# Protection against Storm Surges and Tsunami by Novel Submerged and Vertical Reflecting Barrier

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Tsunami Sumatra 26.12.2004

Tsunami Tohoku, Japan 11.3.2011


Hurricane Katrina 29.8.2004


Typhoon Haiyan, Philippines 8.11.2013

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# INTRODUCTION

**These four recent catastrophes shown on the front page caused numerous fatalities and immense damages:**

| | | |
|---|---|---|
| Sumatra Tsunami 2004 | 210' 000 Fatalities | Damage 10 billion $ |
| Katrina Hurricane 2005 | 1'300 Fatalities | Damage 125 billion $ |
| Tohoku Tsunami 2011 | 19'000 Fatalities | Damage 300 billion $ |
| | | + global & Fukushima consequences |
| Haiyan Typhoon 2013 | 8'000 Fatalities | Damage 2.86 billion $ |
| Total | 238'300 Fatalities | Damage 438 billion $ |

**Such flooding catastrophes can be prevented by the novel Tsunami-Flooding-Barriers (TFB) which are proposed in the following.**
**With your support or collaboration the realization of these barriers could be accelerated.**

**The largest cities like Tokyo, New York, Mumbai, Miami, Los Angeles, Nagoya and many others could be protected against flooding from hurricanes and typhoons. Especially less-developed countries like Philippines, Indonesia, Malaysia, and Bangladesh would need protection. Also the threatened island states like Maldives could survive in view of rising sea level and increasing number and intensity of tropical storms due to climate change. These barriers are designed to withstand storm surges of frequent tropical storms, but their vertical wall submerged in the sea will also reflect the impulse waves of the less frequent tsunami before their catastrophic water fronts build up when approaching the coast.**

# OTHER APPLICATIONS OF TFB BARRIERS

**The high construction costs can partially be compensated by several applications of the large sea reservoirs formed by these TFB barriers. Perhaps the most promising applications are reclamation of new land and large-scale fish farming.**

**Reclaiming new land in front of the large protected cities and in countries with limited land resources like Japan would be interesting. The filling of the sea reservoirs can be achieved by using the large volume of the reservoir as dump for waste disposal, with proper precautions even for low-level radioactive waste. Covering with soil will allow use of the new land for agriculture and for industries.**

**Alternatively the large sea reservoirs could be used for fish farming on a scale which was not possible before. This would allow farming large and most valuable fish like tuna which are now dramatically reduced in the open sea. Fresh sea water could be supplied by the tides through gates with nets, which can be closed in case of contamination from the sea like oil catastrophes.**

**These examples of applications could be worthwhile even for coastlines which are not threatened by flooding.**

# Principle of the Tsunami – Flooding – Barriers (TFB)

**It is the first time that a submerged vertical stable barrier is proposed to reflect tsunami impulse (pressure) waves before the catastrophic high sea waves are formed near the coast. Normally, without TFB barriers, the high velocity of tsunami waves in the ocean of 700 km per hour is reduced in shallow water and their kinetic energy is transformed to potential energy causing very high sea waves. Typical heights of tsunami water fronts are 6 to 10 meters, but in the Tohoku tsunami 2011 water waves up to 38 meters have been reported.**

**With the novel vertical TFB walls the pressure waves (shown red in Figure 1) are reflected as long as the barriers have sufficient depth. This is demonstrated with the Table 1 the values of which have been derived from accepted theory for tsunami speeds and wave heights as function of ocean depth.**

**Speed of Tsunami Wave**

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

*g* = Gravitational Acceleration
*h* = Depth of Sea

**Height (Amplitude A) of Tsunami Wave**

$$A^2 \, x \, c = constant$$

(Energy Conservation)

**Tsunami Wave Heights and Wave Velocities**
(for original Tsunami Speed of 713km/hour at Ocean Depth of 4000m)

| Depth | Speed (Km/h) | Wave Height | |
|---|---|---|---|
| 4000m | 713 | 0.3m* | 0.90m* |
| 200m | 160 | 0.63m | 1.90m |
| 40m | 71 | 0.95m | 2.85m |
| 30m | 62 | 1.02m | 3.05m |
| 20m | 50 | 1.13m | 3.39m |

*Assumed typical values

**Table 1. Tsunami wave heights as function of ocean depth**

**The gap between the TFB and the coast can be filled up with sand or gravel, or it can be used as large dump for waste material which could be of interest for large coastal cities.**

**The concrete wall above the TFB barrier of 6 to 8 meters high will reflect the storm surges assisted by the replaceable surge stoppers. The latter will protect the concrete wall against erosion. The service road will allow to monitor the TFB barrier front and develop as attraction for tourists, but also to replace the surge stoppers.**

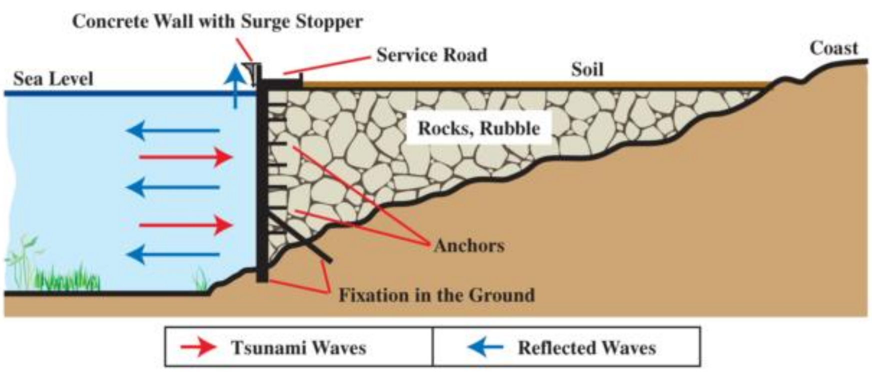


**Figure 1. Schematic cross section of a vertical barrier in the sea which reflects the tsunami impulse waves (shown red). The gap between barrier and coast is filled up for reclaiming new land, thus can be used as dump for waste**

# Brief Description of TFB Construction

## Double-Pontoon Technology:

A double-pontoon bridge starts from a ramp at the coast (see Figure 2a) and allows to insert long steel fences from special trucks on both sides (see Figure 2b), and to drop rocks into the gap between the two pontoons, in order to erect long stable vertical walls fixed at the bottom of the sea. This is assisted by vertical steel pipes, filled with concrete and fixed in the sea bed, to connect neighboring steel fences by steel rings to erect a long horizontal barrier, with depth between 20m and 200m, preferred 30m, parallel to the coast and thickness between 5m and 20m, with TFB extensions to the coast in order to form large sea reservoirs.

This barrier extends 6 to 8m above sea-level and is covered by a supply and service road. This is flanked on both sides by concrete walls with (replaceable) surge stoppers (parapet) which prevent overtopping from storm waves and protect the concrete walls against erosion from the storm waves.

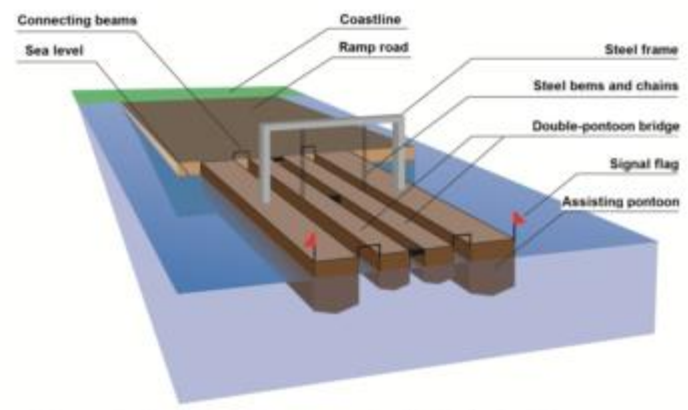


Figure 2a. Double-pontoon connected with the land by a ramp road. Assisting pontoons increase the load capacity. Schematic view.

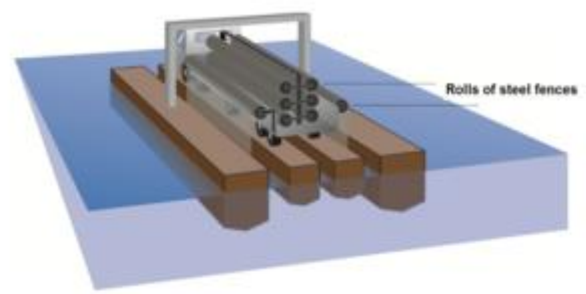


Figure 2b. Schematic view of a truck on a double-pontoon bridge inserting simultaneously two steel fences into the sea

The rocks are excavated from a nearby hill or mountain and transported by special trucks directly to the double-pontoon bridge. By this excavation an artificial lake can be formed which serves as reservoir for pumped hydroelectric energy storage as schematically shown in Figure 3. Excess low-price electricity from photovoltaic solar panels and from gas- or nuclear power-plants is used to pump sea water up to the artificial lake. During night or at times of electricity shortage water from the lake drives the turbines in order to generate electricity. This will assist to balance the electric power grid.

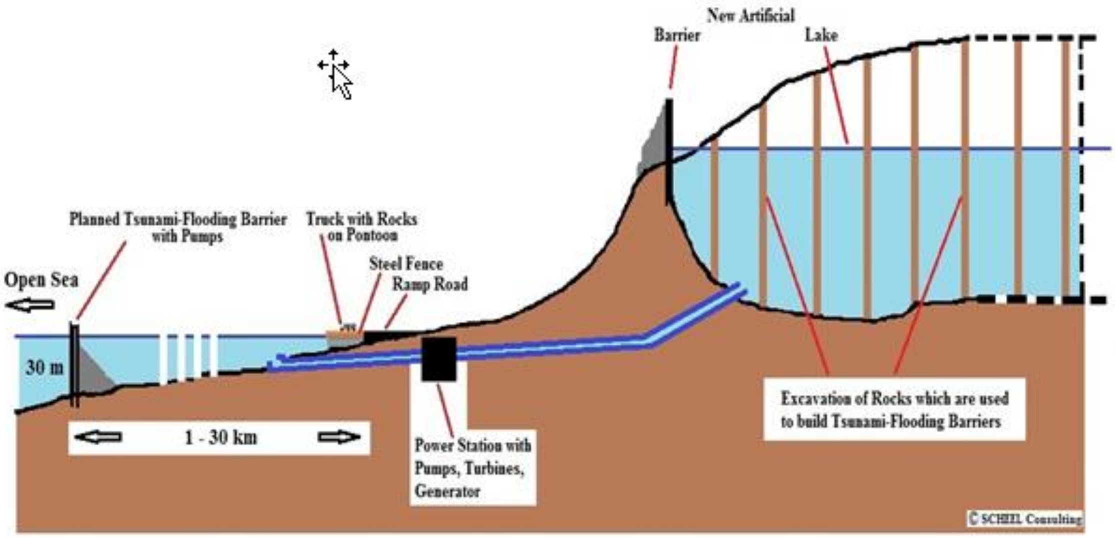


**Figure 3. Hydroelectric energy storage by pumping sea-water to the artificial lake which is formed by excavating rocks for the construction of tsunami-flooding-barriers, schematic cross section**

**Details of the double-fence tsunami-flooding barrier are shown as cross section in Figure 4. The fences consist of corrosion-resistant US 316L or 316LN steel or of a European steel like 1.4429, 1.4571(V4A) of high strength and resistant against sea water. Horizontal steel bars serve as distance holders for the parallel fences and are anchored between the rocks deposited at the coast side of the TFB to increase the stability of the barrier.**

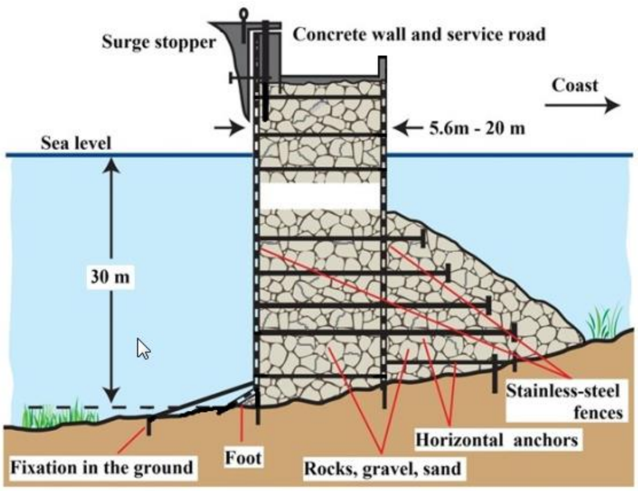


**Figure 4. Double-fence tsunami-flooding-barrier with concrete service road, concrete walls and surge stopper, schematic cross section**

# Cylinder Technology:

An alternative very efficient construction uses very long (0.1 to 1 km) triangular steel-fence or steel-plate cylinders fabricated in the harbor. The steel-fence cylinders are surrounded by steel plates or by geotextile in case of rock-filling. These hollow empty cylinders are floated to the site which before had been prepared by dredging. The floating process is assisted with pontoons or ships which keep the cylinder in horizontal upright position and which control the horizontal sinking to the ground. Figure 5 schematically shows the cross section and the front view of a cylinder barrier. These cylinders are then filled with rocks, concrete, gravel, or sand to achieve a submerged stable vertical barrier, also with a top road, side concrete walls and replaceable surge stoppers of concrete.

This cylinder technology allows to install long tsunami-flooding-barriers in relatively short time.

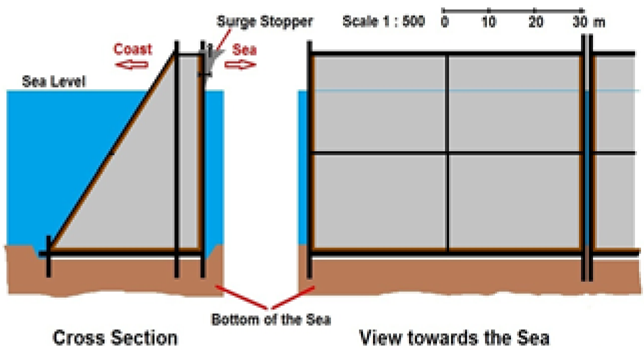


Figure 5. Long triangular and empty cylinders are fabricated in the harbor, transported to the barrier site, fixed in the sea-ground, and filled with sand.

Dredging ship to prepare the barrier site and fill the cylinder (Van Oord ship)

Navigation is arranged with gates, channels and sluices which are closed upon tsunami-, storm- or oil-spill warning and thus the barriers protect flora, fauna, and beaches.

During construction, the work is protected by an extended (0.1 to 1 km) horizontal steel fence, which is kept floating by pontoons and fixed in the sea bed, in order to attenuate storm waves. The holes in the steel fence are optimized for dissipating the wave energy. At heavy storms the work is interrupted.

# Failure of Conventional Breakwater

**A large fraction of breakwaters are composed of caissons sitting on rubble mounds or foundations. Despite theoretical and experimental studies such breakwaters frequently failed because the caissons slit or tilted. A prominent example is the Kamaishi breakwater in Japan. It had been celebrated on September 27, 2010 as the world's largest breakwater after 31 years of construction at the cost of 1.3 billion $. On March 11, 2011 the Tohoku tsunami destroyed the breakwater, lower Kamaishi and caused about 1000 fatalities. Figure 6a shows the Kamaishi breakwater before and Figure 6b after the tsunami. This failure was caused by the deviation from the optimum vertical barrier construction, by the slopes on both sides in front of the breakwater, and by the funneling effect of Kamaishi Bay.**


**Figure 6a shows the north and south sections of the celebrated Kamaishi breakwater after completion Sept. 27, 2010**

**Figure 6b gives the top view of the damaged Kamaishi breakwater after the Tohoku tsunami March 11, 2011**

**A new vertical tsunami-flooding-barrier erected in front of the bay would prevent such catastrophes.**

# Threatened Cities and Coastlines to be Protected

**All coastlines which are threatened by hurricanes, typhoons or tsunami should be protected. However, in view of financial restrictions the priority could be with large cities, with power plants and other important industries, and with popular beaches. Also the survival of the island states like Maldives could be extended in view of raising sea-level and increasing frequency and intensity of storms due to climate change. Helpful are historical and theoretical studies of expected tsunami wave heights as it was done for New Zealand and as it is shown in Figure 7.**

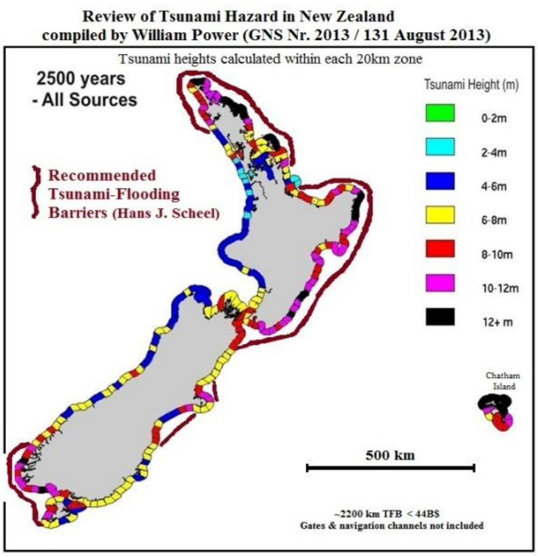


**Figure 7. Estimated tsunami wave heights of New Zealand along with proposed tsunami-flooding-barriers**

**History:** **The author had enjoyed many visits to Japan including collaboration, support and as visiting scholar/professor. He had received the Dr. of Engineering from Tohoku University, Sendai, Japan. After successful career in crystal technology (see www.hans-scheel.ch ) and retirement he was shocked by the Tohoku tsunami catastrophe. In studies of tsunami books and literature he discovered that a submerged vertical barrier reflects tsunami and storm waves. Lectures at international conferences and in publications confirmed the principle, and patent applications were placed internationally. The Project (TsuBar) of collaboration about computer simulation of the hydrodynamics and the stability of tsunami-flooding-barriers with the Technical University Braunschweig/Germany, Department of Hydromechanics and Coastal Engineering, has proven the TFB concept and estimated the load on the barrier.**

## Soonest Possible Protection by TFB

**How can the realization of the Tsunami-Flooding-Barriers be accelerated to save countless lives against flooding from tropical storms and from tsunami?**

**How can the governments of threatened countries be activated to study the necessary conditions and efforts to build such barriers? And thereby stimulate steel-, concrete-, construction-, transport-, dredging- and ship-building-industries and provide jobs for ten-thousands of workers?**

**Such projects are very large so that developing countries like Indonesia, Philippines, Malaysia, and also India and Sri Lanka will need support from World Bank and other institutions and foundations.**

**Japan has started to erect huge concrete walls of more than 8 meters height on the shoreline and expects to spend 8 billion USD for 400 km walls. These gigantic barriers are doubted to withstand strongest tsunami and anyhow will not prevent overtopping from highest storm and tsunami waves. However, these walls will reduce somewhat the harmful effects of flooding as recently demonstrated in Fudai, Japan. There is a lot of resistance from fishermen and coastal population, also from tourist organizations which are afraid of loosing access to the sea and the view to the beautiful shores and islands of Honshu east coast.**

**The now proposed TFB barriers are far out in the sea, would not disturb and would cost much less.**

## How can you contribute?

**As sponsor or as investor and partner for a small company which will take care of the granted patents in Singapore, New Zealand and Europe, the other patent applications and the expected licenses or sales income, which will accelerate collaboration with specialized university institutes and general contractors towards optimization of barrier design and realization, and which will hire an engineer and a marketing specialist for publicity and for contacting general contractors, governments and foundations. Furthermore, the transfer of the project to a strong active industry partner or general contractor could be considered.**

GPE

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*The Logo schematically shows the red Tsunami impulse wave and the reflected white pressure waves as well as the high storm waves (blue) reflected by the vertical submerged barrier.*