Submarine construction for Tsunami and flooding protection, for tidal energy and energy storage, and for fish farming

Field of invention

The present invention relates to the protection against Tsunami waves and against flooding from storms, and also presents a novel technology for submarine architecture and protection of offshore platforms and bridge pillars. Turbines in the barriers transform tidal energy, and pumping into the reservoirs allows energy storage and continuous supply of electricity. The seawater reservoirs separated by the Tsunami barriers can be used for fish/tuna and seafood production and partially can be filled up for land reclamation. A double-pontoon technology allows efficient and economic construction of barriers and roads into the sea. Attenuation of waves protects the construction phase and and utilizes the wave energy.

Cross-References to Related Applications

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 J. Scheel
- PCT/IB2012/056613 filed on Nov. 22, 2012 in the name of Hans J. Scheel
- PCT/IB2012/057458 filed on Dec. 19, 2012 in the name of Hans J. Scheel
- PCT/IB2013/055276 filed on June 27, 2013 in the name of Hans J. **Scheel**
- PCT/IB2013/059511 filed on October 21, 2013 in the name of Hans J. Scheel

- European Patent Application No. EP13162698 filed on April 8, 2013 in the name of Hans J. Scheel
- Japan Patent Application No. JP2013-023131 filed on Feb. 08, 2013, in Japanese March 26,2013, in the name of Hans J. Scheel
- US Patent Application No. 13/861,608 filed on April 12, 2013 in the name of Hans J. Scheel

Background

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 26.12.2004 Sumatra and eight 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 Los Angeles, Mumbai, New York, Osaka, Tokyo, many smaller cities and hundreds of km coastline are threatened with future Tsunami, especially in case of a Mega-Tsunami, and with storm surges caused by cyclones.

Tsunami waves are formed from sudden vertical displacements of the ocean bottom related to earthquakes, from land slides, from underwater volcanic 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 centimetres and rarely exceeds 1m, and the travelling speed is about 700 km/h.

The catastrophic Tsunami sea waves of typically 4 to 10 m height are formed when the impulse waves reach the decreasing water depth at the coast. The long wavelength and the speed of the pressure wave are then reduced and compensated by increased amplitude, or in other words the kinetic energy of the impulse wave is transformed to potential energy by increasing the height of the Tsunami sea wave (law of energy preservation). 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.

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.

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.

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 impulse waves can be triggered by underwater landslides (Hornbach et al. 2007, 2008).

Earlier proposals to reduce the Tsunami risks include the following:

-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 sea-level at the arrival of the tsunami impulse 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.

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 had 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, because neither the position nor the design were suitable: the March 2011 Earthquake and Tsunami killed about 1000 people in Kamaishi and partially destroyed the breakwater. Remainder of this breakwater can be seen on Google Earth. 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 catastrophes 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 20 m to 50m height should be built off-shore.

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) analysed in depth the Indian Ocean Tsunami 2004 and could explain the catastrophic effects in eight countries affected. Coastal protection measures have been reviewed by Allsop (2005) and by Burchardt and Hughes (2002, 2011), and Takahashi (1996/2002) had discussed stability aspects of partially vertical breakwaters.

Deeply immersed vertical Tsunami barrier are needed which reflect most of the impulse waves. However, the reflectivity should be reduced by surface roughness in order to prevent total reflection which may harm opposite coast. This roughness would cause partial dissipation of the wave energy inside the vertical barrier.

Deep-sea construction using conventional concrete technology is in principle possible in view of behaviour 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, and to prevent flooding from high storm surges.

List of Figures

Fig.1 : Vertical Tsunami barrier with reflected shock waves and gained new land (schematic cross section).

Fig.2 : Schematic cross section of seafloor with break of continental shelf and dependence of wave velocity ***c*** to water depth ***h*** (lower section) and to wave height ***A.***

Fig.3: Terrace of Tsunami barriers (schematic cross section).

Fig.4: Tsunami barrier with a gap for navigation (schematic cross section).

Fig.5: Schematic view of a steel fence lowered from a roll on a pontoon.

Fig.6: Steel beam chain with horizontal side arms and anchors.

Fig.7: Vibration shock to densify the fence- rock barrier by a heavy hammer plate of which the height can be adjusted (schematic cross section).

Fig.8: Vertical wall at the coast by excavation (schematic cross section).

Fig.9: Double fence lowered from two pontoons (schematic cross section).

Fig10: Double-fence barrier of 5 m thickness with concrete wall, surge stopper (wave deflector) and service road (schematic cross section).

Fig.11: Double-fence barrier of 20 m thickness with concrete wall stabilized by rocks (schematic cross section).

Fig.12: Weak points (gaps) along Tsunami barrier with bridges and reinforced fence, with possibility to mount turbines or waterwheels for electricity production (schematic longitudinal cross section).

Fig.13: Surge stoppers of concrete with straight inclination (a) and with top curvature (b), (schematic cross section).

Fig.14: Top of concrete wall with hanging surge stoppers of Fig.13.b. (schematic cross section).

Fig.15: Vertical fence structure between steel beams stabilized on coast side with heavy masses, with top service road. The steel beams allow to hang the surge stoppers of Fig. 13.b (schematic cross section).

Fig.16: Vertical concrete wall stabilized towards the coast by heavy masses, with top service road and steel beams allowing later heightening, with hanging the surge stopper of Fig.13.b (schematic cross section).

Fig. 17.a,b,c: Schematic views of double-pontoon bridge with gap for inserting rocks, with assisting pontoons, and with steel-fence lowered into the sea

Fig.18.a. Vertical steel tube, fixed at the bottom of the sea, with steel rings and hooks to connect and fix steel fences and steel ropes (schematic side view).

Fig.18.b. Connection of two sequences of steel fences by two neighbouring vertical steel tubes, overlapping eyes and inserting the bolts (schematic side view).

Fig.19. Schematic top view of fabrication stages of tsunami barriers with

- cleaning of sea floor and inserting steel tubes (not shown),
- insertion of steel fences (fixed on hooks of steel rings) and of rocks from two parallel pontoons,
- fabrication of concrete wall and of service / supply road on top of the steel-fence –rock tsunami barrier

Fig.20: Schematic top view of fabrication stages of tsunami barriers with splitting and bending of the barrier by corresponding coupling elements (assisting pontoons not shown).

Fig.21: Schematic top view of the double-pontoon bridges for trucks with rocks or steel-fence rolls which after delivery return to the coast on single-pontoon bridges (assisting pontoons not shown).

Fig.22.a. Side view, **Fig.22.b.** top view of a turbine / water-wheel fixed by steel rings and inserted between four vertical steel cylinders into the tsunami barrier before the filling with rocks.

Fig.23.a: Schematic top view of Tsunami barrier with service road, supply roads, fishing reservoirs, and access from the fishing harbour to the open sea.

Fig.23.b: Energy scheme for tidal energy and for energy storage by pumping.

Fig. 24.a,b: Schematic longitudinal section of a supply road between coast and Tsunami barrier with gaps and fences covered by bridges (a) and the schematic cross section (b) of the double-fence supply road of 4 to 5 m thickness with side walls.

Fig.25.a,b: Wave-attenuating steel fence floating on the sea surface by means of pontoons and fixed with chains on the seafloor by means of stable foundations, heavy weights and/or anchors (schematic top and side views).

Fig. 26.a,b: Wave-attenuating horizontal and vertical steel fence floating on the sea surface by means of floating elongated pontoons and fixed by chains and steel beams connected to stable foundations, heavy weights and/or anchors at the bottom of the sea (schematic top and side views of a small section of an extended system).

Brief description of the figure legend

(1) Sea level at high tide

(2) Bottom of the sea/ocean

(3) Shore/coast

(4) Tsunami barrier

(5) Gap (filed with rocks, rubble, …)

(6) Surface soil layer

(7) Fixation bars

(8) Service road

(9) Pressure/Shock waves

(10) Reflected waves

(11) Sea floor

(12) Fences

(13) Roll of fence

(14) Horizontal anchors

(15) Rocks, rubble

(19) Surge stopper with straight inclination

(20) Upper curvature

(21) Steel

(22) Steel bars

(23) Steel-enforced concrete

(24) Hooks

(25) Gap for hanging surge stopper onto concrete wall

(26) Fixing to concrete wall

(27) Horizontal anchors

(28) Gap for navigation

(29) Terraces

(30) Concrete wall

(31, 32) Fences parallel to the coast

(33) Distance holders

(34, 35) Ship/Pontoon

(36) Rocks

(37) Delivered steel fence roll

(38) Stable steel frame

(39) Open sea

(40) Concrete foundations

(41) Surge stoppers

(42) Vertical wall at the coast

(45) Heavy masses

(46) Fence (at weak point of Tsunami barrier)

(47) Concrete bridge

(48) Supply road

(49) Pumping of contaminated water

(50) Reservoir

(51) Fishing harbour

(52) Steel bars

(53) Main supply road

(58) Swinging weight

(59) Height adjustment

(60) Pull and loosen of weight

(62) Fence

(65) Gabion-wall Tsunami barrier

(66) Gabion

(67) Crane

(101) Double-pontoon bridge, two parallel connected pontoons hanging on a frame of assisting pontoons

(102) Vertical steel tubes fixed in the ground and filled with concrete

(103) Rolls of steel fence

(104) Opening for inserting the rocks

(105) Connecting beams between the two pontoons

(106) Special trucks for transporting steel tubes and steel-fence rolls, and not shown dump trucks and haul trucks to transport the rocks

(107) Steel fences lowered into the sea between the steel tubes

(108) Rocks, rubble, other solid material, blocks of concrete, gravel, sand

(109) Sea level, sea surface at high tide

(1010) Connection of two sequences of fences by two vertical steel tubes and overlapping eyes and inserting bolts

(1011) Steel ring with hooks

(1012) Additional supply of rocks, steel tubes, steel fences, and of concrete by ships and pontoons

(1013) Double-fence tsunami barrier filled with rocks finished: now fabrication of concrete wall and of service/supply road

(1014) Supply and service road with small slope and draining tube

(1015) Shore, coastline

(1016) Large parking area for trucks and building machines, for loading with steel-fence rolls, steel tubes and rocks, and for concrete-delivering trucks. Storage of building material.

(1017) Parallel to the coast

(1018) Coupling for bending

(1019) Coupling for splitting the double-pontoon bridge

(1020) Water depth about 40m (20m to 200m) below sea level

(1021) Work in progress

(1022) Tsunami barrier with supply road finished

(1023) Direction of trucks with steel-fence rolls, steel tubes, steel rings, dump trucks with rocks, and concrete mixer transport trucks

(1024) Return of empty trucks on single-pontoon bridges

(1025) Main supply road

(1026) Section of large steel fence with 5 small pontoons

(1027) Pontoon

(1028) Steel fence

(1029) Cross section/side view of steel fence and pontoons

(1030) Weight hanging on steel chain

(1031) Sea level I

(1032) Sea level II

(1033) Row of pontoons

(1034) Horizontal steel-fence section

(1035) Vertical hanging steel fence

(1036) Fixed by steel chains to the bottom of the sea by foundations, by heavy weights, or by anchors

(1037) Hooks for transport

(1038) Turbine, waterwheel

(1039) Tidal flow changes

(1040) Steel fence with large gaps

(1041) Assisting pontoons to reinforce capacity of double-pontoon bridge

(1042) Frame of steel tubes to carry double-pontoon bridge with heavy trucks

(1043) Outer walls with surge stoppers for protection against high sea waves

(1044) Steel chains and steel beams

(1045) Rocks filled up after removal of double-pontoon bridge

(1046) Outer and inner steel fence

(1047) Rocks inserted from trucks on double-pontoon bridge

(1048) Distance holder

(1049) Steel beam

(1050) Surge stopper

(1051) Sea-facing concrete wall

(1052) Bolt

(1053) Coast-facing concrete wall

(1054) Ramp supply road

(1055) Foot of barrier

(1056) Pump

. (A) Wave height

. (I) Typical example I

(II) Typical example II

. (c) Wave velocity

. (h) Water depth

General description of the Invention

The principle of the invention is shown with a cross section in Fig.1 with the impulse waves (9) from earthquakes or landslides reflected (10) at the stable vertical wall, with release of some impulse energy by upward motion of water in front of the barrier and with dissipation of some wave energy in the rough surface volume 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.

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) with rocks, gravel, debris, sand and a cover by a soil layer, new land can be gained the value of which could compensate all or at least a large fraction of the construction costs. An alternative for new land could be based on permanently floating structures between barrier and coast.

The gap between barrier and coast encloses huge seawater reservoirs which can be used for large-scale farming for tuna and other fish or seafood. Also they can be used for energy storage by means of pumping water to a high level with excess low-cost electricity and gaining electricity by lowering the water to a lower reservoir with turbines when needed.

Fig. 1 represents a schematic cross section of a vertical barrier (e.g. a Tsunami barrier) reflecting the impulse 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 200 m or even only 30 m. Their velocity ***c*** is given in a first approximation (Levin and Nosov 2009 Ch.1.1 and Ch.5.1) by

$$c = \sqrt{(g \times h)}$$

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

$$A^2 \times c = \textbf{constant.}$$

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 200 m, and only at water depth around 50 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 economically be erected at water depth between 20 m to 200 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.

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.

In exceptional localities the initial offshore Tsunami wave may reach more than one meter 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 affected 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 seafloor becomes relevant when the Tsunami pressure waves reach shallow waters which with the present invention is prevented.

Construction of Tsunami barriers

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. 5 shows a schematic cross section of a pontoon for inserting the fence from a roll (13). Steel fences are produced in many countries. Wire thickness of about 4mm will often give sufficient strength, especially since the required saltwater-corrosion-resistant steel has excellent high tensile strength. For exceptional requirements, for example above sea level, the high-strength steel nets of

Geobrugg AG Switzerland may be applied with the additional advantage of their high elasticity, important for surviving earthquakes and the highest waves. 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) or ASTM type 316, 316L or 316LN. 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. 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.

The overall surface topology and the local roughness of the fence-rock structure determine the reflectivity of the impulse waves. Reflectivity can be decreased by zigzag or undulating structures of the Tsunami barriers. These reflected impulse waves may harm opposite coasts on the other side of the ocean or islands. A slight downward inclination from vertical could 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 could 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

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, 3, 4, 10, 12, 15, 16) and/or by concrete foundations. Before this procedure the sea-ground is cleaned from sand and soft material by dredging and/or by high-pressure water jets arriving through pipes or produced locally by submerged compressors or fans, and steep slopes may be removed by excavation. A small "foot" **(1055 in Fig.10)** of the barrier in direction sea may be provided in order to prevent or reduce scouring, the removal of sand from below the barrier by currents. 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. 3, 4, 10. 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).

For Tsunami protection the steel fence extends preferably between 20m to 50m below sea level down to the sea floor. The length of fence in rolls can be adjusted accordingly taking into account the length below sea floor and the extension above sea level. 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.

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 or steel pipes. 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. 6 is inserted seaward just in front of two **neighbouring 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. 6.a, 6.b and 6.c. The spines can be replaced by automatic clamps which lock to the fence upon contact, when mechanically pulled in landward direction.

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.

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. 3. This would also become important in case the epicentre of the earthquake would be near to the coast and thus between two steps of the terrace.

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 10 m below sea level at low tide for navigation or for preserving beaches and harbours, as shown with the gap (28) in Fig. 4. 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.

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 7 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.

An alternative vertical protection can be established directly at the coast by excavation to achieve a deep vertical wall (42) (Fig. 8) 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

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. 9. 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 up to 20m. The height should extend 2 m to 4 m beyond sea level at high tide, see Fig. 10. 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. This flexibility can also be used to arrange a certain extension at the foot **(1055)** of the barrier in order to reduce scouring. 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 stabilization against strongest impulse waves, rocks are deposited on the coastal side of the double-fence barrier as shown in Fig.10, and the barrier, in this case of **5.6 m to maximum 20m** thickness, is further stabilized by horizontal anchors (27) 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.

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. The turbines with generators are installed at the weak points of the tsunami barrier, below the bridges, where also significant water flow is expected as discussed below, or they are installed within the barriers.

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. 11.

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 2m to 5m and where a concrete bridge (47) passes over the gap as shown in Fig. 12. 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.

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

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.

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.

Cleaned rocks are inserted from top after the lowest double-fence section has reached the sea floor.

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.

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

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. 10, 11, 14, and to protect the new land (see Fig.1 and Fig.3). 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 to allow replacement. Two such inclined concrete structures are shown in Fig. 13. Fig. 13a shows a structure with a straight inclination (19) only corresponding to a tilting angle, and Fig. 13b shows a second triangular structure with a straight inclination (19) and an upper curvature (20). Fig. 14 shows the triangular structure from Fig. 13b 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.

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 instance 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 knowhow.

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. 10, 15, 16, 23, 24.

b) Application to Dikes and Levees

In another embodiment the invention includes seawards oriented surge stoppers hanging on stable vertical double-fence-rock 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.

Basic walls according to one embodiment of the invention are schematically shown in Fig. 15. 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.

The walls are preferably built from double-fence-rock structures as described above, in this case with steel fences between vertical steel beams or between vertical steel tubes filled with concrete **(7),** fixed in the ground, and with anchors and rocks for fixation of the anchors and the steel-fence dike. For highest stability against storm surges, the seaward steel fence is made from ultra-high strength steel nets of Geobrugg, Switzerland. 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. 15.

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. 16. 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.

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. The surge stoppers are fabricated from saltwater-resistant concrete or are angle-shaped gabions made from stainless-steel fence and filled with rocks.

During time, sand and gravel may be washed towards the coast and deposited in front of the novel dikes, thereby reducing the protection-effective vertical height. This material should be dredged and deposited on the landward side of the barrier, or the wall height has to be increased in order to remain fully protective. On the other side, sand may be removed from below the barrier, and this will be reduced by "feet" (1055) extending sea-side and built at the low end of the barrier **as** shown in Fig. 10.

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

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

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.

Double-Pontoon Technology for Efficient Barrier Construction

The construction of the tsunami barrier in open sea including the transport of rocks, fences, concrete is quite difficult. In the following a **simple approach** starting from the coast is described.

According to a preferred embodiment of the invention two parallel pontoons (Fig. 17.a,b) with a gap between the two allow trucks arriving from the coast to deliver steel tubes, steel-fence rolls, and rocks, the rocks directly from the quarry. For carrying the weight of trucks with rocks, the two pontoons are connected by a stable frame **(38)** with assisting pontoons outside (Fig.17.a,b). Furthermore these assisting pontoons have a damping effect for the ocean waves. High walls at the outside of the assisting pontoons will reduce overtopping of the waves to the central double-pontoon bridge.

Vertical steel tubes are fixed in the ground at a horizontal regular distance corresponding to the width of the steel fences (Fig.18.a). The steel fences are lowered between the steel tubes (Fig. 17.c), connected by hooks on steel rings (Fig. 18.b), on both sides of the double-pontoon bridge. Rocks **(36)** are inserted from the trucks through the gap between the pontoons into the sea in order to fill the space between the parallel steel fences for building a stable wall. The first rocks are inserted in a way to establish the foot (1055) of the barrier in order to reduce scrouting, the removal of sand from below the barrier by water currents, see Fig. 10.

For the top of the barrier extending above sea level the double-pontoons have to move on so that the gap between the fences can be

filled with rocks from ships. In the next step trucks deliver the concrete and steel beams for building the concrete wall and the supply road on top of the steel-fence rock wall. The empty trucks move on a single-pontoon bridge and return by U-turn to the coast (Fig. 21) or temporarily remain on a pontoon-parking site (Fig. 19). Fig. 20 shows the bending and the splitting elements for the pontoon-bridge traffic. The concrete applied for building the top walls and the supply roads should have improved resistance to sea water by a low water/cement ratio and very low permeability (Zacarias 2006/2007).

The size of the rocks (or rubble) should fit into the gap between the pontoons, but should not pass through the gaps of the fence and best be in the range of 40 to 90 cm. Rounded rocks tend to move later so that rocks with edges are preferred. In order to settle the rocks, the vibration shock with heavy weights can be used, see Fig. 7.

Vertical Gabion barrier

A vertical Tsunami barrier can be erected from gabions, steel cages filled with rocks. These gabions have an elongated shape of 3m to 20m length and are positioned in a direction towards the sea. The shape allows closed packed fitting to build a vertical wall, with a concrete road and wall on top (not shown by figures). Also here the surge stoppers will be useful.

Protection of the construction site against high sea waves from storms

These works need to be done at relatively quiet sea. In view of frequent storms and high sea waves, a wave-damping structure is invented as shown in Fig. 25 and Fig. 26. A large horizontal steel net, with lateral dimensions between 50m and 500m, is held floating by means of small pontoons or light-weight bodies (Fig.25), and its

position is fixed by chains or steel ropes connected to stable foundations or heavy weights and/or anchors on the sea-floor.

Fig. 26 shows a row of long pontoons which themselves assist to wave damping. The horizontal pontoon-steel-fence with long pontoons can be enforced by a hanging deep steel fence on the sea-side as a weight and acting to reduce the energy of the arriving tsunami wave, in addition to reducing the power of storm waves. These pontoons with combined horizontal and vertical steel fences are schematically shown in Fig. 26.a and 26.b. The openings of the horizontal and vertical steel fences determine the water penetration as a function of the angles between wave-front and the actual steel-fence surface, and thus determine the energy dissipation of the waves. Also the total mass of the fence-pontoon structure helps to increase the attenuation efficiency as it counteracts mainly the rising waves. The attenuation effect will be reduced when due to small penetration the steel fence partially follows the wave motion up and down. With theoretical estimations and numerical simulations the required size of these fence-pontoon structures has to be found and experimentally tested. The damping mechanism of vertical fishing farm net structures with openings up to 25 mm has been studied by Lader et al. (2007). By intuition the width of the fence towards the open sea in our case should not be much smaller than 100m, and the diameter of the circular steel rings of the fence could be 30 to 50 cm. Also the shape and size of pontoons will have an impact on the efficiency of these wave attenuators (here the study of Koraim (2013) about suspended horizontal rows of half pipes is of interest).

It is important that these pontoon-fence structures are fixed by steel ropes, chains and steel beams to the bottom of the sea by solid foundations or by heavy weights or by anchors. The elongated

pontoons will also allow to use the energy of waves when the latter activate corresponding generators (dynamos).

After the stable Tsunami barriers have been built or independently, the pontoon-steel-fence structures can also be used along the coast and in harbour bays to reduce the energy of storm waves and of tsunami waves. In harbours these structures can be folded to open a channel for navigation, and closed in case of tsunami warning.

Specific Application of Tsunami Protection in North-East Japan with 800 km double-fence-rock Tsunami barrier, depth 30 m, width 5.6 m; from Shirya saki (41°26´N 141°34´22" E) to Chõshi/Inubõ zaki (35°42´05"N 141°14´23" E); requires per km about 70'000 m^2 steel fence (ca. 15% ultra-high-strength net); ca.400'000 tons of rocks; 12'000 m steel pipes or profiled steel beams, and 6'000 m^3 concrete for walls & roads.

Land Reclamation

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).

Renewable Energy from Tides and Energy Storage by Pumping

Fig. 23.b shows reservoir I for using tidal energy by reversable turbines (1038). The large volume of the reservoir can utilize small tide height differences.

Reservoirs II and III also can use tidal energy, but he main application is by pumps (1056) activated by low-cost electricity for instance during night to increase the water level in reservoir III. The turbines (1038) are activated when electricity is needed so that a continuous supply of electricity can be provided. A successful example for these energy applications was built in Rance, **Northern** France in 1967.

Fishing Farms

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. This water reservoir will be partially connected with the ocean. Extended conventional fishing nets will prevent escape **and separate different sizes o**f fish. In certain areas the application of copper-alloy nets will be used to prevent fouling. For example the North-East coast of Japan protected by 800 km Tsunami barriers can be divided into sections divided by supply roads 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. 23.a. 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.24.a and 24.b. These gaps can be closed by gates with fences or with completely closing gates. 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.

Deep-Sea Mining

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 30 + 5m high Tsunami barriers discussed above.

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- **and manganese-**containing deposits. Such double-fence-rock circles and crosses can also be used for geographic marking points in the sea.

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 sea-wave/flooding risks, on the industrial capabilities, on the planned application, 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.

The novel submarine architecture is useful worldwide, besides protection against Tsunami and flooding, not only for renewable energy and energy

storage, for fishing farms and for deep-sea mining, but also for any buildings in the sea, in lakes and in rivers.

References

- O.S.B. Al-Amoudi, "Durability of plain and blended cements in marine environments", Advances in Cement Research 14(2002)89-100.

- N.W.H. Allsop, editor, "Coastlines, Structures and Breakwaters 2005", Institution of Civil Engineers, Thomas Telford Ltd., London 2005.

- A. Annunziato, G. Franchello and T. De Groeve, "Response of the GDACS System to the Tohoku Earthquake and Tsunami of 11 March 2011", Science of Tsunami Hazards 3 No.4(2012)283-296.

- D. Bingham, T. Drake, A. Hill and R. Lott, "The Application of Autonomous Underwater Vehicle (AUV) Technology in the Oil Industry – Vision and Experiences", FIGXXII International Congress, Washington D.C. April 19-26, 2002.

- E. Bryant, "Tsunami, the underrated Hazard", second edition, Springer ISBN 978-3-540-74273-9, Praxis Publishing Ltd, Chichester UK 2008.

- H.F. Burchardt and S.A. Hughes, "Types and Functions of Coastal Structures" in Coastal Engng. Manual, chapter 2: US Army Corps of Eng. Rep. EM 1110-2-1100 Part VI (30 April 2002; change 3, 28 September 2011).- Geobrugg (2012) AG, Geohazard Solutions, 8590 Romanshorn, Switzerland, www.geobrugg.com.

- H. Kawai, M. Satoh, K. Kawaguchi and K. Seki, "The 2011 off the Pacific Coast of Tohoku Earthquake Tsunami Observed by the GPS Buoys, Seabed Wave Gauges, and Coastal Tide Gauges of NOWPHAS on the Japanese Coast", Proceedings of Twentysecond (2012) International Offshore and Polar Engineering Conference Rhodes, Greece, June 17-22, 2012, p. 20, www.isope.org.

- B. Levin and M. Nosov, "Physics of Tsunamis", translation, Springer 2009, ISBN 978-1-4020-8855-1, e-ISBN 978-1-4020-8856-8.

- P.J. Lynett, "A multi-layer approach to modelling generation, propagation, and interaction of water waves", Ph.D. thesis, Cornell University, USA, http://ceprofs.tamu.edu/plynett/cv/index.html.

- P.J.. Lynett and P.L.-F. Liu, "A Numerical Study of Submarine-landslidegenerated waves and run-up", Philos. Trans. Roy. Soc. A458(2002)2885-2910.

- P.K. Mehta, "Concrete in the Marine Environment", Elsevier Applied Science, New York 1991.

- T.S. Murty, "Seismic Sea Waves: Tsunamis", Bulletin 198, Department of Fisheries and the Environment, Ottawa, Canada 1977.

- T.S. Murty, U. Aswathanarayana and N. Nirupama, editors, "The Indian Ocean Tsunami", Taylor & Francis, London 2006.

- H.J. Scheel 2012a, "Structures and Methods for Protection against Tsunami waves and high Sea-waves caused by Storms", WIPO PCT/IB2012/054543 of September 03, 2012.

- H.J. Scheel 2012b, "Tsunami Protection System", WIPO PCT / IB2012 / 057458 of December 19, 2012.

- H.J. Scheel (2013), "Submarine construction for Tsunami and flooding protection, for fish farming, and for protection of buildings in the sea", Japanese Patent Application No. 2013-23131 of February 8, 2013 (English text) and March 26, 2013 (Japanese Translation).

- D. Stark, "Long-time Performance of Concrete in a Seawater Exposure", PCA R&D Serial No. 2004, 1995.

- A.Strusinska, "Hydraulic performance of an impermeable submerged structure for Tsunami damping", PhD thesis 2010, published by ibidem-Verlag Stuttgart, Germany 2011, ISBN-13: 978-3-8382-0212-9.

- S. Takahashi, "Design of Vertical Breakwaters", Short Course of Hydraulic Response and Vertical Walls, 28th International Conference on Coastal Engineering, Cardiff, Wales UK, July 7, 2002, revised version 2.1.

- S. Takahashi, K. Shimosako, K. Kimura and K. Suzuki (2000), "Typical Failures of Composite Breakwaters in Japan", Proc. 27th International Conference on Coastal Engineering, ASCE, pp. 1885-1898.- WHOI (2012) Woods Hole Oceanographic Institution: www.whoi.edu/main/auvs.
- P.S. Zakarias, "Alternative **C**ements for Durable Concrete in Offshore Environments", ShawCor Ltd, www.brederoshaw.com/literature/techpapers

Claims

1. Barrier against impulse waves such as Tsunami and/or against high sea waves comprising a wall extending preferably 20 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 which is connected with the coast in order to form large seawater reservoirs.

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 or by steel pipes 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,

-connecting the fences horizontally by formerly inserted and fixed vertical steel pipes, preferably filled with concrete, and connecting steel rings

- 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:

-Simultaneous 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. The Tsunami barrier of claims 1 to 9 and 11 is fitted with waterwheels or turbines using the inward and outward water flow for producing electric energy.

15. The Tsunami barrier establishes large reservoirs between barrier and coast which are used to pump water from one reservoir or from the sea to another reservoir using excess or low-cost electricity, and to use the height difference with turbines for generating electricity when needed.

16. 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.

17. 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.

18. 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.

19. 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.

20. 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.

21. 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.

22. System for constructing a submarine wall, such as a tsunami barrier, which is essentially made of a double-fence structure, the space between said fences being filled with rocks or rubble or concrete blocks; said system being a double-pontoon bridge comprising two parallel pontoons separated by a gap broad enough to let said rocks being immersed through it and wherein each pontoon contains fence-expending means for temporarily holding and immersing the fences into the sea.

23. System according to claim 22 wherein said double-pontoon bridge is adapted in a way as to let trucks move on it.

24. System according to anyone of the previous claims comprising assisting pontoons which are connected on one side or on both sides to said double-pontoon bridge by means of a frame of steel tubes or steel profiles from which the double-pontoon bridge is hanging by steel chains or ropes.

25. Method for constructing a submarine wall comprising the following steps :

- building a stable road as a ramp with a water depth allowing to connect to a double-pontoon bridge as defined in claim 22,
- moving and positioning the double-pontoon bridge as defined in claim 22,
- bringing unexpended fences on said pontoons,

- expending and immersing said fences and fixing their basis on the sea ground,
- horizontally connecting said fences with hooks of rings which are surrounding the vertical tubes, or by mechanical clamps, to form an extended continuous fence line,
- bringing rocks or rubble or concrete blocks on said pontoons,
- immersing said rocks through the gap formed between said two pontoons of the double-pontoon bridge.

26. Method according to claim 25 comprising furthermore the following steps :

- extending the tube and fence height to at least 2m above sea-level at high tide,
- filling the gap between the fences with rocks from ships or pontoons after the double-pontoon bridge has been moved to the next construction site,
- building a supply road on top of the fence-rock structure,
- building concrete walls seaside and coast side on top, with steel beams extending above the concrete, and thus protecting the concrete service/supply road against storm waves.

27. Method according to anyone of claims 25 or 26 comprising furthermore the temporary protection of the barrier construction work by extended horizontal steel fences floating by means of pontoons or light-weight bodies, assisted with vertical hanging

steel fences, and kept in position by fixation to the sea ground by means of chains or ropes connected to stable foundations or to heavy weights or to anchors.

28. Method according to claim 27 wherein said horizontal and vertical steel fences have, by means of holes of 10cm to 50cm diameter, a permeability for seawater which is optimized, in combination with hanging weights and fixation to the seabed, to attenuate the energy of sea waves from storms.