

## The safety of the shipping and ports in the aspect of the tsunami events

## Bezpieczeństwo żeglugi i portów w aspekcie wystąpienia tsunami

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**Key words:** tsunami, the safety of the shipping and ports, tsunami arrival time

### Abstract

The paper presents the influence of the tsunami on the safety of the shipping and seaports. The analysis based on the tsunami from 11 March 2011 on Japanese islands and coasts of Pacific. The paper describes the destruction caused by tsunami waves, both in port and coastal infrastructure. A list of casualties in dry bulk vessels and boats in Japan and in the U.S. coasts is presented. Recommendations for ships with the warnings and messages before the tsunami are identified.

**Słowa kluczowe:** tsunami, bezpieczeństwo żeglugi i portów, czas przybycia tsunami

### Abstrakt

W artykule przeanalizowano wpływ fali tsunami na bezpieczeństwo żeglugi i portów morskich. Analiza oparta jest o tsunami z 11 marca 2011 r., które wystąpiło na wyspach japońskich i wybrzeżach Pacyfiku. Opisano zniszczenia wywołane falą tsunami w infrastrukturze portowej i brzegowej, a także przedstawiono wykaz strat wśród statków masowych i mniejszych jednostek w Japonii i u wybrzeży USA. Wskazano rekomendacje dla statków przy ostrzeżeniach przed tsunami i komunikatach.

## Introduction

The term tsunami has been adopted directly from the Japanese language, a combination of the words *tsu* and *nami*, which mean, respectively, port and wave, that is a port wave. The tsunami is most often the effect of seismic phenomena occurring on the Earth. It is formed as an effect of an earthquake that takes place on the ocean or sea bottom, or earthquakes in the coastal area. It can also be generated by an underwater explosion of a volcano, slip of a steep slope on the coast, landslide phenomena in ocean trenches or underwater canyons. It is also assumed that the tsunami may be caused as a result of a huge meteor hitting the surface of the ocean or sea.

Arcas mostly endangered by tsunami waves are the coasts of the Pacific Ocean, and less likely, other regions of the Earth, such as the coasts of the Mediterranean Sea and the Caribbean and the Indian Ocean. It often happens that densely populated, well developed and tourist-attracting areas are struck. In the years 2001–2011 all over the world appeared 100 fully documented the tsunami events. The most of events was caused by the earthquakes from 5.3 to 8.0 on the Richter scale. As many as 11 events tsunami after the earthquake occurred above 8°R [1]. In recent years, the most significant events include the tsunami in the Indian Ocean of 12.26.2004 (9.1°R), the Solomon Islands from 01.04.2007 (8.1°R), the Samoa Islands from

29.09.2009 (8.0°R), in Chile from 28.02.2010 (8.8°R). The last catastrophic tsunami was a tsunami in the Japanese islands (Honshu island) of 11 March 2011 (9.0°R) as a result of which died more than 15 800 people.

The purpose of this paper is to analyze the impact of tsunami on the safety of shipping and ports on the example of recent catastrophic tsunami that occurred on the Japan islands and the Pacific coast on 11 March 2011. The result of this analysis are recommendations for ships operating in the coastal zone, as well as for ships at berth in port or on moorings. Such recommendations are designed to improve maritime safety procedures and to reduce risks in ports and coastal areas in the event of a tsunami.

The physical description of the phenomenon of tsunami authors concluded in previous publications [2, 3, 4, 5].

### The destruction of ports and ships during the tsunami events at March 11, 2011

1 March 2011 at 5:46:23 UTC (2:46:23 p.m. local time) in the northeastern part of Japan occurred earthquake with a magnitude 9 on the Richter scale. Hypocentre was located under the seabed, some 130 kilometers east of the Oshika peninsula on the island of Honshu, at a depth of 24.4 km. Force magnitude made it the largest earthquake in Japan since 140 years.



Fig. 1. Japanese ports damaged by the tsunami of March 11, 2011 [7]

Rys. 1. Porty japońskie uszkodzone przez tsunami z dnia 11 marca 2011 [7]

The earthquake created a high, over 8-meter tsunami waves that hit in almost the entire north-east coast of Japan, flooding, sea ports, industrial zones, cities, villages, farms, fields and forests of the coastal region of Tohoku. On plains the sea water intruded upon 10 km far inside the land. It is estimated that the total area flooded was 561 km<sup>2</sup> [6]. As a result of the earthquake and tsunami damage occurred in all the various ports in the north-eastern coast of Japan until the Tokyo Bay (Fig. 1).

Overall, the tsunami disaster on the Japan's coast touched 16 major ports. The most seriously damaged by the tsunami and earthquake were ports: Hachinohe, Sendai, Ishinomaki and Onahama. These ports were engaged in container handling medium size, fuel products and dry bulk trade. Reopened on a limited basis a few months. Port of Sendai, who was one of the 23 ports designated by the Japanese government as particularly important for international maritime transport, it was only in September 2011 launched its container services, transport routes with China and South Korea were reopened [8, 9].

Ports with less severe damage (of varying degrees of damage) are: Hitachinaka (forwarding cars and mid-size containers), Kamashi (handling large containers), Hitachi, Kesenuma, Miyako, Ofunato, Shiogama, and Soma. These ports were reopened a few weeks. Port of Tokyo and south port of the capital of Japan was not affected by the tsunami and were closed only in the short term disaster [10].

The closure of the ports was expected to cost Japan more than US\$ 3.4 billion in lost seaborne trade each day, according to shipping trade publication Lloyd's List Intelligence [8].

The observed damage to the ports in the north-eastern coast of Japan were characteristic port damages after this type of disasters (Table 1).

Many ships broke the mooring ropes and chains, the vessels collided with another ship, port facilities or buildings, many ships and smaller boats, the tsunami wave was ashore. Some of the damaged ships have caused oil spills in the waters in the harbor. Tsunami inundation height and a list of damages to Japanese ports during the tsunami of March 11, 2011 shown in table 2.

Container terminals in ports strongly affected by tsunami flooding. More than 4,000 containers at the port of Sendai outflow from the storage locations and 1,000 of them flowed into the sea. The processes of the outwashing and sediment deposit occurred in the majority of ports and shipping channels (with one of the piers was observed flushing of sediments

Table 1. Damages due to tsunami more than 10 m [11]

Tabela 1. Rodzaje zniszczeń przez falę tsunami o wysokości ponad 10 m [11]

| General  | Ports and Coasts  | Coastal Defenses   |
|--|---|--|
| <ul style="list-style-type: none"> <li>– Destruction and washed-away of houses</li> <li>– Drift and crash of cars</li> <li>– Fires</li> <li>– Destruction of tanks and oil spill</li> <li>– Destruction of Railways, Road and bridges</li> <li>– Subsidence of ground</li> <li>– Inundation of rice paddles</li> </ul> | <ul style="list-style-type: none"> <li>– Drifting and collision of ships</li> <li>– Destruction and inundation of port facilities</li> <li>– Drifting and collision of timbers and containers</li> <li>– Debris deposit in ports</li> <li>– Scouring and deposit in ports</li> <li>– Scouring of sandy beaches and destruction of green belts</li> <li>– Destruction of aquaculture facilities</li> </ul> | <ul style="list-style-type: none"> <li>– Scouring and sliding of Breakwaters and quaywalls</li> <li>– Destruction of jetties and detached breakwaters</li> <li>– Destruction (scouring) of Dykes and Seawalls</li> <li>– Destruction of water gates</li> </ul> |

Table 2. Height of tsunami inundation and destruction in the ports of north-eastern Japan [12]

Tabela 2. Wysokość zalania falą tsunami oraz zniszczenia w portach północno-wschodniej Japonii [12]

| Port            | The inundation heights of the area or the maximum tsunami wave height [m] | Destruction of port facilities and hydrotechnics   |
|-----------------|---|--|
| Hachinohe       | Areas of the breakwater: 5.4–6.4 m<br>Other areas: 8.0–8.4 m              | North breakwater caissons of 1870 m out of the total length of 3500 m were slipped out and submerged, being affected by tsunami. Significant seabed scours were observed at the mouths of the breakwaters as well as along with the reclaimed island quay. |
| Kuji            | Port areas: 8.3–8.5 m<br>Other areas: to 13.4 m (max. wave height)        | Outer breakwaters were visibly observed un-damaged. Floating dock was half-sunken, which was moored near the central point in the harbor. Upper concrete walls of caissons temporarily placed behind the breakwater were damaged.                          |
| Kamaishi        | Inner port area: 6.9–9 m  | Most wooden houses were floated out completely. Reinforced concrete (RC) buildings and large-scale grain silos were damaged but not collapsed. A number of vehicles together with destroyed houses were observed floated out on the road.                  |
| Ofunato         | Inner port area: 9.5 m<br>Other areas: 11–23.6 m (max. wave height)       | Many iron concrete buildings were observed inundated up to the second floor, having many logs stuck in windows, while most wooden houses were completely destroyed.  |
| Onagawa         | Port areas: 14.8 m  | Almost all the wooden houses were completely destroyed on the flat area. Reinforced concrete buildings were severely damaged but stayed at the original position. However, some steel-frame buildings were over-turned.                                    |
| Ishinomaki      | Port areas: 4.1–5 m   | Warehouses and reinforced concrete buildings were damaged but not collapsed. On the other hand, some wooden house were floated out several hundreds meters inland.   |
| Sendai-Shiogama | Port areas Sendai: 7.3–8.0 m<br>Port areas Shiogama: 4.1 m                | Significant numbers of tank trucks, vehicles and containers were floated out on the roads, having resulted in some damages on the many buildings.  |

to a depth of 10 m). Work on removing the debris sunk in port waters began immediately after the resolution of a wave and a week after the earthquake a few ports opened to a limited number of berths [11].

Number of quays provisionally available for use at the affected (public quays of 4.5 m or deeper): 253/373 berths ports by the state on 6 December 2011. Most of the transshipment facilities after the tsunami required or requires repair. Some of them are available only with restrictions loads. All operators of passenger ferry services partially resumed and middle-long distance ferries operated by Taiheiyo Ferry Co. Ltd. have complete resumed [13].

The central government has said that 319 fishing ports in seven prefectures ranging from Hokkaido to Chiba – about 10 percent of the country's 2914 fishing ports – were damaged in the March disasters [14]. Also small boats including fishing boats

were carried far inland areas and it is estimated that more than 17,000 boats were damaged [11].

As a result of a nuclear power plant disaster in Fukushima, Japan, the authorities introduced a temporary 20-nautical-mile safety zone around the port Daichi, in which navigation is prohibited [15, 16] (Fig. 1).

#### Japanese ports – hydrotechnical shield against tsunami

Japanese hydrotechnical objects in different ways and to varying degrees, protected the ports and coastal zone during the tsunami of 11 March 2011. Ofunato Bay is an elongated stretch of north-south direction which facilitates the emergence of the resonance wavelength during the tsunami attack. After the tsunami in Chile in 1960 the entrance to the Gulf of Ofunato at a depth of 22 m seawall with a height of 6 m was built. However, the tsunami of March 11, 2011 swept through

the seawall and flooded the port and the coastal areas 3 km inland, reaching a maximum level of 23.6 meters in height (tsunami run-up). Another example is the Fudai port located south of the port of Kuji in northern Japan. In Fudai in 1984, built 15.5 meter high gate before the tsunami after the tragic tsunami disaster of 1896 and 1933, when died several hundred people. Although in 2011 tsunami reached a height of 17 m and overflowed through the gate, however, was flooded only a few hundred meters of area of the gate and there were no fatalities [17].

In the port Kamaishi the tsunami wave exceeded and damaged the breakwater (6 m) and the seawall (4 m) and rushed in downtown with a very large speed from 10 to 30 km/h. One ought to notice that the tsunami wave (the average height – 8 m) exceeded in this port the wave height during the tragic tsunami of the year 1896 – 5 m [11] (Fig. 2).

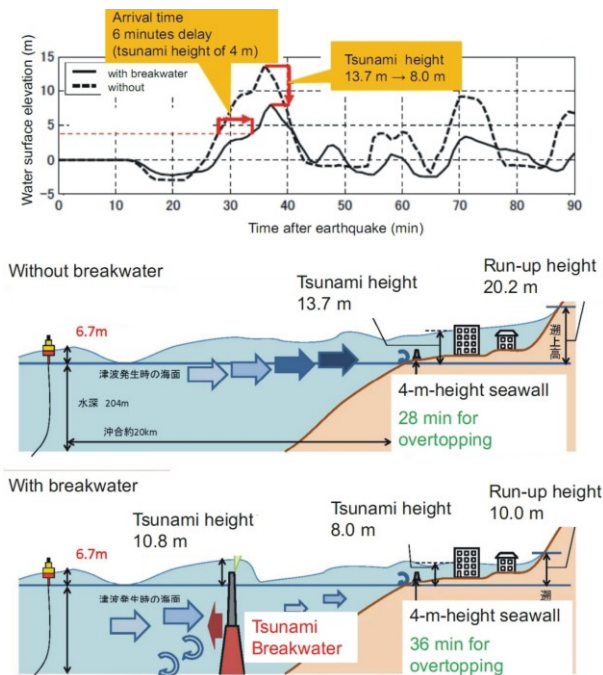


Fig. 2. Effect of breakwater during the tsunami from 11 March 2011 [18]

Rys. 2. Efekt działania falochronu podczas tsunami z 11 marca 2011 r. [18]

The results of analyzes carried out by the Port and Airport Research Institute indicate a large utility breakwaters both in reducing tsunami wave heights of 13.7 m to 8.0 m, as well as the delayed wave arrival at the port (6-minute delay in the coming four meter waves). Although the construction is not completely protected the port from flooding and damage, but by precipitation of the tsunami wave energy on the breakwater port infrastructure damage was less and the same delay flooding the port could save human lives [18]. However, experts

disagree as to the overall effectiveness of this type of building safety. Some even believe that such structures increase the extent of the damage, because they do not allow water back into the sea during the negative phase of the wave [19].

**Destructions and damages of ships during the tsunami on 11 March 2011**

At the time the tsunami hit, Lloyd’s of London reports that up to 3300 vessels were located along the eastern coast of Japan [10]. 31 passenger ships were severely damaged including 2 partially damaged according to Tohoku-disrict passenger ship association [11].

The tsunami of March 11, 2011 damaged at least a dozen large commercial vessels, including vessels connected to major ocean carriers “K” Line, NYK Line, Mitsui O.S.K. and Hyundai. The list of damaged large vessels are shown in tables 3 and 4 [10, 20, 21, 22].

Table 3. Ships damaged which ran aground or ashore  
Tabela 3. Statki uszkodzone, które osiadły na mieliźnie lub lądzie

| The type of the ship | DWT [tonnes] | The ship name         | Port                |
|----------------------|--------------|-----------------------|---------------------|
| freighter            | 175 775      | China Steel Integrity | Kashima,            |
| bulk                 | 91 439       | MV Shiramizu          | Soma (Shinchi)      |
| bulk                 | 77 739       | MV Shirouma           | Haramachi           |
| bulk                 | 32 385       | Victory               | Ishinomaki          |
| freighter            | 6 901        | Glovis Merkury        | Sendai              |
| freighter            | 6 175        | Asia Symphony         | road close Kamaishi |
| general cargo        | 1 592        | Koshin Maru           | –                   |
| Reefer               | 523          | Khrizolitov           | Ofunato             |
| fishing vessel       | 379          | Yahata Maru No.35     | Kesennuma           |
| fishing vessel       | 221          | Kinei Maru No. 31     | Kesennuma           |
| fishing vessel       | –            | Genei Maru No. 88     | Hachinohe           |

Table 4. Damaged vessels that broke moorings and drifted in the harbor

Tabela 4. Statki uszkodzone, które zerwały cumy i dryfowały w porcie

| The type of the ship | DWT [tonnes] | The ship name | Port                                    |
|----------------------|--------------|---------------|---|
| tanker               | 75 395       | Coral Ring    | collision with a pier in Onahama        |
| bulk                 | 51 149       | Emu Arrow     | Kashima                                 |
| container            | 44 585       | Long Mu Wang  | Kushiro                                 |
| research/drilling    | 27 161       | Chikyu        | collision with a pier in Hachinohe      |
| general cargo        | 24 000       | Sider Joy     | Yamanishi shipyard / port of Ishinomaki |
| general cargo        | 24 000       | Tulipan       | Yamanishi shipyard / port of Ishinomaki |
| tanker               | 9 515        | Golden Grace  | Kashima                                 |

Tsunami wave reached the coast of Hawaii after 7 hours of the earthquake in Japan, and after a further 2–3 hours to the coast of California. Damage in Hawaii and California ports, mainly related to port facilities and tourist yachts and fishing boats. A detailed list of damaged yachts is shown below [20].

#### Vessels that have been damaged or which sank in Brookings Harbor, Oregon

1. Panda – 48 feet (sunk, scrapped).
2. Lions Whelp – 92 feet (sunk, scrapped).
3. Super Star – (damaged).
4. Haida – 68 feet, 220 tons, (damaged).
5. Pegrin II – 46 feet (completely destroyed).
6. Bret Mar – 34 feet (damaged).

#### Vessels that have been damaged or have sunk in the Crescent City Harbor, California

1. American Maid – (sunk).
2. Banshee – (damaged).
3. Bonita
4. City of Eureka
5. Cyrano IV – (sunk, scrapped).
6. Daphne – (sunk).
7. Debi J – (damaged).
8. Ge Ge – 38 (sunk, scrapped).
9. Hard Rock – (sunk, scrapped).
10. Kodiak – 68 feet (sunk).
11. Nellie – 34 feet (sunk, scrapped).
12. Neva D – removed from the port.
13. Award – 39 feet (sunk).
14. Ruth M – 29 feet (sunk).
15. Stormy – 33 feet (sunk).
16. Tamera – 30 feet (sunk, scrapped).

Damage to the port of Santa Cruz, California, as a result of the tsunami is estimated at 17 million dollars. In the harbor were sunk or damaged about 40 private yachts worth a total of four million dollars [23]. The greatest damage in Hawaii, the tsunami has made the island Oahu in Keehi Lagoon at the port of Honolulu. There were damaged about 200 boats. Many of them free themselves of berths and freely floating down the lagoon [24].

### **Recommendations for vessels operating in the coastal zone**

The characteristics of the tsunami shows that the wave can be dangerous only for vessels in coastal areas and in ports. On the open sea the tsunami wave is not noticeable for the crews of ships. The situation changes when the waves reach the coast zone, where depths are less than 50 m and height of tsunami waves grows rapidly.

In order to avoid danger from the tsunami waves in coastal areas it belongs to move the ship in an

area with greater depths. However, remember that today's progress in building ship's the value of 50 meters may be insufficient. Ships such as VLCC (Very Large Crude Carrier – vessels for the transport of petroleum products 160 thousand to 320 thousand DWT) and ULCC (Ultra Large Crude Carrier – 320 thousand – 550 thousand DWT) are characterized by a considerable size and draft. Maximum draft of these vessels is 28 and even 30 meters. In this case, the depth limit given above can not be taken into account because the supply of water under the keel is too small. This threatens with drifting of the ship, with the embedment aground and in some cases at the large wave height with the strike for the bottom. The vessels of this type should have accepted the limit of the depth even 120 metres. In order to unify this dependence can be assumed for all ships – safe depth limit as 4 to 5 times as the draft. This result, however, may not be less than 50 meters [25]:

$$H_{\text{safe}} = 4 \div 5 D_S \text{ [m]}$$

where:

$H_{\text{safe}}$  – safe depth for the tsunami,  $H_{\text{safe}} > 50$  [m];

$D_S$  – draft of the ship.

This dependence will allow vessels working on the engine to safely stay in the tsunami.

Another suggestion to avoid the direct impact of the tsunami it belongs to move the ship in sheltered place, part of the island or peninsula, which significantly reduce the impact of the wave. Such a manoeuvre can be applied in the absence of time to ship out to deeper water.

### **Recommendations for ships at berth in port or on moorings**

The tsunami of 11 March 2011 revealed the real danger for ships staying in the port [26].

The effect of tsunami on ships in port are presented in table 5.

Table 5. Relations between tsunami magnitude and ship damage [26]

Tabela 5. Związek między wysokością tsunami a zniszczeniami statku [26]

| Tsunami Magnitude                                | Ship Size  | Damage Pattern   |
|--|------------|--|
| Small<br>(Tsunami height:<br>more than 2 or 3 m) | Small Ship | – Drifting<br>– Collision with quay wall<br>– Overturning / Sinking<br>– Being cast ashore |
|  | Small Ship | – Being cast ashore<br>– Collision with buildings  |
| Large<br>(Tsunami height:<br>more than 5 or 6 m) | Large Ship | – Drift<br>– Collision with quay wall<br>– Being cast ashore<br>– Collision with buildings |

Table 6. Standard recommendations for the operations of the ship before the tsunami (own study based on the data from the Japan Association of Marine Safety 2004 [26])

Tabela 6. Standardowe rekomendacje co do działań statku przed tsunami (opracowanie własne na podstawie danych z Japan Association of Marine Safety 2004 [26])

| Tsunami magnitude forecast |   | Time until tsunami arrival | Moored ship in port  | Anchored ship, buoy-moored ship   | Ships during the shipping in the port and in the roads |
|----------------------------|---|----------------------------|--|---|--|
| Tsunami Warning            | Strong tsunami (3 m, 4 m, 6 m, 8 m, > 10 m) | Short (< 0,5 h)            | Halt cargo handling. The recommended evacuation of the crew to land  | Use engine  | The recommended offshore evacuation                    |
|                            |   | Medium (0.5–1.5 h)         | Halt cargo handling. The recommended offshore evacuation of the ship. Possible evacuation of the crew to land          | Use engine or possible offshore evacuation  |  |
|                            |   | Long (>1.5 h)              | Halt cargo handling. Offshore evacuation.  | Offshore evacuation   |  |
|                            | Average tsunami (1m, 2 m)                   | Short (< 0.5 h)            | Halt cargo handling. Strengthen mooring. Possible evacuation of the crew to land                                       | Use engine  | Offshore evacuation                                    |
|                            |   | Medium (0.5–1.5 h)         | Halt cargo handling. Strengthen mooring. Offshore evacuation or evacuation of the crew to land                         | Use engine or possible offshore evacuation  |  |
|                            |   | Long (>1.5 h)              | Halt cargo handling. Strengthen mooring. Offshore evacuation or evacuation at designated places of refuge in the port. | Offshore evacuation   |  |
| Tsunami Advisory           | Small tsunami (< 0.5 m)                     |                            | Halt cargo handling. Strengthen mooring. Possible offshore evacuation  | Note the conditions (if not worse in the next message). In these cases, use engine or offshore evacuation | Offshore evacuation                                    |

It is therefore essential to develop a set of effective remedies that can be used by ships in the event of a tsunami. A good example of the procedures proposed Japan Association of Marine Safety (2004) [26]. The specific procedures that should be done by the captains of ships depend on the height of the tsunami, time available, size and condition of the ships. According to these guidelines, the main actions that can be taken are: evacuation on the vast, deep offshore waters and mooring, the ship with many long mooring-ropes on the open and deep anchorage. In this paper, the authors present a simplified procedure for the action before the tsunami, which take into account the division of the ships moored in the harbor, as well as vessels in navigation (Tab. 6).

The best way to prevent damage to the ship by a tsunami is evacuation outside the port. However, this method can only be used if there is enough time before the arrival of the tsunami. If there is not enough time before the tsunami attack, ships should remain in port. Such a situation is possible when the expected wave height is not excessive. In addition, the favorable conditions is the location of a port that is not directly exposed to the shock wave. An important element is also the form of seabed in the coastal zone and at the entrance to the harbor. Ships in the harbor in tsunami time should get maximum draft at port area. Such location during the tsunami attack will cause backboard ship's

hull on the quay. In addition, a maximum draft at raising the water level will allow for good contact between the hull and the quay [25].

Another of the countermeasures is reinforcing the mooring system and the properly evaluation of tsunami forces and mooring forces. The calculated mooring forces are usually small when the tsunami current is parallel to the ship. However, if the tsunami induces the harbor oscillations (so-called long-period oscillations with the period of 1 to several minutes) the mooring forces become large since the inertia force becomes large due to high current acceleration. The mooring becomes difficult especially when the period tsunami wave is close to a resonant period of ship motion [27].

Countermeasures for mooring during the tsunami should be:

- increasing the number of mooring ropes;
- automatic regulation of mooring ropes – the ship cannot “hang” on the ropes;
- avoid the places in the port where the tsunami current is complicated and strong. Especially the places where the harbor resonant oscillations are significant should be avoided.

## Conclusions

Since we are not able to predict an earthquake, earlier prediction of tsunami is not possible. However, we know that a tsunami wave spreads with



a finite speed and thus, if we know the place where an earthquake struck, we know its force and the shape of the bottom of the water area, we can evaluate the speed with which a tsunami wave is going to spread and its initial energy

The relation used for forecasting tsunami arrival time has been worked out from many empirical data obtained from previous earthquakes and tsunami wave  $T_{TS} = 5x$  [s], where:  $T_{TS}$  – time of tsunami arrival in seconds,  $x$  – distance from the epicenter in kilometers [25].

Japan is independent of the Pacific (Pacific Tsunami Warning Center) tsunami warning system. This system monitors seismic activity around the clock and issue tsunami warnings, both the Japanese islands and adjacent seas. It consists of a network of 182 terrestrial and 80 underwater seismometers, a network of 3900 sensors – seismic intensity meter, a network of 180 gauge stations (measuring sea level). Data from all measurement networks are collected and analyzed in real time through a special computer system in Japan Meteorological Agency (JMA). If there is an earthquake, JMA immediately determines its hypocentre, magnitude (size) and intensity. If the earthquake occurred on the ocean floor and had a size pointing to the emergence of potential tsunami database, system immediately analyze measurement data and numerical simulations and then issues tsunami warning containing the arrival time to the coast and the tsunami wave amplitude. JMA provides warnings and messages about the tsunami to government and local emergency response teams, Japan Coast Guard and broadcasting stations within 3 minutes. Messages about the possible tsunami appear on television at the moment in which they are issued. The alarm is also sent by mobile phones and the Internet. Local authorities start sirens and megaphones and decide to evacuate people from areas at risk of tsunami [19, 28].

Although, such an advanced tsunami warning system at 13 March 2011 failed to fully protect the population and to secure infrastructures of ports and shippings. Testified that statistics of deaths and economic losses estimated at hundreds of billion dollars. However, the existing warning system in Japan came true. Losses in the population in Japan were more than 10-fold lower than during the tsunami on the shores of the Indian Ocean where there was no warning system.

Ships which got the warning before the tsunami and were not during the unloading, attempted to go out from ports to the offing. But too close distance from the epicenter to the coast of Japan, it caused that many ships have been damaged or sunk by

tsunami. Therefore, it is very important for the safety of shipping and ports immediate implementation of existing procedures and recommendations for the operation of ships before the tsunami.

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