Thus the new Tsunami barrier is remote from the shore so that the funnel effect of bays and fjords is prevented.

[0020] In exceptional localities the initial offshore Tsunami wave may reach a few meters so that geophysicists and seismologists should estimate the maximum expected vertical displacement of the ocean floor. This then indicates the preferred position and depth of the Tsunami barrier and the height of the top Tsunami barrier plus concrete wall. If this scientific estimation is not yet possible, the historical data should give an idea about the maximum expected Tsunami waves at the ocean depth of 4 km. Furthermore, the Tsunami wave velocity c given above is effected by the relief of the ocean bottom, especially at shallow water, and its direction is influenced by mid-oceanic ridges acting as wave guides. Also friction at the seaground becomes relevant when the Tsunami pressure waves reach shallow waters which with the present invention is prevented.

Construction of Tsunami barriers

[0021] In a preferred embodiment, net structures, preferably in steel, like fences (12) are lowered into the sea by assistance of weights (for instance of hanging anchors (14)) together with a sequence of steel anchors which in horizontal position fix the fence in vertical position after rocks have been deposited. Fig. 3 shows a schematic cross section of a pontoon for inserting the fence from a roll (13).

[0022] A variety of high-strength steel fences are produced by Geobrugg AG, Romanshorn, Switzerland (Geobrugg 2012). This company has shown that their special fences have a combination of high strength and elasticity so that they can stop falling rocks and thus protect mountain roads and railroads. Typical fence designs are shown in Fig. 4.a to 4.c. The weights of square meter fence are 0.65 , 1.3 , and between 4.5 and 10 kg/m^2 for 4.a, 4.b and 4.c, respectively, depending on wire thickness and steel net structure. All steel components for the present invention are produced from saltwater-corrosion-resistant steel, for example chromium- and molybdenum-containing low-carbon-steels with European numbers 1.4429 (ASTM 316LN), 1.4462, 1.4404 or 1.4571 (V4A). All metal alloys should have the same or similar composition in order to prevent electrolytic reactions and corrosion at the connecting points. Furthermore, long-time corrosion may be prevented by coating all metal parts with special corrosion-resistant paint or by an elastic polymer, or by covering the steel fence structure seaward by concrete, or by embedding the steel fence.

[0023] The specific fence structure and the thickness of the wires and of the steel ropes have to match the strength and elasticity requirements depending on the total height of the fence-rock structure, the size and shape of rocks, the number and structure of horizontal anchors, and the risk of earthquakes. Also a variation of the type of fence along the height or along the length of the barrier may fulfil local requirements. A stabilization of fence-rock barriers can be achieved by crossing steel ropes in front of the steel fence, the ropes being fixed to the fence.

[0024] The overall surface topology and the local roughness of the fence-rock structure determine the reflectivity of the pressure waves. This can be adjusted by zigzag or ondulated structures of the Tsunami barriers, whereas the rough fence-rock surface can be flattened for instance by concrete or by an elastic polymer in order to enhance reflectivity.

[0025] These reflected gravitational waves may harm opposite coasts on the other side of the ocean or islands. A slight downward inclination from vertical should be applied to reflect the pressure wave for example at the north-east coast of Honshu/Japan down into the deep Japan trench, or the inclination should be slightly upward to transform the kinetic energy of the pressure wave into potential energy by formation of dispersed sea waves moving away from the coast.

Single-Fence Technology

[0026] When the lowest fence and the lowest anchors have reached the desired position on the sea-ground they are fixed there to the ground by anchors, by steel bars (7 in figures 1, 6, 7, 11, 12, 14, 18, 22, 23) and/or by concrete foundations. Before this procedure the sea-ground is cleaned from sand and soft material by high-pressure water jets arriving through pipes or produced locally by submerged compressors or fans, and steep slopes may be removed by excavation. Now rocks of specified size and sharp edges are inserted from sea level on the landward side so that they cover and fix the horizontal anchors and thus also the steel fence which is thus held in more or less vertical position, as shown in Figs. 6, 7, 11. The first-deposited rocks are washed before so that the clear view allows to control the process by strong illumination and video cameras, by divers, by diving bells, or by Remotely Operated Vehicles ROV (Elwood et al.2004, Tarmey and Hallyburton 2004), or by Autonomous Underwater Vehicles AUV (Bingham et al. 2002, WHOI 2012).

[0027] For a Tsunami protection the steel fence extends preferably 200 m down to the sea floor. If the fence is delivered in rolls of 100 m length, this requires 2 rolls. The upper end of the first roll is on the pontoon or ship connected to the lower end of the second roll to be inserted into the sea. The delivery ships or pontoons are arranged in a horizontal line following the depth level of the sea or following the coast-line, and this work requires relatively quiet sea. An alternative approach could be used to produce the steel fences directly on the pontoon with steel wires to be supplied, or to deliver the fence rolls over supply roads or over long (temporary) bridges from the coast, or over permanent bridges which later are used to establish "Swimming Land Surface", or would be used as "supply roads", see below.

[0028] The horizontal connection of the steel fences can be achieved above sea level by means of steel ropes or clamps or alternatively their side holders can glide down along steel beams. This is arranged on the ships or pontoons, but it is a critical procedure. It would be easier when, together with the fences, a chain of steel beams (16) shown in Fig. 5 is inserted seaward just in front of two neighboring fences, and these steel beams have side-arms (17) corresponding to the openings of the fences respectively on the size of the inserted rocks. These side-arms not only prevent the rocks to fall seaside, but they also contain spines in landward direction which enter openings of the steel fences on both sides and thus connect two parallel horizontal fences: this allows large distance tolerances between parallel horizontal fences. The vertical steel beams are also equipped with horizontal anchors (18) of 2 m to 20 m length to fix the steel fences in vertical position by subsequent rock deposition, so that the anchors need not to be fixed directly to the steel fences. These steel beams with side-arms, spines and anchors are shown in Fig. 5.a, 5.b and 5.c. The spines can be replaced by automatic clamps which lock to the fence upon contact, when mechanically or magnetically pulled in landward direction.

[0029] The space between the Tsunami barrier and the coast can be filled (5) with rocks, rubble, etc. and soil on top (6), in order to gain new land as shown in Fig. 1. However, this requires huge quantities of material to be transported.

[0030] A simple terrace structure with terraces (29) requires less rock fill material, still allows to gain new land (6), and therefore may be preferred on certain coasts, see Fig. 6. This would also become important in case the epicenter of the earthquake would be near to the coast and thus between two steps of the terrace.

[0031] At certain coasts the total height of the Tsunami barrier will be reduced when the Tsunami barrier has to end for example 5 m to 30 m below sea level at low tide for navigation or for preserving beaches and harbours, as shown with the gap (28) in Fig. 7. In this case a fraction of the Tsunami wave and also high sea waves from storms may reach the coast which therefore requires a protection line with high stable walls or buildings behind the beach or the harbour. For the terrace barriers and for the Tsunami barrier with a gap, the amplitude of the Tsunami waves derived from the reflection and transmission coefficients depend on the depth ratio of barrier and ocean depth, as discussed by Levin and Nosov 2009 in Ch. 5.1.

[0032] The rocks will settle with time, especially assisted by man-made vibrations (explosions) or by vibrations caused by earthquakes, typically 2000 per year in Japan. A novel technology to enhance the density of the fence-rock barrier consists of a heavy metal weight (58) hanging from a ship/pontoon (34): the weight is pulled upwards and then loosened (60) so that it bangs against the fence-rock barrier causing strong vibrations. The schematic figure 8 shows this procedure and also the possibility to adjust the height of the weight (59). Furthermore the rocks are fixed by gravel and/or sand which are inserted periodically when the rock layer has grown to a layer of say 2m to 5m. In order to prevent major movements of the rocks, more or less horizontal steel fences can be deposited about every 20 m to 50 m rock thickness.

[0033] An alternative vertical protection can be established directly at the coast by excavation to achieve a deep vertical wall (42) (Fig. 9) to reflect the Tsunami shock waves, and the excavated rock material (43) used to stabilize the nearby fence barrier or basket barrier.

Double-Fence Technology

[0034] An alternative to minimize the amount of rock fill material uses two parallel fences (31,32), closed at the bottom, with horizontal separation distances between the fences between 1 m and more than 20 m established by distance holders (33). This double-fence basket is lowered from two pontoons (34, 35) into the sea to the desired depth and filled with washed rocks (36) and gravel, see Fig. 10. The thickness of these double-fence walls is determined by the required stability, with Tsunami shock waves requiring a thickness of at least 3 m. The height should extend 2 m to 4 m beyond sea level at high tide, see Fig. 11.. These double-fence rock structures of many km length are flexible at the bottom and therefore can match the local topology of the sea-ground after this has been cleaned by high-pressure water jets as described before. Alternatively, first a single fence with anchors is introduced in order to match to the seafloor topology followed by connected double-fence basket. These baskets are closed at their horizontal ends. For stabization against strongest shock waves rocks are deposited on the coastal side of the double-fence barrier as shown in Fig.11, and the barrier, in this case of 5 m thickness, is further stabilized by horizontal anchors as discussed above. Also shown is the concrete wall (30) above sea level with hanging triangular structure (41) (surge stopper) which will prevent overtopping of sea waves and reduce the splashing over of the lifted sea water from reflected Tsunami pressure waves. The steel bar (22) extending from the concrete wall is used both for later heightening of the concrete wall and for hanging the surge stopper (41). The service road (8) along the concrete wall allows to transport the surge-stopper (wave deflector) and to control the Tsunami barrier.

[0035] The submarine constructions offer the possibility to produce electric energy by using the inward and outward currents due to the tide and due to water transport from the wind. A flexible Tsunami barrier shown in Fig. 12 reflects some of the pressure wave. Another part of the wave energy is lost by frothing and by deflecting the heavy wing of the flexible barrier. The residual Tsunami pressure will continue towards the coast and must be stopped by a solid barrier (30) near the coast as shown in Fig. 12. Waterwheels and / or turbines produce the electric energy. These can also be installed at the weak points of the tsunami barrier, below the bridges, where also significant water flow is expected as discussed below. In the case of 20 m wide Double-fence Tsunami barriers the top concrete wall is stabilized by rocks on the coast side, between concrete wall and service road as shown in Fig. 13. Very long double-fence barriers have a certain elasticity to withstand medium-level earthquakes. However, for very strong earthquakes they are too rigid and thus may break. In order to prevent such severe damages, which are difficult to repair, it is foreseen to establish weak points where the barrier is interrupted by 2 m to 5 m and where a concrete bridge (47) passes over the gap as shown in Fig. 14. This bridge is then easily repaired after a severe earthquake. The gap below the bridge is filled with a high-strength steel fence (46) and with a fine-grid fence to prevent escape of fish. At the same time the fence allows exchange of seawater and equilibration of tidal height differences which gives the possibility of energy "production" by turbines or waterwheels which regularly turn with inward and outward flow (not shown in a figure). Instead of fixed fences the gap can be provided with gates (not shown in the figures), one with a fence and one with plate doors or sliding gates for complete locking.

[0036] The double-fence baskets filled with rocks can also be pre-fabricated on the coast and then inserted and connected in the sea.

Protection of submarine buildings

[0037] Double-fence barriers may also be used in annular tube structures for offshore platforms, for pillars of bridges, and for wind-power plants (not shown with figures). Double-wall tube structures with rocks inserted between the inner and the outer tube extending above sea level protect the central pillars of offshore platforms or of wind-power plants from Tsunami pressure waves, Tsunami sea waves, and from high sea-waves caused by storms. The shape of the structure/pillar to be protected can be circular, but it can have any other cross section like square, oval, rectangular, triangular etc.

[0038] In such a double-tube structure the outer and the inner fences are connected and thus closed at the bottom. The construction is done in analogy to the Tsunami barrier construction. The first double-fence unit to be inserted into the sea has the largest circumference (normally at the bottom of the pillar). The inner fence is kept apart from the outer fence by distance holders or by small vertical walls . This fence unit is then connected on the supply pontoon /ship (by using clamps, steel ropes or other means) to the next double-fence section to be inserted, and so on. This annular structure is arranged when the platform pillar or the stand of the wind-power plant have only partially been raised. However, also existing pillars for instance of bridges can be protected by producing the double-fence-rock structure on site. This alternative method to produce the double-fence protection tube is to wind long fences from rolls around the pillar in a screw fashion, with distance holders to keep the two fences apart, and continuously connect the lower section with the upper section by clamps, steel ropes, or other means.

[0039] Cleaned rocks can be inserted from top after the lowest double-fence section has reached the sea floor.

[0040] The height of the protection tube and the distance between inner and outer fence, and thus the outer diameter and the mass including the filled-in rocks, depends on the expected highest sea waves. In most cases the horizontal distance between the fences will be in the range 1 m to 5 m, and a height of 2 m to 10 m above sea level at high tide is recommended. The inner fence will be fixed to the pillar, or a buffer is installed around the pillar to prevent mechanical damage from the steel net and the rocks of which many corners may be outside the inner fence surface. Alternatively, the inner fence can be omitted and the outer fence directly connected by distance holders to the pillar.

[0041] The upper rim of the outer fence should have warning signals or signal lights for navigation (the same as for the Tsunami barriers ending below sea level).

Top Concrete Wall with Surge Stopper

a) Application to Tsunami Barriers

[0042] A vertical wall of concrete (30) of at least 5m height should be built on top of the Tsunami fence barriers to protect the coast and the harbour from partial Tsunami waves and from high sea waves caused by storms, see Figs. 11, 13, 16, 17, and to protect the new land (see Fig.1). For highest resistance to seawater attack, the concrete of Portland cement should have a low water content and be impermeable; a content of 5% to 10% of tricalcium aluminate has been proposed (Zacarias). The thickness of this concrete wall should be at least 1 m at the sea and at least 50 cm along rivers. The top of this concrete wall may have steel beams (22) so that later heightening may be facilitated and that inclined structures with inclination towards sea (surge stoppers (41)) may be hung onto these concrete walls to reduce overthrothing, reduce erosion of the concrete wall, and allowing replacement. Two such inclined concrete structures are shown in Fig. 15. Fig. 15a shows a structure with a straight inclination (19) only corresponding to a tilting angle, and Fig. 15b shows a second triangular structure with a straight inclination (19) and an upper curvature (20). Fig. 16 shows the triangular structure of Fig. 15a mounted onto the top of the concrete wall (30), and Fig. 17 shows the triangular structure from Fig. 15b mounted onto a basic concrete wall (30). The optimum tilting angle can be determined theoretically, experimentally, and by computer simulation. However, for practical reasons and weight limitation, the chosen angle is preferably between 10 degrees and 15 degrees with respect to the vertical direction. For instance, with an angle of 11.3 degrees and a length of 5 m downward, a concrete structure of 2 m length would have a weight of about 12.5 tons. These surge stoppers have to be moved on the service road (8) and lowered onto the vertical concrete wall by means of hooks (24). These triangular structures have the advantages that

a) they protect the basic vertical wall from erosion;
b) they can be replaced to change the tilting angle or for repair;
c) they can be curved outward on the upper part so that overtopping of highest waves can be minimized;
d) they can be replaced to test different construction designs and materials; and
e) they can be used again when the vertical concrete wall is heightened in future.

[0043] Concrete is used for the high compressive strength of concrete and steel for the high tensile strength of steel. The replacement possibility allows to test alternative construction materials and material combinations, for example partially fused recycled glass or composite plastic with protection steel plate, for instane the double-fence-rock structure, or to use hollow structures or wood to reduce the weight: the decision depends on timeliness, lifetime experience, and on local resources and know-how.

[0044] A heightening of the concrete walls may also be required in case the whole fence-rock structure should sink (as in the case of Kansai airport), or that the sea level is increasing from climate change, or that higher sea waves from heavy storms are expected. A service road (8) along these vertical concrete walls allows transport of the surge stoppers, repair, and access for the public, see Figs. 1, 11, 14.

b) Application to Dikes and Levees

[0045] In another embodiment the invention includes seawards oriented surge stoppers hanging on stable vertical double-fence-rock walls or concrete walls which significantly reduce the total shear and impact from the sea-waves and thus provide increased stability and lifetime. The walls, extending typically 5 to 10 m above sea level, reflect the sea waves, and the reflected waves reduce the power of the oncoming waves. The height of the walls has to be higher than the highest expected sea wave level during high tide. The seawards inclination angle of hanging triangular structures prevents or at least reduces overtopping and splashing of seawater towards the land, especially when an upper curvature is provided. The walls according to the invention offer an efficient alternative to existing dikes which are usually defined with slopes on both sides, i.e. sea side and land side, which cover large land areas and which provide in many cases insufficient stability leading to catastrophic flooding.

[0046] Basic walls according to one embodiment of the invention are schematically shown in Fig. 18. These double-fence-rock dikes with hanging surge stoppers (41) will also be effective to reduce erosion of the steep coasts in North-East England and at other steep coasts. In this embodiment, the walls (62) are perpendicular with respect to the surface of the sea (1), i.e. their inclination is 0°, and extend above sea level.

[0047] The walls are preferably built from double-fence-rock structures as described above, in this case with steel fences between vertical steel beams (7) fixed in the ground, and with anchors and rocks for fixation of the anchors and the steel-fence dike. The landward side of these steel fence dikes are stabilized by heavy masses (45) and by material of former conventional dikes as shown in Fig. 18.

[0048] Alternatively the dikes (30) are built from steel-enforced concrete (23) of at least 1 m thickness against the sea (1) and at least 50 cm thickness along the rivers inside the land as shown in Fig. 19. The highest density of steel beams is towards the sea and below the surface of the walls for maximized stability and for repair of eroded wall surfaces. These walls are deeply anchored in the sea floor or in the ground by a foundation of concrete and by means of a steel beam fixation (7) and stabilized in direction land (continental) by anchors and heavy dense masses (45) consisting of rocks, gravel, sand, rubble and soil of present dike material. The actual height along the coasts in general should be higher than the highest expected sea waves at highest tide, along the North Sea coasts it should be 8 m to 10 m, but steel rods (22, 52) and the surface morphology of the concrete wall (30) should allow to increase its height in future with increasing sea level from climate change and higher expected sea waves caused by storms.

[0049] The basic walls may be perpendicular with respect to the surface of the sea, but additional elements showing an inclined face, surge stoppers, may be hung to the basic walls, the general structure being then inclined with respect to the surface of the sea, as discussed above.

[0050] Sand and gravel may be washed towards the coast and deposited in front of the novel dikes, thereby reducing the protection-effective height. This material should be dredged, or the wall height has to be increased in order to remain fully protective.

[0051] Like the state-of-the-art dikes the walls with surge stoppers according to the invention may extend over many kilometres along the coast.

[0052] A road (8) along the top of the wall allows control, service, repair of the walls, transport of the surge stoppers, and also public traffic, for instance by bikes.

[0053] The construction and maintenance of the dikes with double-fence-rock structure (or with concrete walls) and surge stoppers according to the invention offer an improved stability and lifetime and further that much less land area is occupied (perhaps less than 50 %) compared to conventional dikes with seaward slopes and small landward slopes. New land can be gained if these new dikes are built on the seaward side of present dikes, and when these old dikes are removed or flattened.

[0054] Specific Application of Tsunami Protection in North-East Japan (see Fig. 20) with 800 km double-fence-rock Tsunami barrier, depth 200 m, width 5 m; from Shirya saki (41°26'N 141°34'22" E) to Chõshi/Inubõ zaki (35°42'05"N 141°14'23" E); requires about 400x10^6 m^2 steel fence; ca. 3x10^9 tons rocks; and 12'000 m^3 concrete for walls & roads.

Gaining new land

[0055] If new land is developed between the Tsunami barriers and the coast, for example 500 km^2 , this would correspond, at a typical price of 100 USD per m^2 Japanese land, to 50 billion USD. However, in this case huge masses of rocks, rubble and soil would have to be transported. An alternative could be to fill some part of the gap between Tsunami barrier and coast with "swimming land surface" or with land surface on pillars or on vertical steel-fence-rock structures (not shown with figures). With open gaps within the swimming land surface, algae etc. could be grown to allow fish and shrimp production. This water reservoir could be partially connected with the ocean.

Fishing Farms

[0056] A large fraction of the sea water reservoir between coastline and Tsunami barrier can be used for fishing farms, for instance for salmon, bluefin tuna, sea flounder etc. For example the North-East coast of Japan protected by 800 km Tsunami barriers shown in Fig. 20 can be divided into sections divided by supply roads (48) according to the boundaries of Prefectures. An alternative arrangement for the supply roads allows navigation from the cities and fishing harbours (51) to the open ocean as schematically shown in Fig. 21. The access to the open sea (39) is protected by a short Tsunami barrier which stops the direct move of the Tsunami wave into the harbour. The supply roads are on top of double-fence-rock barriers of 4 to 5 m thickness which have gaps with bridges (47) and fences (46), the latter with openings according to the separated fish sizes, see Fig.22.a and 22.b. These gaps can be closed by gates with fences or with completely closing gates. An alternative access for fishing boats to the open sea consists of a long steel-fence channel which is fixed to the seagound by steel bars (7) or by double-fence pillars, see the cross section in Fig. 23. A fraction of the fences (62) consists of antimicrobial copper alloys which prevent biofouling. The system closed for fish reduces the risk of contamination from the open sea, although fresh water from the ocean can be exchanged through the fences in the openings of the Tsunami barrier.

[0057] A variety of technical solutions have been discussed for the various aspects of this invention. The detailed technical realization depends on the estimation of the local Tsunami and seawave/flooding risks, on the industrial capabilities, and on the local expansion of the continental shelf which is quite different for example along Japan's coasts and along the coasts of Chile and the East and West coasts of North America.

[0058] The novel submarine architecture will be useful worldwide not only for fishing farms, but for any buildings in the sea, in lakes, and in rivers.

Deep-Sea Mining

[0059] Double-fence-rock structures of three to more than 100m height and horizontal length of five to more than 100m can be lowered to the seafloor in order to define, separate and mark specific areas and in order to mark paths and directions. The vertical fence-rock structures of one to more than 20m width are connected in order to form cages of square, round or other shapes. These separation walls also may prevent overflow of material from one specific area to another area and thus contribute to the efficiency of deep-sea mining. Furthermore, such walls can be covered by roofs (with slits for the transport ropes) of fence-rock structures or of other material in order to provide space for storage of diving bells and other equipment. The specification of the steel wires and of the fences is less stringent compared to the 200m high Tsunami barriers discussed above.

[0060] A specific application is envisaged for mining rare-earth containing mud, gravel or rocks from the 5 to 6 km deep sea-ground near Minami-Torishima Island near Japan and from other rare-earth-containing deposits.

[0061] Such double-fence-rock circles and crosses can also be used for geographic marking points in the sea.

[0062] The novel submarine architecture is useful worldwide, besides protection against Tsunami and flooding, not only for fishing farms and for deep-sea mining, but also for any buildings in the sea, in lakes and in rivers.

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Claims

1. Barrier against shock waves such as Tsunami and/or against high sea waves comprising a wall extending preferably 50 m to 500 m, maximum 4 km below sea level, a wall of which the lowest end is adapted to be fixed on the sea floor or in the ground, said wall being furthermore designed to be stabilized in a substantially vertical position and to be protected against erosion above sea level by hanging and replaceable surge stoppers or wave deflectors.

2. Barrier according to claim 1 wherein said wall is a fence with horizontal anchors stabilized landward by rocks, concrete blocks or other solid bodies, or is a double-fence wall filled with rocks.

3. Barrier according to claim 2 comprising several fences horizontally and vertically interconnected to form a large continuous surface.

4. Barrier according to claim 2 or 3 wherein said fence(s) is/are made of steel.

5. Barrier according to anyone of the previous claims 2 to 4 comprising anchors which are fixed to said fence(s) and which are held horizontally and adapted to be fixed by rocks or concrete blocks inserted from above.

6. Barrier according to anyone of the previous claims 2 to 5 comprising two substantially parallel fences connected at the bottom and thus forming a fence basket adapted to be filled by rocks and/or similar materials, and with distance holders to keep the parallel fences apart.

7. Barrier according to anyone of the previous claims 2 to 6 comprising a chain of steel beams with side-arms, spines and anchors to connect neighbouring fences and to provide the horizontal anchors to stabilize the vertical fences by rocks.

8. Barrier according to anyone of the previous claims 2 to 7 wherein said fence(s) is/are coated or filled in by a salt-water resistant elastic polymer like a natural or a synthetic rubber, poly-urethane, or by concrete.

9. Barrier according to anyone of the previous claims

where the surface topology and structure and the inclination from vertical are adjusted to reduce the harmful effect of reflected pressure waves on opposite coasts.

10. Barrier according to claim 1 of at least 1m thickness at the sea and at least 50 cm thickness along rivers, fixed by concrete foundation or by steel beams in the sea floor or in the ground and extending at least 4 m above the sea level to replace conventional dikes, with vertical steel beams for later heightening and for hanging triangular long structures, preferably of concrete or of double-fence-rock structure, of 1 m to more than 5 m horizontal length to protect the fence-rock wall or the concrete wall, and to be replaced when eroded or damaged, said barrier being stabilized landward by heavy masses to withstand sea waves from heaviest storms and recover at the same time land surface.

11. Barrier according to anyone of the previous claims 1 to 9 comprising a sequence of submerged walls in terrace (step-riser) structure.

12. Method for constructing a barrier as defined in anyone of the previous claims 1 to 9 and 11, said method comprising the following steps:

- Lowering of fence(s) with anchors into the sea by assistance of weights,
- Horizontally fixing said anchors by rocks or concrete blocks inserted from above,
- Filling the coast side of said fence with rocks and/or similar materials and a top soil layer to gain new land.

13. Method for constructing the double-fence-rock barrier comprising of the following steps:

- Simutaneous lowering of two fences with anchors and distance holders into the sea,
- filling the gap between the vertical fences with rocks or concrete blocks,
- inserting further rocks on the coastal side of the double-fence for enhanced mechanical stabilization and with the possibility to fill the gap towards the shore for gaining new land.

14. Flexible submerged barrier, hanging on bearings or on chains, can partially replace the Tsunami barrier of claims 1 to 9 and 11 and can be fitted with waterwheels or turbines using the inward and outward water flow for producing electric energy.

15. Swimming roads and land surfaces, and of roads and land surfaces on pillars or on fence-rock structures, created between barriers as defined in claims 1 to 9 or 11 and the coast, and to leave openings on top so that algae and other plants can grow and that feeding can be supplied for production of fish and other seafood.

16. Using the sea-water reservoirs between Tsunami barriers and the coast for large-scale fish farming, the reservoirs being separated by supply roads which allow access to the open sea by ships and fishing boats.

17. Use of a circular (or other closed shape) double-fence tube barrier with distance holders and filled with rocks or other solids as defined in claims 5 and 6 for protecting bridge pillars, offshore platforms, wind power plants, light-towers, Tsunami warning systems and other submarine buildings.

18. Use of a circular (or other closed shape) single outside fence which is fixed to the pillar or other submerged building to be protected, by means of distance holders for filling the gap between pillar and fence with rocks or other solid materials.

19. Under-water densification (compacting) of the fence-rock structures of claims 2 to 9 and 11 to 13 by repeated lifting a hanging heavy weight (of adjustable height) and loosen it so that it hits the fence-rock structure thereby causing vibrations.

20. Method of fabricating double-fence-rock structures of three to more than 100m height and 5m to more than 100m horizontal length to be lowered into deep sea to assist deep-sea mining, in order to define and separate specific areas, and in order to mark paths, directions and geographic points; the vertical fence-rock structures of one to more than 20m width are connected to form cages of square or any other shape and can be covered to provide storage room for diving bells and other equipment.

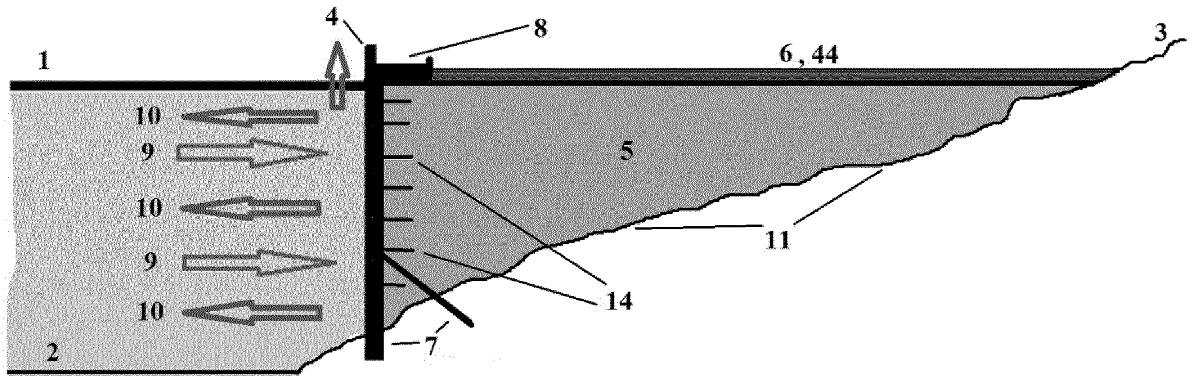
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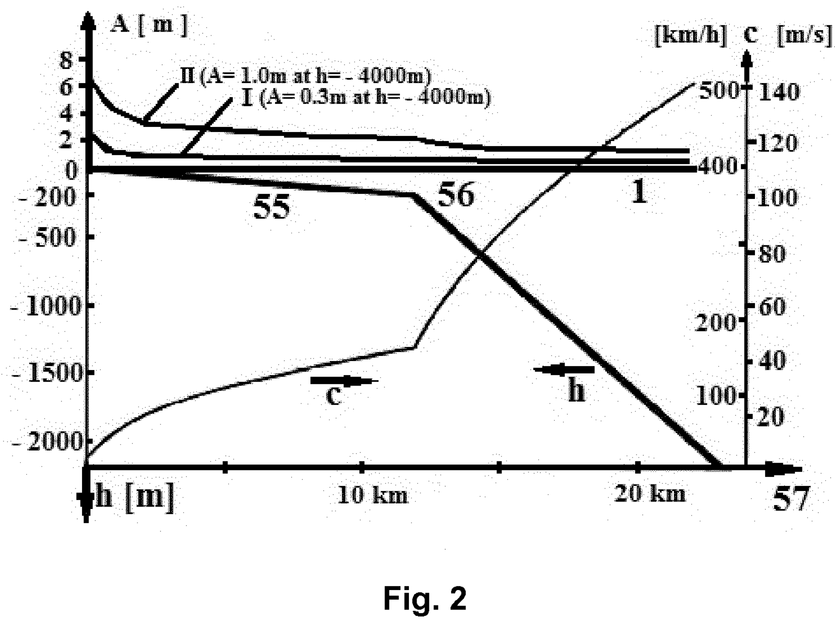
Fig. 1


A [m]
[km/h] c [m/s]
II (A= 1.0m at h= - 4000m)
I (A= 0.3m at h= - 4000m)
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4
2
0
- 200
- 500
- 1000
- 1500
- 2000
500
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200
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10 km
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57

Fig. 2

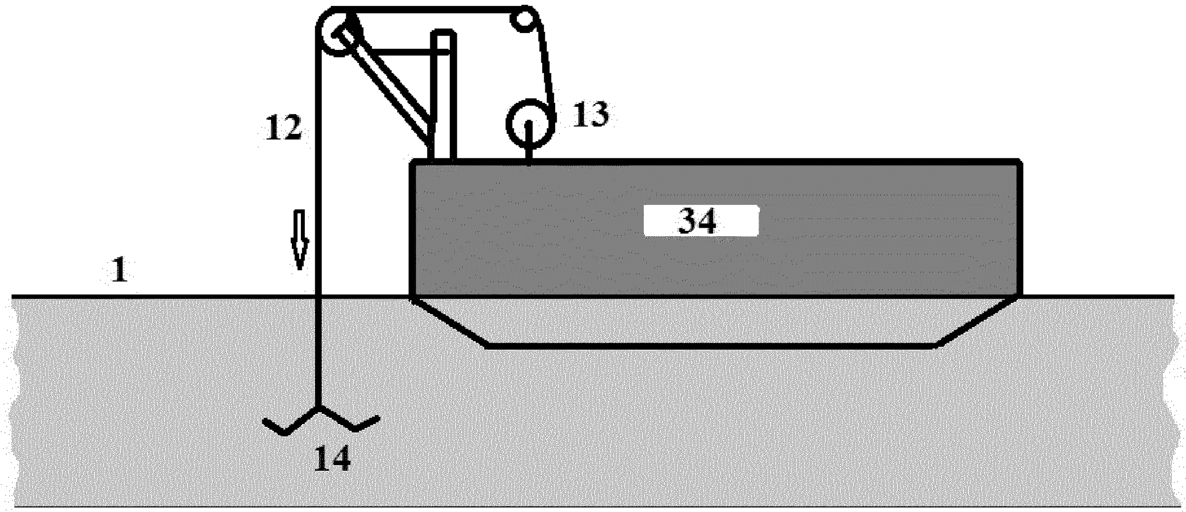
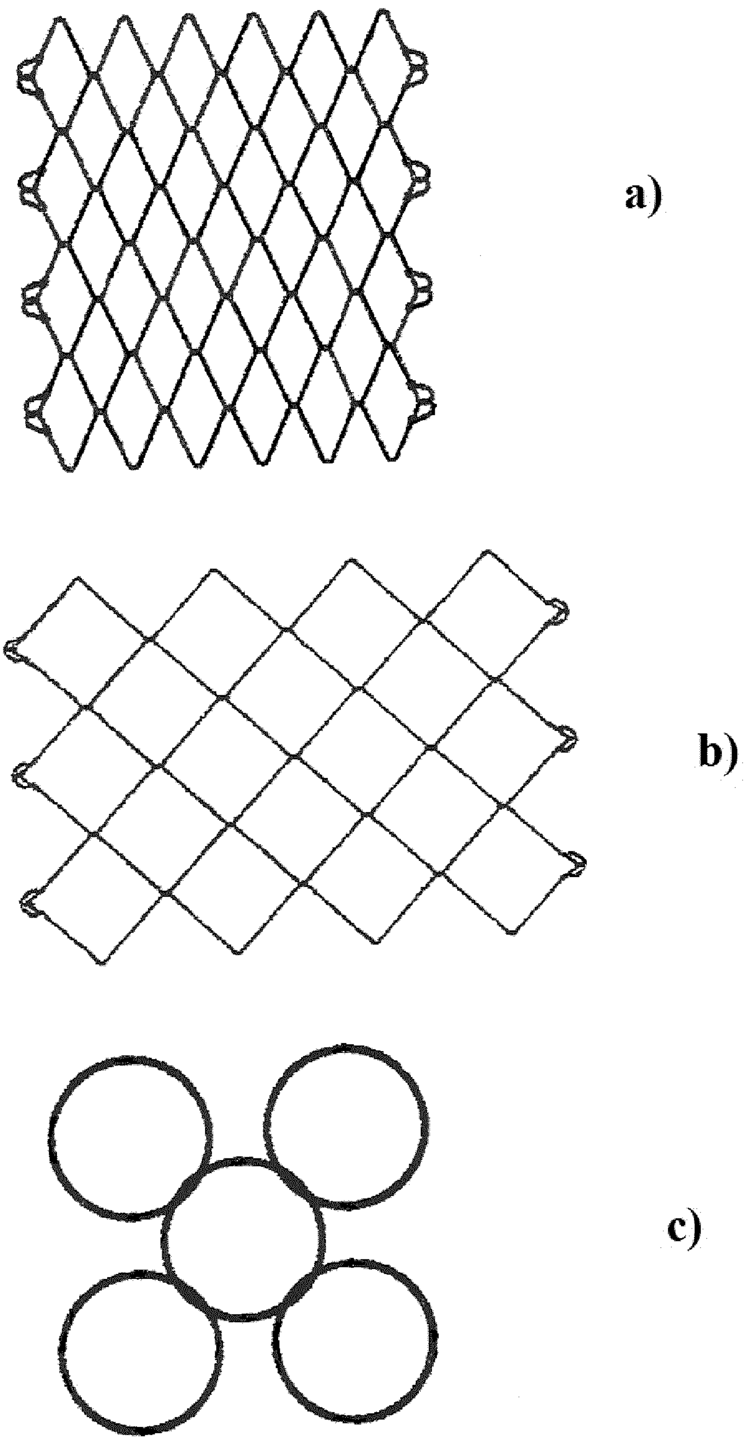


Fig. 3



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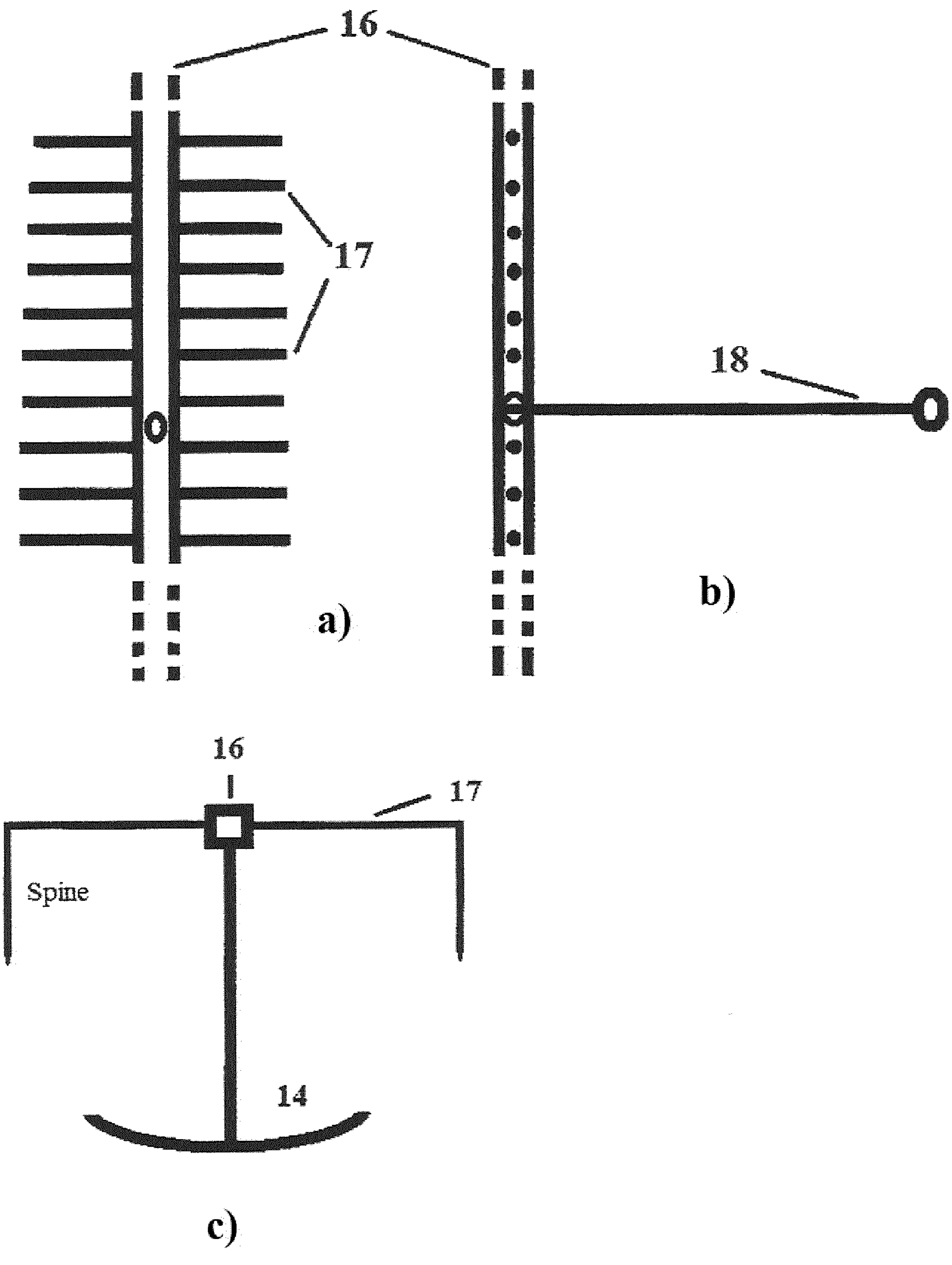

Fig. 5

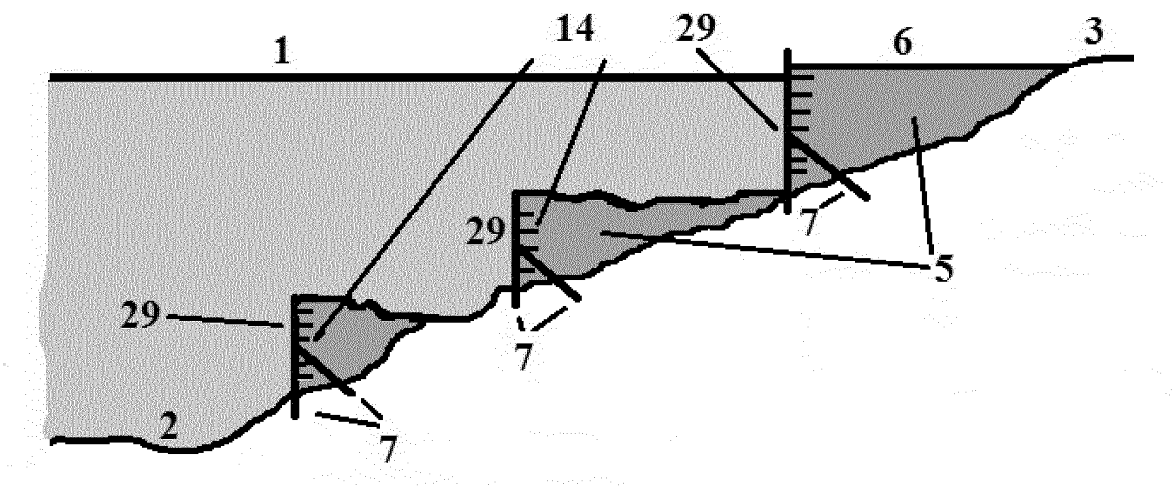

Fig. 6

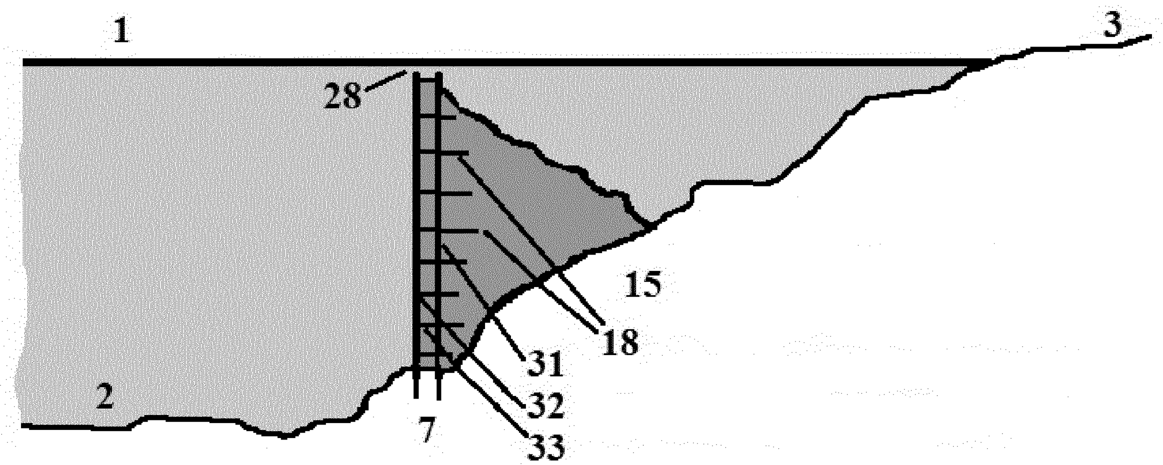

Fig. 7

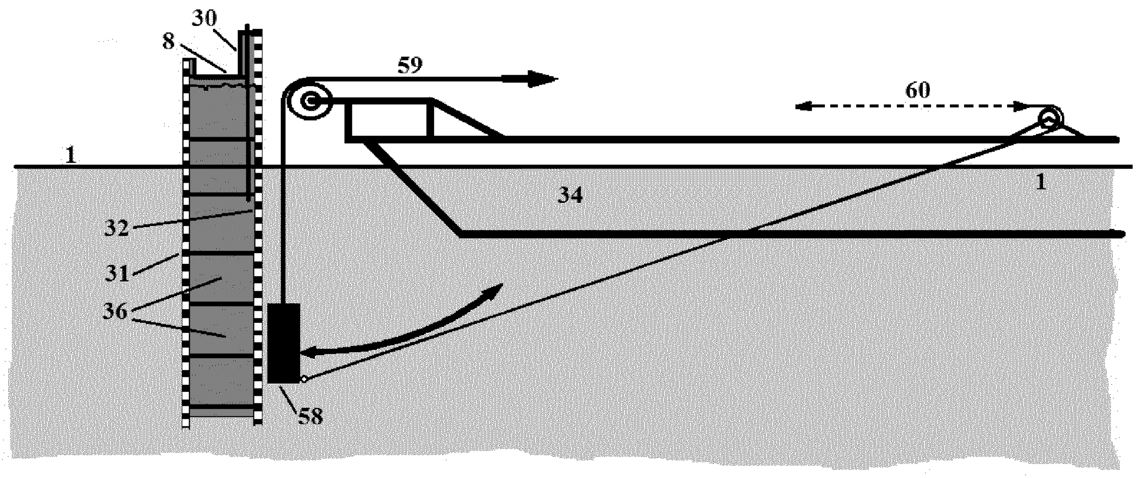

Fig. 8

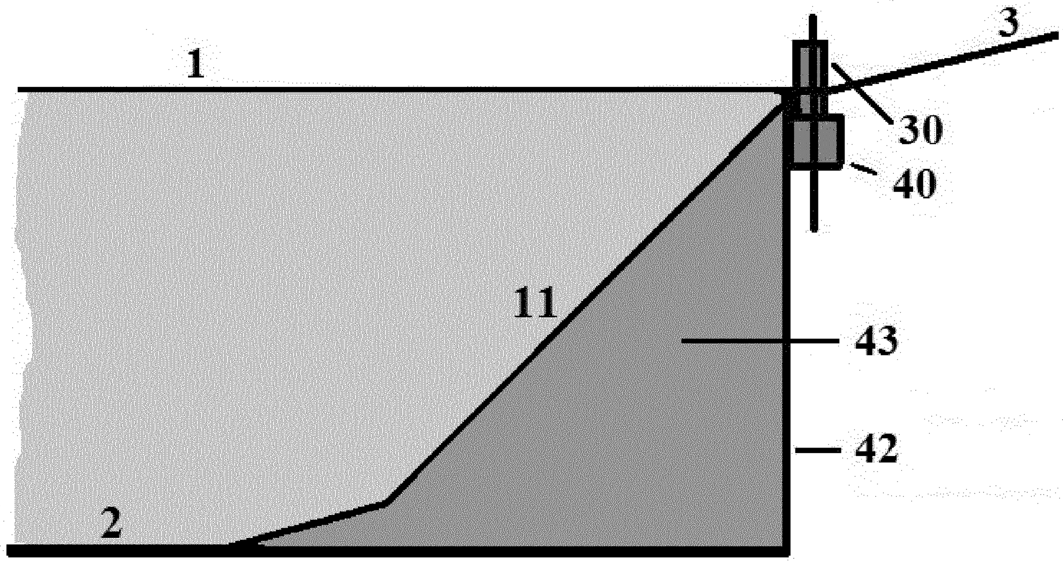

Fig. 9

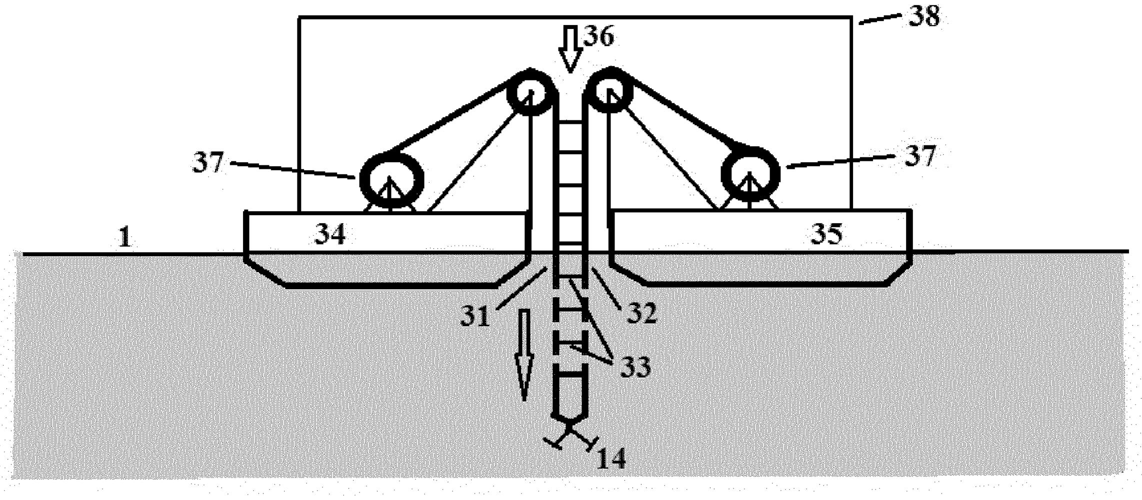
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Fig. 10

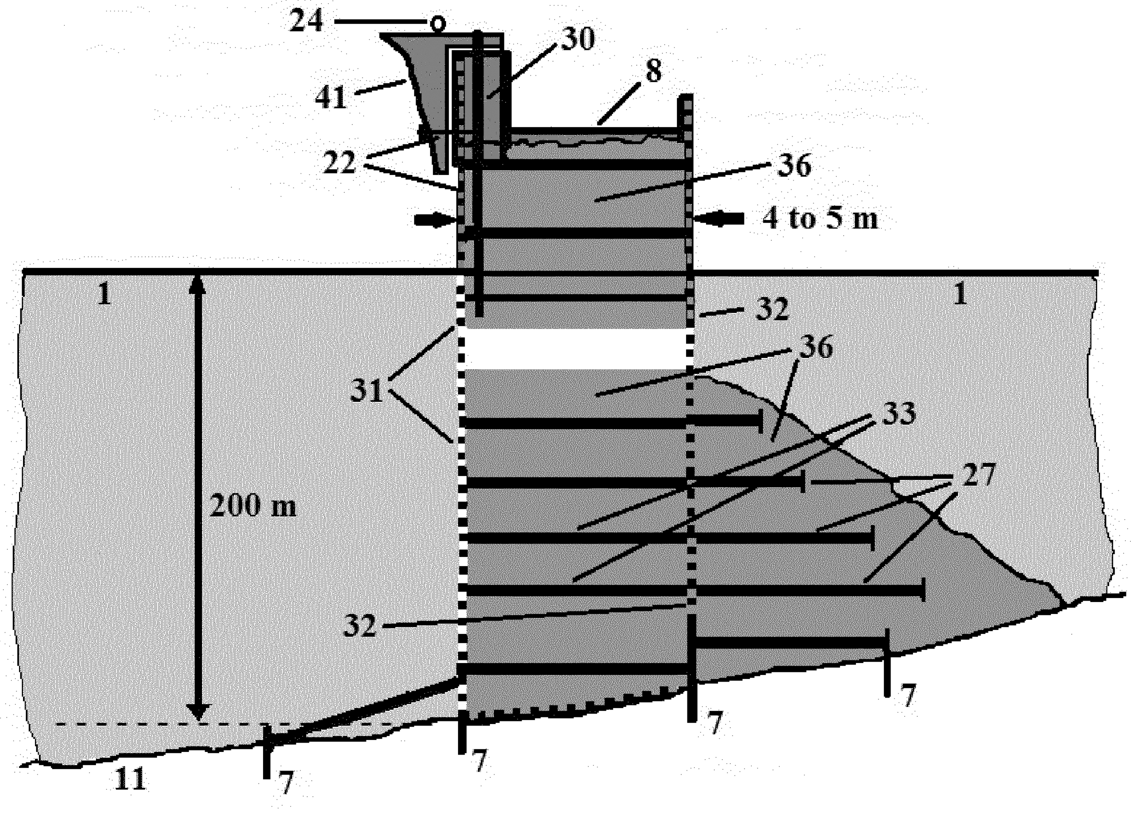
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Fig. 11

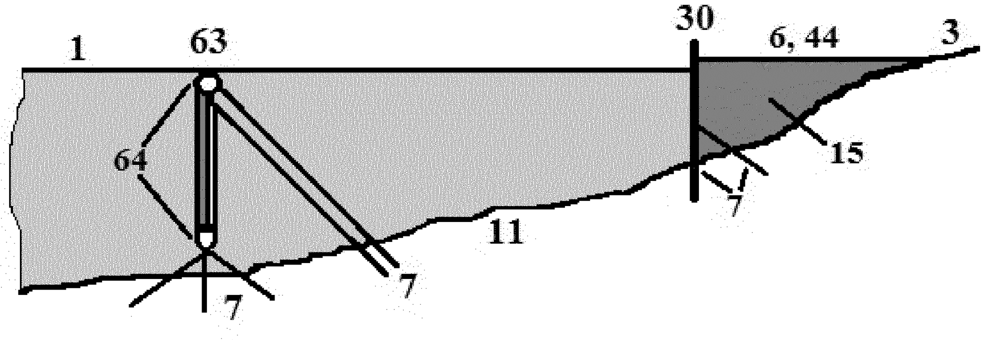

Fig. 12

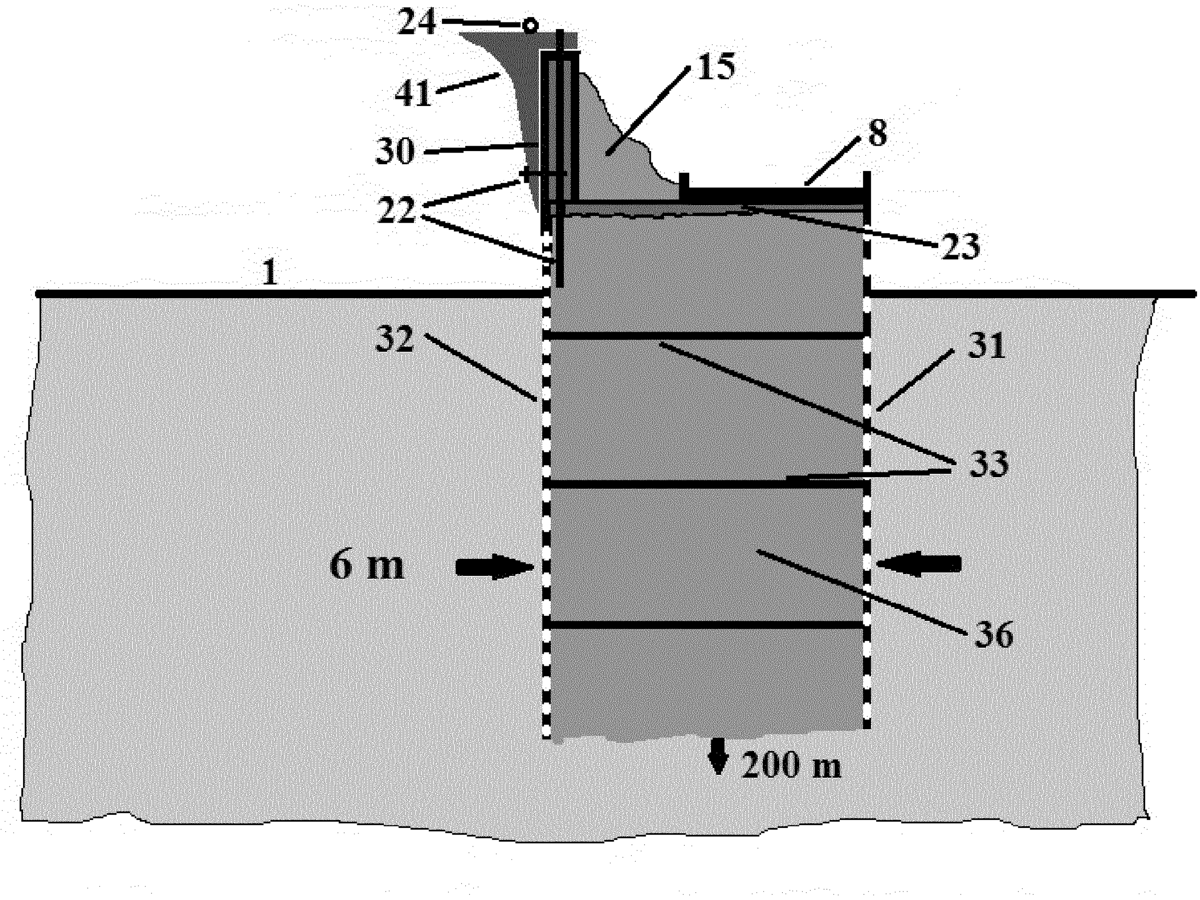

Fig. 13

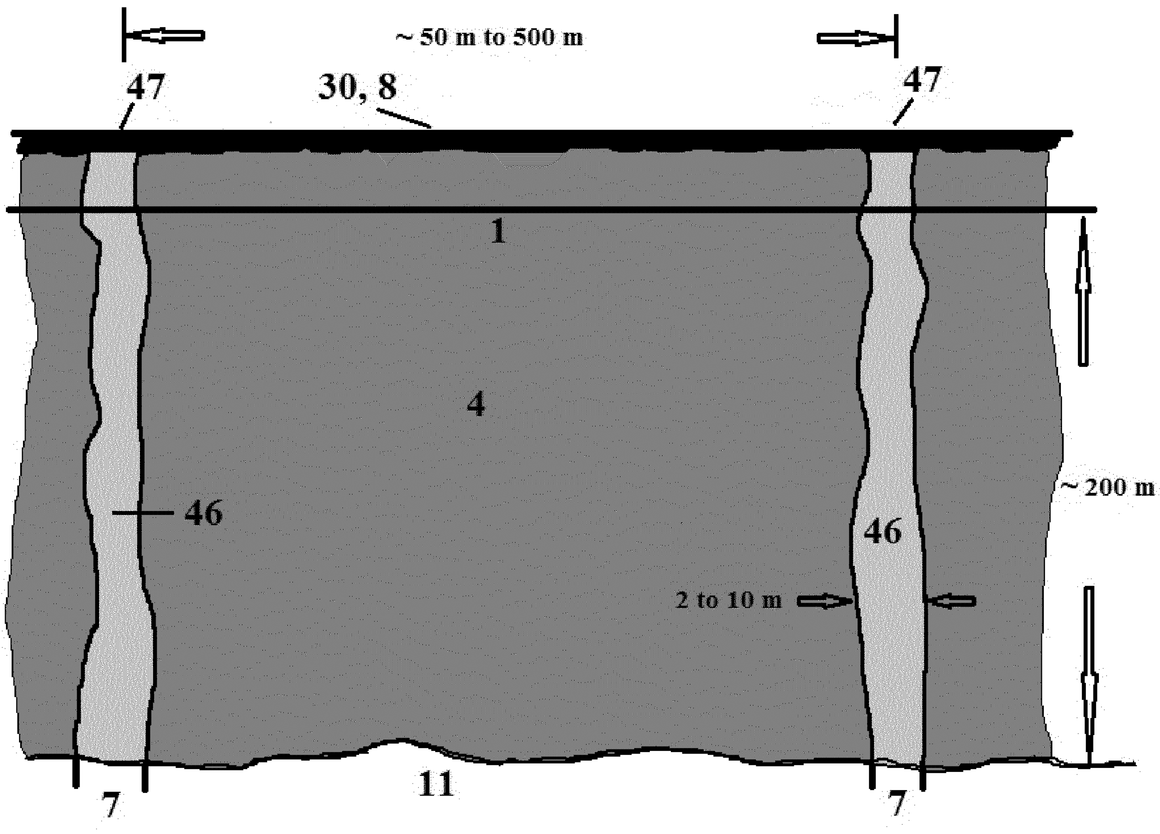

Fig. 14

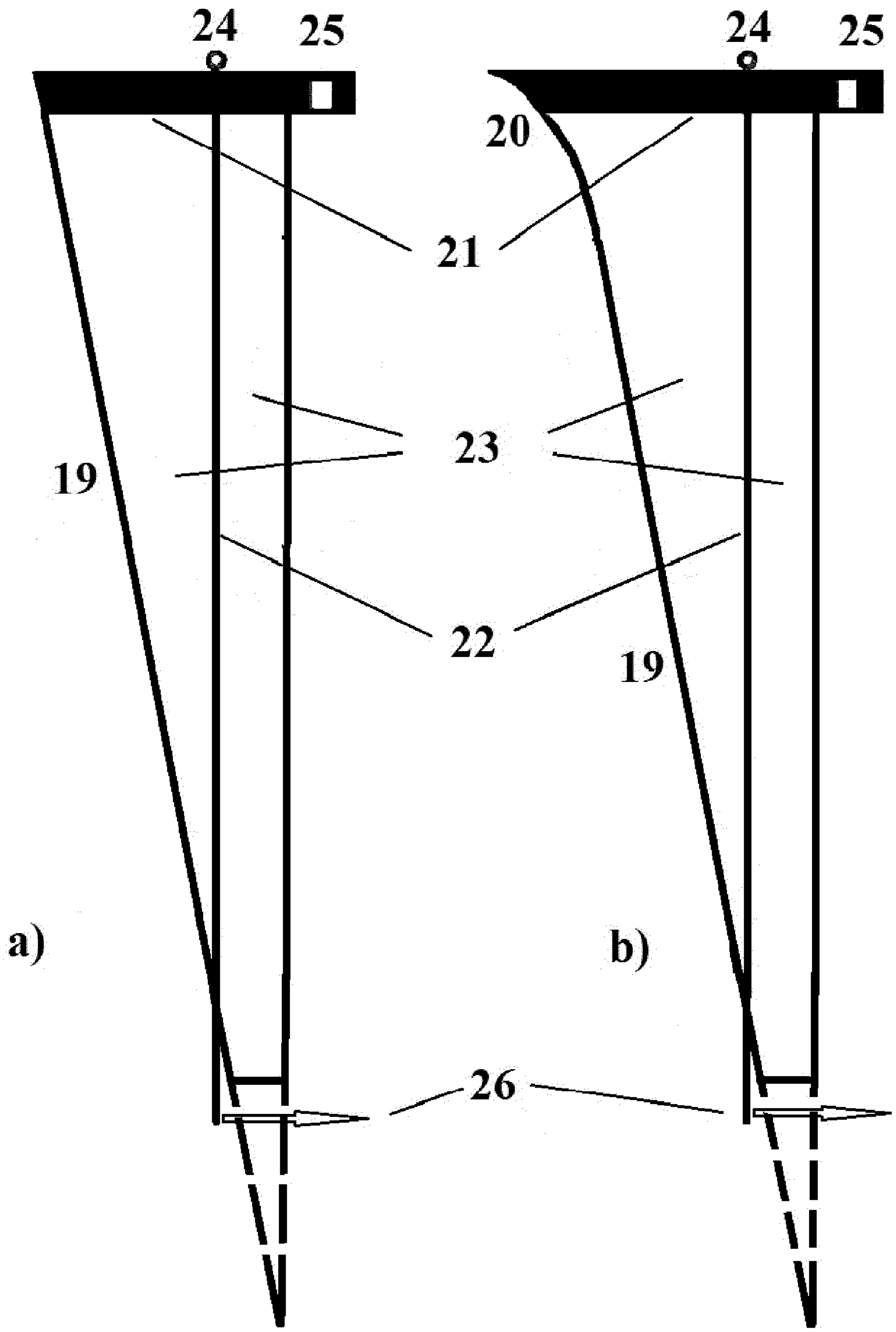

Fig. 15

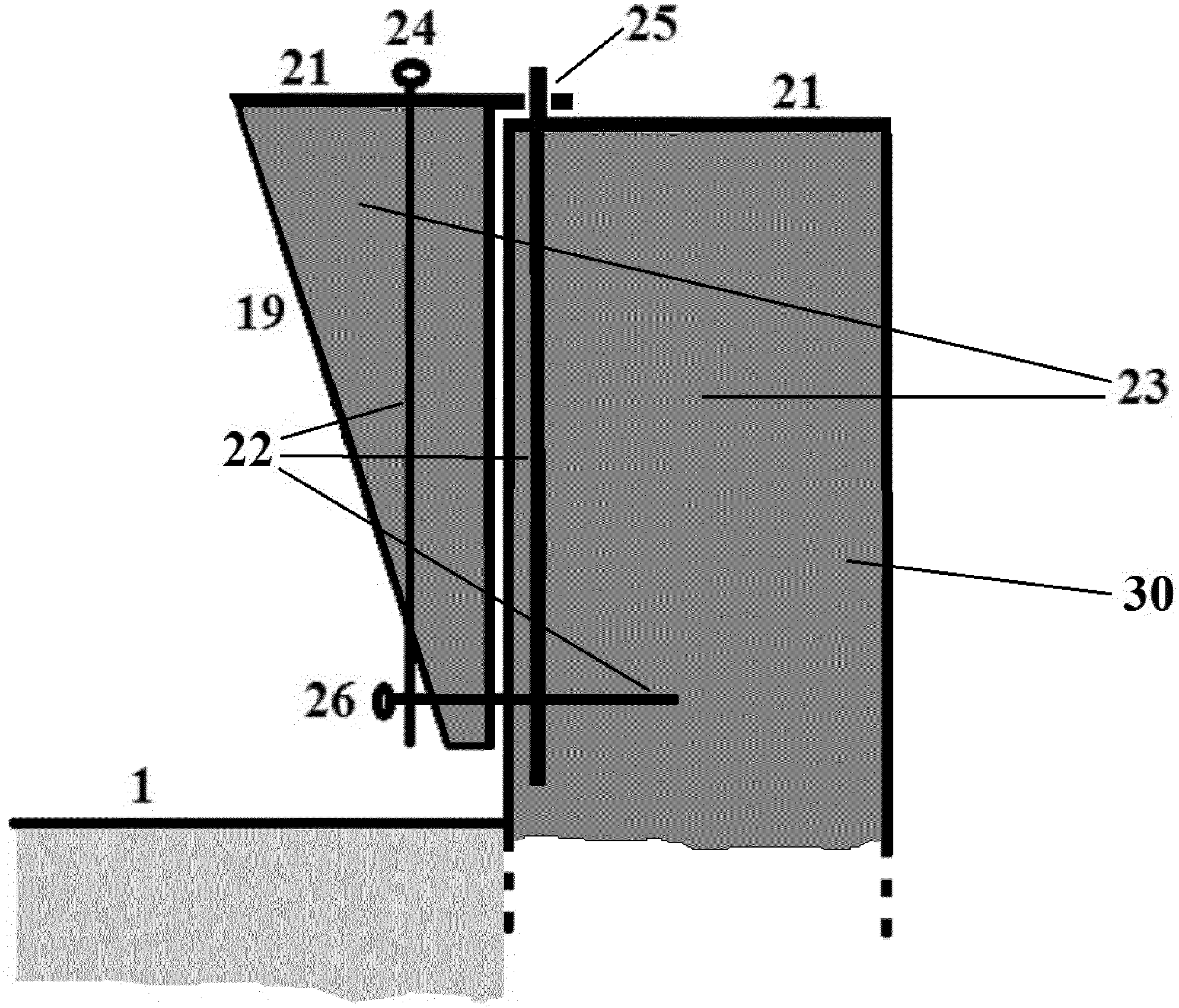

Fig. 16

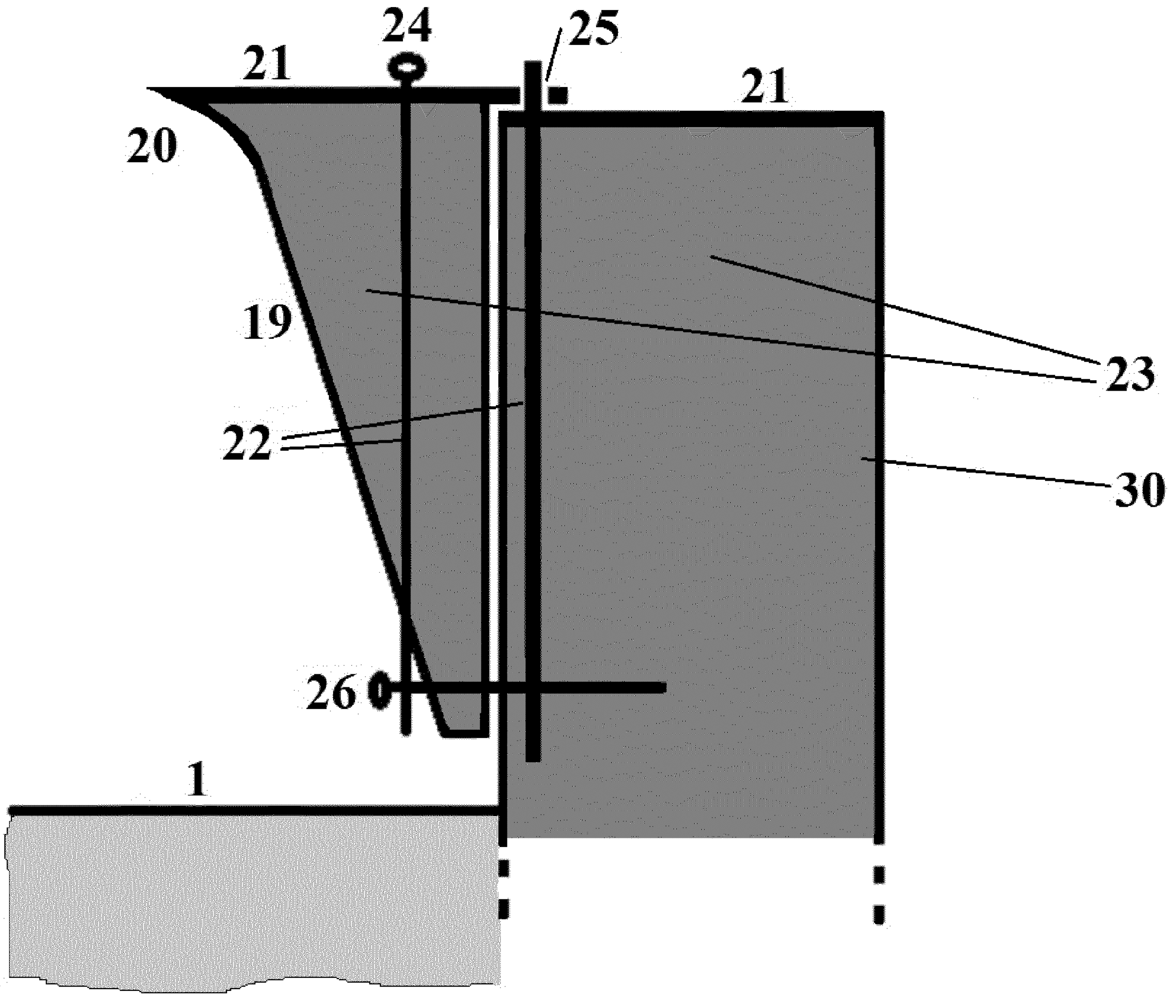

Fig. 17

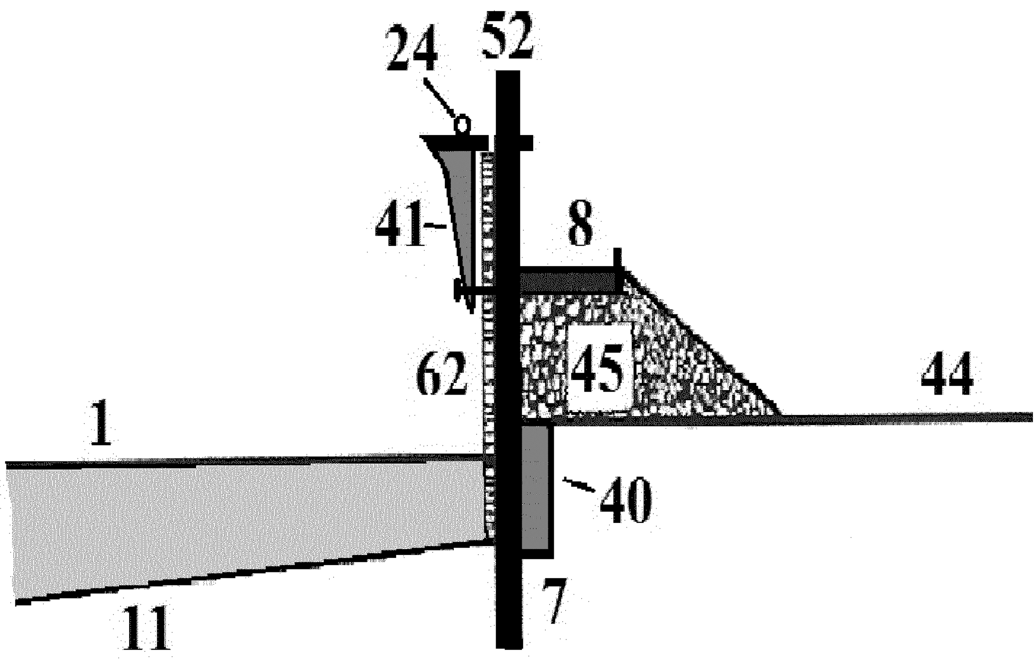

Fig. 18

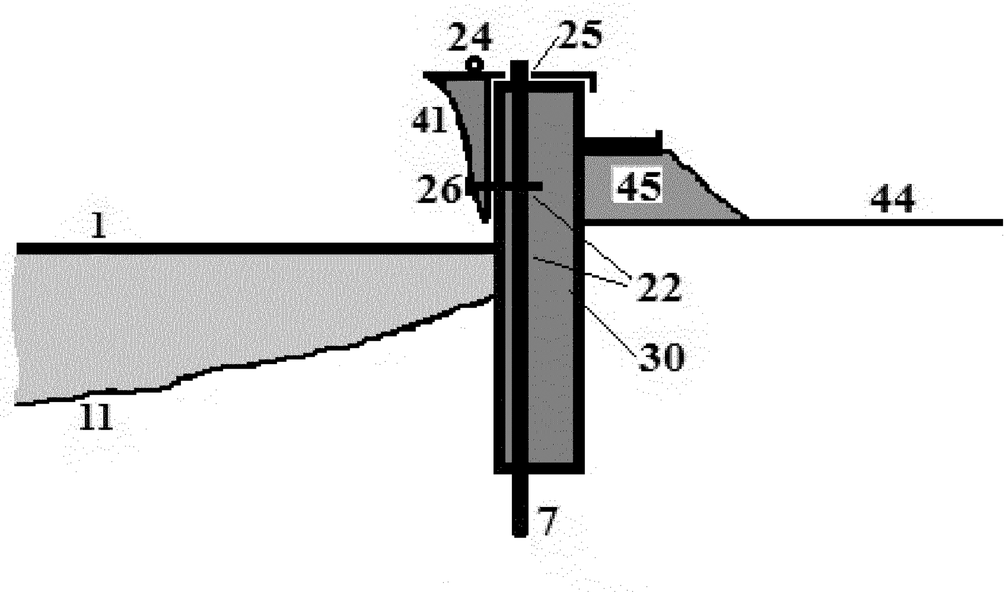

Fig. 19

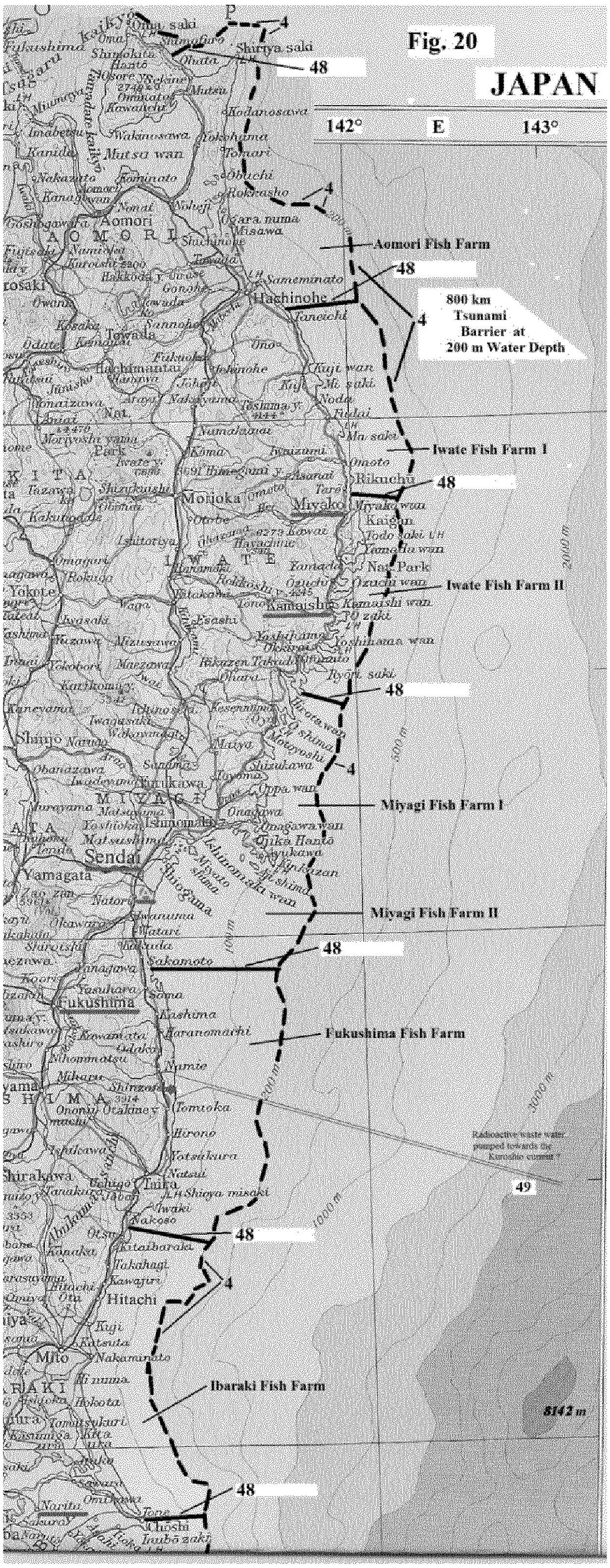
Fig. 20
JAPAN
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E
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Aomori Fish Farm
800 km
Tsunami
Barrier at
200 m Water Depth
Iwate Fish Farm I
Iwate Fish Farm II
Miyagi Fish Farm I
Miyagi Fish Farm II
Fukushima Fish Farm
Ibaraki Fish Farm
49
8142 m

Fig. 20

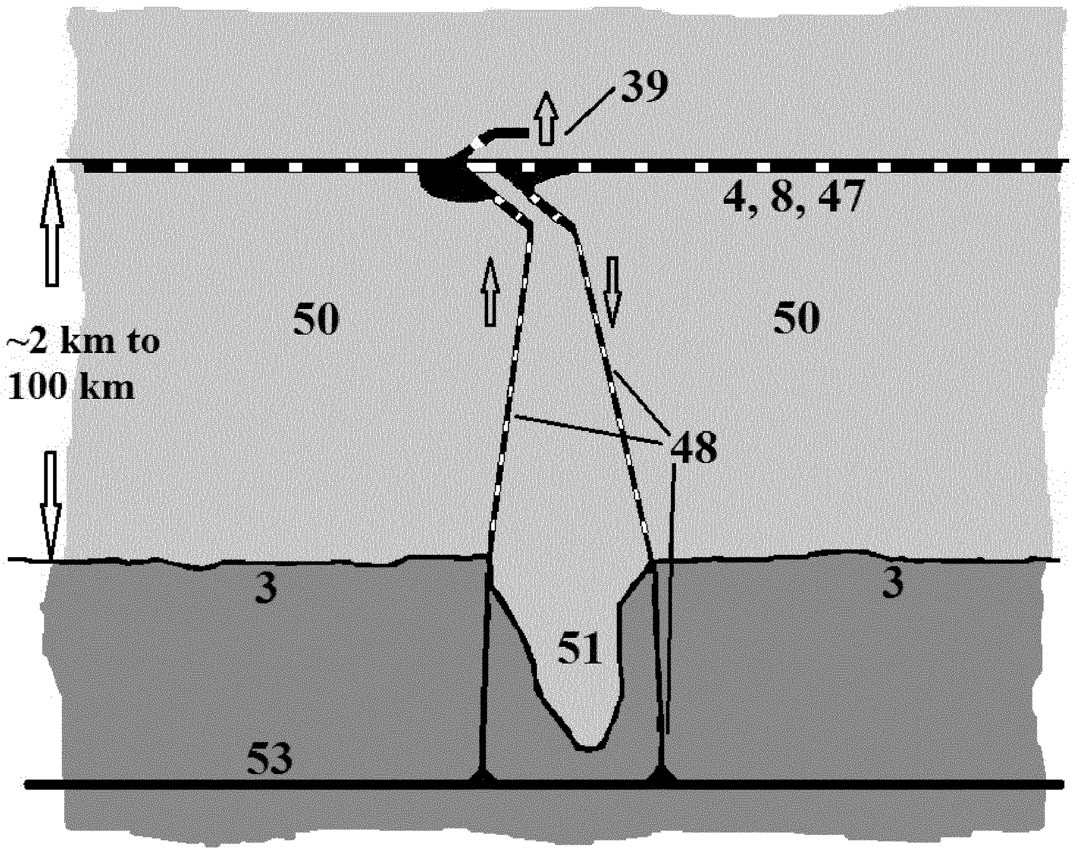

Fig. 21

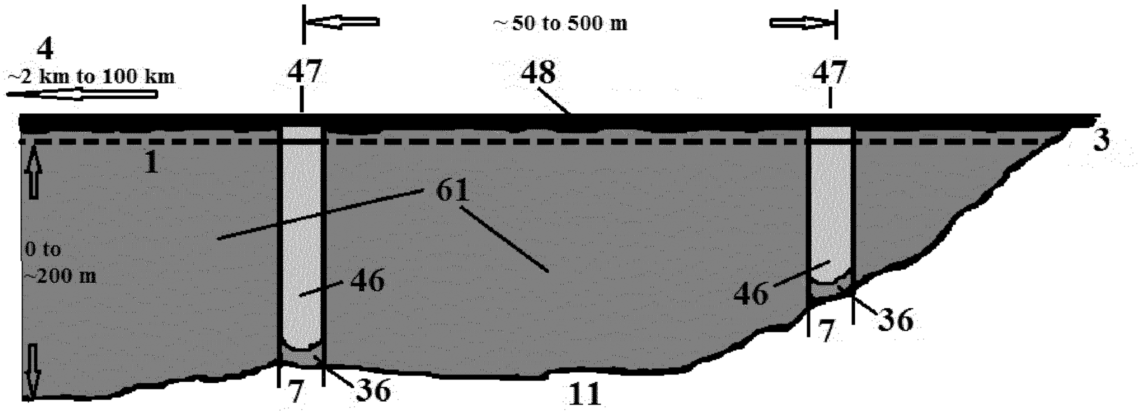

Fig. 22 a

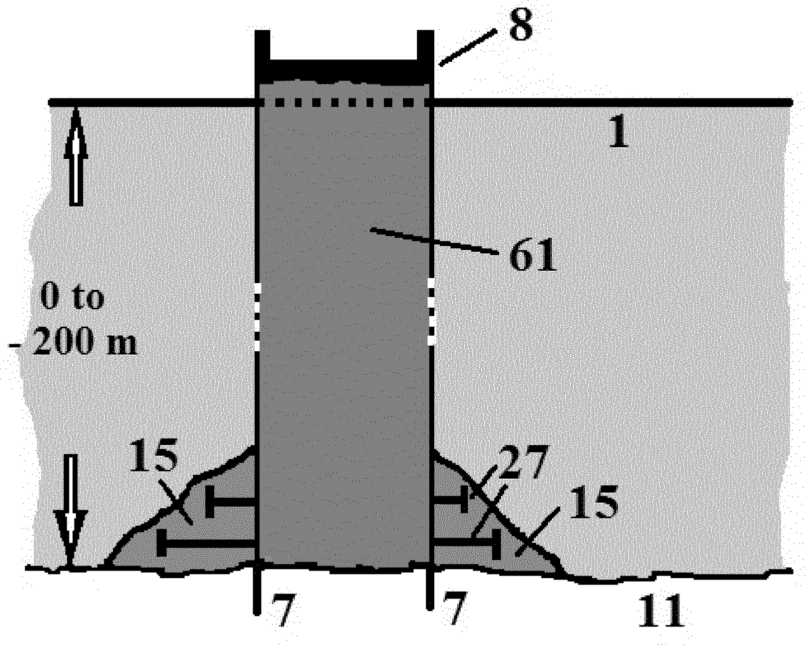

Fig. 22 b

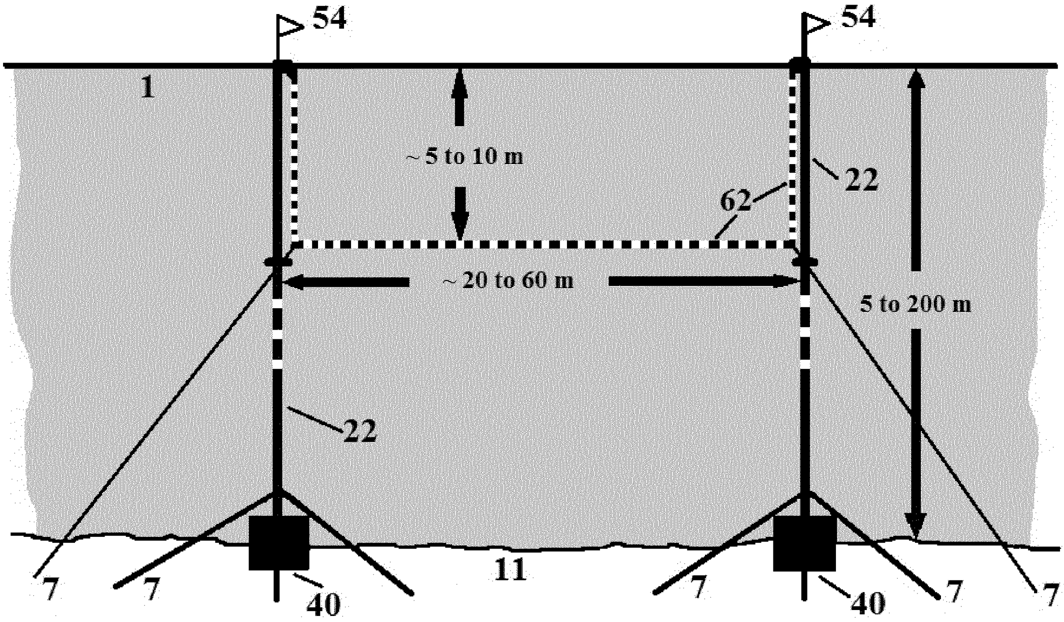

Fig. 23

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PARTIAL EUROPEAN SEARCH REPORT

under Rule 62a and/or 63 of the European Patent Convention. This report shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number
EP 13 16 2698

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	FR 2 958 666 A1 (VAVASSEUR GUY LE [FR]) 14 October 2011 (2011-10-14) * the whole document *	1	INV. E02B3/06 E02D29/02
Y	US 2011/305511 A1 (HESELDEN JAMES [GB]) 15 December 2011 (2011-12-15) * the whole document *	1-8, 10-13	
Y	US 4 913 595 A (CRETER JR FRANK E [US] ET AL) 3 April 1990 (1990-04-03) * the whole document *	1-8, 10-13	
Y	US 4 407 608 A (HUBBARD THOM W [US]) 4 October 1983 (1983-10-04) * the whole document *	1-8, 10-13	
Y	US 4 117 686 A (HILFIKER WILLIAM K) 3 October 1978 (1978-10-03) * the whole document *	1-5	

TECHNICAL FIELDS SEARCHED (IPC)

E02B
E02D

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

1

Place of search	Date of completion of the search	Examiner
Munich	14 August 2014	Horst, Werner

CATEGORY OF CITED DOCUMENTS

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INCOMPLETE SEARCH SHEET C

Application Number
EP 13 16 2698

Claim(s) completely searchable:
1-8, 10-13

Claim(s) not searched:
9, 14-20

Reason for the limitation of the search:

Claims 14-20 are additional independent claims in the same category which contravene the requirements of rule 43(2) EPC.
The only feature of claim 9 is so unclear that no meaningful search is possible, hence the claim was not searched.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 16 2698

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14-08-2014

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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