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PILOT IMPLEMENTATION OF TSUNAMI DESIGN STANDARD IN RUSSIAN FAR EAST

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Abstract

Pilot implementation of a draft of tsunami design code is under consideration. This code is intended to ensure the sustainable safety of coastal urban area and should be tested in practice to meet the conditions of permissible risk. The lessons learned from Tohoku tsunami disaster allowed to improve the previous standard. Terms and definitions, tsunami hazard maps and other source data, design conditions and safety criteria in relation to both of coastal and onshore facilities and also to coastal urbanization as a whole were improved. Implementation into practice is shown on the examples of the 23 berthing facilities in the ports of Korsakov and in the port of Kholmsk on Sakhalin Island, Russian Far East. Additional theoretical research, simulations and natural experiments on interaction of long tsunami waves with structures of various sizes, shapes and permeability and streamlining are required to better understand how to assign the tsunami loads. The engineering community is invited to join efforts in order to create a global directory of the protecting methods and technologies against tsunami impact. Directory has to be supplemented by examples of applications into practice.

Keywords: tsunami hazard map; urban areas; coastal and onshore; tsunami design code; pilot implementation

1. Introduction and background

Awareness of necessity to develop special regulations (building code) to protect the coastal urban areas against tsunami impact appeared in Russia after devastating tsunami which struck the Eastern coast of Kamchatka and Paramushir Island in 1952. Since the beginning of 1970-th first engineering problems of dynamic interaction between various barriers and waves of "tsunami type" were studied and solved in R & D Centre #26 (Russia), using testing pools and artificial water flow, with the active participation of I.Nudner, V.Maximov and S.Manoilin [1,2,3]. Attempts to develop a tsunami engineering code and rules to increase the safety of the floating, onshore and offshore structures in tsunami hazardous areas (THA) and reduce the real economic damage caused by this destructive and unpredictable phenomenon were repeatedly initiated by M.Klyachko since 1982. As a results of above mentioned attempts, only one not very large guideline [4] was accepted by "Soyuzmorniiproekt" since 1986 in order to use in the design practices as an institutional document. Unfortunately, a national tsunami design code (TDC) was not created at that time. Only 25 years later in accordance with the decision of the intergovernmental Council for cooperation in construction activities of the CIS countries (10-11 June 2010) the 1st edition of the project for the international standard "Buildings, structures and grounds. Safety requirements when the impact of the tsunami" (1.13.465-2.014.11) began to develop in the RADAR and were finally registered in Rosstandart on 28 February 2011. However, the subsequent restructuring of the system of building coding in Russia has demanded changes for such documents as "the standard", which could not by itself be used as a fundamental norm for design. Lots of investors in construction of oil and gas objects in the Russian Far East are alarmed by the increased cost of construction after the approval of the TDC mandatory application. To revise a previously developed standard under the new format, it took special order of the President of the Russian Federation, which we received on 18 May 2015, and the appropriate letter on behalf of the Government of the Russian Federation appeared on 27 September 2015. Since then the TDC developers did not waste any time improving TDC and testing it on the examples of existing marine and on-shore facilities of various types located in tsunami hazardous areas (THA).

2. Terms and definitions

An important basic element of the structure of the TDC was to use clear, unambiguous terms and their definitions, which must be harmonized with the one's adopted by international community [5, 6]. That is why the tsunami Glossary [5], developed by geophysicists - oceanologists, was supplemented by some necessary terms and definitions related to the field of engineering and emergency management [7]. However, some new terms and definitions needed to be discussed and unified multidisciplinary worldwide. For example, the new term "close or not far" tsunami inherently depends on the readiness of the national tsunami warning system, and the value of permissible risk level (PERIL), which is determined by the economic capacity of a given country/state to withstand the disaster and also by the level of insurance.

3. Regarding the main source data

3.1 Tsunami hazard maps – Historical survey

The first attempt to create the tsunami hazard maps were made in the 60th and 70th for Hawaiian and Russian Far Eastern coasts [1, 2]. The emergence of new ideas and technologies caused the creation of new maps for different coasts and countries [3-9]. During this time the conception of "quantitative estimate" of the tsunami hazard has been worked out. Many of the initial tsunami hazard maps (THM) contained distribution of the "maximum" tsunami height along the coast but the values of the "maximum" tsunami heights are very critical because their evaluation is really unstable having not enough data. Additionally, there is an essential stochastization of the tsunami wave field due to the wane propagation over the irregular bottom topography. Several tsunami run-up heights measured on the coast (31.7 m by the 1993 Okushiri tsunami, 34 m by the 2004 Indonesian tsunami, 56 m by the 2011 Tohoku event) are essentially larger than the most prognostic tsunami heights. Because of it, all the new maps are based on the probabilistic models [5-12]. Such approach is related to the probabilistic definition of the hazard and risk [13-14]. Correct tsunami hazard evaluation is very important for the tsunami design.

Regardless of the source of material used for creation of the THM, all the tsunami hazard parameters should be correct, i.e. should be accompanied by evaluation of their a priori errors.

Depending of the scale the THM are divided into the overview map, or maps for general tsunami zonation (M1:5 000 000 – M1:1 000 000) and detailed maps (M1:500 000 – M1:100 000). On the shorter parts of the sea coasts we can use THM of scale 1:100 000 – 1:20 000, and on local small sea coasts (for specific critical facilities, etc.) tsunami event scenarios must be developed.

Problems of the tsunami phenomena are studied by nine research institutes of Russia Academy of Sciences (RAS).

3.2 Condition and requirements for source data

The sea coasts where the heights of tsunami wave are equal to or greater than 0.5 m, are named as THA. The main parameter of tsunami–hazard is a probability of at least one tsunami which occurs in given place during a time *t*, with a tsunami heights more than *H*. Additional parameters are the wave period and the speed of a tsunami, so that we can know about formation of a tsunami bore and a magnitude of the vertical and horizontal runup. The accuracy of the estimates of the parameters above should not be below 75%. Values of the tsunami heights on the maps and tables of the TDC supplement need to be given for a recurrence period 100 yrs. (Pacific coast) and 500 yrs. (for other sea coasts of Russia). Detailed THM has to be presented in two versions: on the water's edge (zero bathymetry) and on 50 m depth (bathymetry), which is used in different ways for design of the onshore, coastal and offshore structures.

Source data (maps and tables) which to be included in the application to TDC, are prepared by specialized institutes of the RAS on the basis of the Technical Assignment of the Ministry of construction, and then these data are analyzed and recommended for use by “WG on the development of THM”, created under umbrella of IPE RAS.

4. Purpose, tasks and scope of TDC

TDC is intended to ensure the sustainable safety of urbanized THA. Tsunami safety is a state of coastal and offshore structures, as well as adjacent THA, in which the impact of the tsunami does not cause a threat to the life and health of people, does not cause secondary disasters, does not violate the functioning of critical infrastructures, and economic damage does not exceed the permissible level. The standard establishes the following mandatory requirements for the built-up and for planning of sustainable development of the urbanized THA, including:

- design loading and modeling of the onshore, coastal and offshore structures under tsunami impact; serviceability and ultimate limit state;
- rules for sustainable development of the urbanized THA; new point of view on the city planning and development renovation, retrofitting and strengthening of buildings;
- design of port & marine structures under tsunami impact; tsunami protection of critical facilities and of the potentially dangerous objects to minimize the disaster risk;
- recommendations for the design of special structures for the emergency vertical evacuation;
- development of probable disaster damage scenarios; tsunami disaster assessment, risk-analysis & control, provision of the resilience community in THA (tool-box see [22-27]).

The standard primarily considers a seismogenic tsunami. However, all of the estimates and the requirements set out in the standard apply to the tsunami waves of any genesis.

5. Tsunami risk assessment and analysis

Tsunami risk assessment & analysis performs in accordance with [25, 28] by means of toll-box, developed on the basis of the method of logical estimation and system analysis (MELESA), which uses mathematical theories of “fuzzy sets” and of “eroded images”. Procedure of the tsunami risk analysis is performed as for the secondary EQ- disaster. A source data base collection must follow the rules given in [24, 27]. In this case the input data mainly consists of local information – “DIABASE” [27], because the additional information (engaged knowledge & experience) learned from the past disasters is still insufficient and needs to be well-studied. As a result of the tsunami risk analysis we can develop probable disaster damage scenarios and measure a size of a calamity according to a scale of disaster magnitude “DIMAK” [23]. If the evacuation of population will be timely and successful, an index of relative human vulnerability (p), as a rule, is acceptable ($p<0.25$). Only the magnitude of the disaster (M_d) and index of economic capacity characterize the disaster. By means of managing these parameters, the tsunami disaster should be reduced to permissible risk level (PERIL), which is assigned in this or that country/state. In the case of a powerful the “not far” tsunami even for developed countries the tsunami disaster mitigation strategy cannot be successful without an insurance. An insurance of the critical infrastructure and of potentially dangerous objects against the tsunami impact should be mandatory. In any case, the foundation of an effective insurance should be well-grounded scenarios of disasters [25].

Disaster risk is divided on 6 levels: prohibited, tolerable, permissible (PERIL), suitable, acceptable, and negligible. Tsunami is such a destructive phenomenon that it is very difficult to assign the PERIL for any country. That is why the choosing of PERIL or optimal risk level will be not so easy.

6. On classification of seaports and of structural vulnerability

In accordance with the Russian national hydrotechnic structures code [29] the class of seaports depends on the amount of annual passenger traffic and/or of cargo turnover of a port. The class of the berthing structure depends on its height. This classification includes 4 classes of seaports. According to [29] the port of Korsakov and the port of Kholmsk have been classified as a class of 3. This classification needs to be adjusted to select the ports or the separated berthing structure of higher class of liability, serviceability of which is necessary for functioning in extreme situations.

A very significant and perspective issue which ~~-~~is not sufficiently covered in the TDC is an improvement of tsunami safety by means of reducing the vulnerability of buildings and structures under tsunami impact.

Vulnerability assessment is performed according to [27] using the ten-level~~s~~ classification of structural vulnerability (6 main levels are: negligible, slight, light, moderate, high, very high).

With the seismically prone THA we should talk about both EQ-vulnerability and Ts-vulnerability of structures considering the “no far” tsunami and the design situation, when buildings and structures will be subjected to two consecutive impacts – EQ and then a tsunami, as happened, for example in Indonesia (2004) and Japan (2011).

This important and technically meaningful direction includes the activities such as usage of the streamlined and permeable structures, application of energy absorption, of dynamic dampers and dissipative connections, and also the design of solutions to prevent the progressive collapse and the implementation of new advanced construction materials [30, 31], etc. This area of R&D requires experimental support (full-scale and simulation) as well as mathematical modeling.

7. Requirement of city planning for tsunami safety

After catastrophic tsunami disaster of 1952 on the Eastern coast of Kamchatka and on Paramushir Island, the project of relocation of the town of Ust-Kamchatsk was developed at the Institute "LENGIPROGOR" (now RosNIPIurbanistiki) under the leadership of Dr.Leonid Puterman and then was implemented by moving the town to higher tsunami safe place. However, in other development projects in urban THA the measures to mitigate the tsunami were not provided due to the lack of such requirements in the urban planning norms. Only since the mid-90th on the initiative of L.Puterman the requirements of the tsunami safety began to be taken into account in

the Institute "RosNIPIurbanistiki" in development of projects for territorial planning and urban development in THA of Kamchatka, Sakhalin Island and Primorsky Krai. The successful experience of city planning of Ust-Kamchatsk (Russia), Kodiak Island (USA) and the other~~s~~ urbanized THA are summarized in this chapter.
Here it is important to note that many cities at the tsunami risk are partially or even fully built (City of Poronaysk, Sakhalin Island) on water-saturated sandy soils capable of liquefaction both under EQ-impact and under tsunami impact. This specific geotechnical problem is not addressed in TDC. Since 2009 city of Poronaysk is a testing ground from the point of view of the planning and development for sustainable EQ & Ts safety.

8. Testing area for pilot implementation

Sakhalin Island, the coastal urbanized area of which is the THA, was selected as a testing area for pilot implementation of the TDC. In a case of emergency the problem of life sustainability becomes a very acute and the reliable operation/high serviceability of seaports must be mandatory provided. That is why the port facilities were taken as testing objects. The main sea ports of Sakhalin Island – the port of Korsakov and the port of Kholmsk - are located in a zone of strong (< 4 m) tsunami hazard [32]. Port of Korsakov is located in the "shadow" of the Pacific tsunami. The port of Kholmsk is susceptible to the tsunami generated by the local focal seismic zones located under the Tatar Strait. The Navels EQ (Sakhalin Island, 02.08.07, M=6.4) happened not far from Kholmsk and caused the tsunami of height above 3 m.

In the South of Sakhalin Island 15 berthing facilities in the port of Korsakov were considered. Eleven of the berthing facilities were made of concrete massive masonry, but the other four of them were built from artificial arrays-giants. The berthing facilities mostly were built in the twenties and renovated in the 90^{th} of the last century. In the port of Kholmsk eight ferry berthing facilities crossing Vanino-Kholmsk, built in 1935-1938 were also considered.

In the process of testing the TDC, the following tasks were under consideration:

- selection of the berthing facilities for testing/calculation;

- testing procedure of the runup assessment;

- testing procedure of the tsunami loading assessment;

- estimation of Ts-resistance of the selected berthing facilities;

- assessment of the port serviceability (as a whole) after tsunami impact;

- evaluation of the possibility of increase in berthing depth for mooring of modern ships with bigger draft.

9. Testing calculations berthing facilities

9.1. Description of the selected berthing facilities

9.1.1. Korsakov Seaport. Northern District. Berth #5 (A)

According to the passport data and study results, Berth #5 is 135 meters long, 20 meters wide, and is the structure of the gravitational type made of 9 giant arrays set up on the rock bed 1.3-1.5 meters thick. The bed is made of basalt stone mass of 5-25 kg. The width of the berm stone bed is from 2 to 3 meters. Eight giant arrays have a length of 15 m, the corner array (pairing 5th and 6th berths) enters the fifth pier end and has a size of 7.5 meters. All giant arrays (but the corner one) have a width of 4.83 m at the top and 6.44 m at the bottom.

The increase in the width of the sole is achieved through consoles with the fly (jetty) 80 cm, height at the front edge of 55 cm and the upper bound of the slope of 1:2. Height of the giant arrays is 9.65m, and the soles (bottom) of the building are – 8.0 m.

The thickness of the walls of giant arrays is constant and equal to the height of 28 cm to the rear wall and 40 cm to the front wall of giant arrays. Each array has a giant longitudinal bulkhead and several transverse bulkheads. The superstructure has a trapezoidal cross-section with the upper base of 2.3 m, the lower base of about 2.8 m and a height of 2.0 m. The front face of the superstructure extends beyond the frontal plane of the giant up to 15-20 cm. The superstructure is divided into sections by stitches 7.5 m long.

Backfill is done with gravel siltstone of different sizes, boulders, and clay loam. The study has not found any soil sediment, separation of the superstructure cracks resulting from the inclination of giant arrays in the direction of the sea.

9.1.2 Korsakov Seaport. Southern District. Berth #3 (B)

Berth #3 (length 140 m width 20 m) is composed of three parts slightly different in design because of the different elevations of the sole structure. The first section (10 meters long) is a wharf or levee of gravitational type built in a regular massive laying with stepped rear face resting on a stone bed of about 1.3 m thick. Laying is performed without any stitches ligation. All arrays have a length (along the pier) 183 cm. The height of all arrays on the dock, except for arrays of the first course is 213 cm. In the first section, the height of the lower course is 173 cm, with the sole of 6.25 m. The second section is comprised of arrays of the first course with the height of 213 cm, and respective depth 6.70 m at the berth. The depth of the third section is 7.43 m which differs from that of the previous sections. This special laying/masonry from massive concrete blocks, which consists of four courses and has the following dimensions of the arrays in the cross section: the first course - 411 cm, the second - 365 cm, the third - 320 cm, and the fourth - 274 cm. Five-course laying has the same dimensions except the first course with the width of 457 cm.

The superstructure has a rectangular cross-sectional shape and originally had a shelter belt, a strip protected by hewn stone. Subsequently basalt rock tumbled almost all along the quays and was replaced by concrete.

Stone bed has a trapezoidal shape and is formed in the mound. The size of the upper base varies depending on the width of the array of the first course. For areas of the four courses it is equal to 7.2 m, for the rest to about 7.6 m. Before construction the verge is 155 cm. As a result, an unloading platform was built, thus increasing the load to the “O” category [4, 29].

The platform consists of a series of concrete plates 300 mm wide and 4300 and 7250 mm long, with one end resting on the array of the 4th and 5th courses, the second end resting on the concrete pilewort. The pilewort connects concrete piles with pile cross-section 300 x 300 mm or 350 x 350 mm. The shelter belt is moved closer to the border line and the bar rests on the rear part of the upper face of the upper course of arrays. Piles are scored in one case, to a stone bed, the other to the roof of the rocky soil. The berth has a cement-concrete cover 200 mm thick.

9.1.3. Kholmsk Seaport. Berth #1 (ferry) 2nd stage (C)

Berth 117m long and 8.1m wide is “the bulwark” type quay designed on separate “goby” supports with cross section of 6.65m x 4.0 m supports are rounded at the border and made of two rows of concrete arrays up to 50t weight. Bottom mark is at – 0.85m.

The supports are located at a distance of 17m in the middle spans, 13.35 and 14.5 meters in the head spans, and the core or root span respectively. A 1.0m deep monolithic screed is placed over the massive arrays. The design of the top structure of the pier on the head support is also made of reinforced concrete (RC). The base of the poles is a monolithic concrete structure of about 1.0m height, and limited by concrete laying in bags.

The upper structure of the pier is a multi-span beam system with hinged supports, whose role is performed by monolithic rails R-43 rails and steel pins with a diameter of 32 mm.

In conjunction of the berth and territory concrete barrel-type blocks are used. There are holes in the blocks to squelch the waves. They also have ledges to support grid plates.

Behind barrel-type blocks there is a paved rock prism reinforced with counterforce. Over it there is stacking of concrete slabs with holes. Evenly distributed load on a dock in shelter belt zone is 1.5 t/m^2.

9.2 Procedure of assessment of Ts-resistance of berthing facilities

The starting point of the design procedure depends on the method of setting up source of tsunami hazard information. Both full scenarios of tsunami event and other methods of tsunamimicrozonation are still used in Russia very rare. In our case, the information about tsunami hazard specified using the table of the annex of TDC, in which the estimated tsunami height is given for different geographical locations, including Korsakov and Kholmsk. As additional information wave period was included in the source data separately for Korsakov and Kholmsk. Usually the first step is to define shape of tsunami waves (Ts-bore will be or not) when the tsunami impact on the vertical structure located within runup. As a result of hydraulic calculation of all test examples we are dealing with boreless raw wave, which presses on a vertical barrier of long berth quay before the water edge. A direct procedure for estimation of the load on the berths consists of assessment of the height of the wave along the berthing quay – h_0, the depth of the wave - d_0, the maximum exceeding of the water level above its original level before berthing quay – η. Then we find the values of the horizontal P_x and vertical P_z load on a given ~~the~~ berthing quay depending on the relative heights of the waves and pier. In the test examples, two design cases were considered:

- the runup of tsunami on the undamaged structure;

- the situation when tsunami is going off shore (recession, low water) - for type C only.

Design situation, namely

- the integrated ~~the~~ impact of the earthquake and tsunami (the tsunami's impact on the damaged structure);

- the impact of repeated tsunami;

- the impact of the tsunami with the inclusion of ice scrab and debris

were not considered during the testing calculations.

All formulas and nomograms required for the testing calculations are given in TDC.

9.3 Estimation of the tsunami impact and loads on the testing of berthing structures

9.3.1 Tsunami impact was estimated on the following construction type of berthing facilities:

A. Berthing quay built from the artificial arrays-giants.

B. Berthing quay built from the laying of large-size/massive concrete blocks of regular form.

C. Berthing quay of “the bulwark” type with mooring wall of no more than 18 meters span.

9.3.2 Design tsunami impact was taken in accordance with an annex A “Table A-1. Design tsunami height values on the Russian Pacific coast” of TDC and from corresponding tsunami zonation map.

For Korsakov tsunami height h_{100}=1.4 m and wave period is large (for example, approx. 5 hrs. after Tohoku tsunami).

For Kholmsk tsunami height h_{100}=3.2 m and wave period T=8 min.

9.3.3 For initial data for calculation of the tsunami impact on the berthing structure of the types A and B see subsections 9.1.1 and 9.1.2.

Water depth d = 8 m; the slope of the bottom $í$=0.02

The collapse of the wave (“bore”– formation) is checked by formula

$$k=\left(\frac{2\pi}{T}\right)^2\frac{h_{100}}{gi^2}=\left(\frac{6,28}{8\cdot 60}\right)^2\frac{1,4}{9,8\cdot(0,02)^2}=0,06<1$$

When a criterion of wave collapse k<1, a “boreless wave” does not collapse. Then we calculate a size of the runup η on the berthing wall and horizontal the water pressure on the facade of this wall.

According to nomogram 7.1 of TDC n = 0.85, and we can find the size of runup η=2nh=2.38 m. Guided the subsection 9.2 and the chapter 7.1 “Loads on the non-streamlined structures” of TDC, we have received the appropriate values of pressure at levels of calm water p_{cw}=23.32 kPa, and at the bottom p_b=18.66 kPa. Total horizontal wave load on the vertical wall P=195.7 kN and is concentrated in the point at 4.8 m above the bottom.

9.3.4 Initial data for calculation of the tsunami impact on the berthing structure of the type C see in subsection 9.1.3.

Water depth d = 7.5-8.5 m; the slope of the bottom í=0.02; diameter of the support is 4 m. Criterion of wave collapse k <1, i.e. a wave is boreless/non-collapsed. The water load is estimated for vertical wall strip of 4 m width. Next, similarly to 10.3.3 we find η=4,16m, p_{cw}=40.8 kPa on the one support, p_b=36.2 kPa on the one support. Total horizontal wave load on the one support of 4 m width is P=309 kN.

9.4. Assessment of the stability of the berthing structures against tsunami impact

In the process of calculation, structural stability on the shift and rollover for each of the three considered facilities was checked. In view of the considerable length of the berthing quays, plane problem was considered, and calculation of the stress was made on 1 m length of berthing wall (A and B types) and for each support of 4 m-width (C type). In the case of the berthing structure of "bulwark" type (C), two design situations were considered: runup with height - *h* and the lowering of the water level before the arrival of the wave is *h* and *2h*. According to Table B.1 SNIP 33-01-2003 [29] the berthing structure of height less than 20 m of general purpose belongs to class III. The bearing capacity of the mooring and its components were calculated the usual way by the formula (4.1) from [4] and the formula (1) from [29]. Calculations have shown that with virtually identical loads, safety factor of stability of the pier A is less than of the pier B. Thus, table shows the calculation results for pier type A only.

Table - Estimation results of bearing capacity of mooring

Structure and components	elevation of level η, m	width of the calculation area, m	shear force, kN	overturning moment, kNm	holding force, KN	holding torque, kNm	Safety factor of stability	
							shear	the rollover
Berth #5 Korsakov	0	1	342,2	1456	453,6	2431	1,326	1,669
Berth #5 Korsakov	2,38	1	146,5	450	453,6	2431	3,096	5,4
Berth #5 Korsakov	-1,4	1	376	1581	493,4	2644	1,31	1,672
Berth #5 Korsakov	-2,8	1	403,3	1662	533,2	2857	1,32	1,72
Berth #1 Kholmsk	4,16	4	1648	4076	1964	6546	1,19	1,6

Table shows that all three types of berthing structures have sufficient bearing capacity both on shift and on the rollover.

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11. Conclusion

The draft of interstate standard “Buildings, structures and areas. Safety requirements under tsunami impact” (developed in 2011) and the draft of the national standard “Construction in tsunami hazardous areas. Design rules” created on its basis are discussed in the article from the standpoint of their practical application. Opinions and conclusion, related to various aspects (from the source data to the Ts-risk analysis) of TDC are presented below.

11.1. Currently, the main sources of information about tsunami in Russia are tsunami hazard maps (THM). Because both tsunami height and the wave period are involved in the formation of the tsunami loads on the hydraulic structures, the THMs, which reflect the tsunami height only, are insufficient to describe the tsunami hazard. That’s why the table of the Annex to the TDC must contain several parameters. Besides, because the input data are very important for the estimation of the probability and the frequency of occurrence (recurrent period) of the mixed impact of “EQ+Ts”.

11.2. When assigning the tsunami impact on offshore, coastal and onshore structures, some geophysicists are trying to draw the analogy between the procedure of assessment of seismic and tsunami hazards. However, for example, the analogy between seismomicrozonation and tsunamimicrozonation is incorrect because “site effects” can increase an EQ-intensity twice, whereas the tsunami runup can grow in several times due to local conditions. Nowadays it is required to provide the paleo study to identify prehistoric tsunami. It is necessary to extend and improve the catalog of tsunami and then refine the recurrency.

11.3. When developing the scenarios of probable tsunami event (tsunami hazard scenario) it is required to know the bottom topography (bathymetry map) of the coastal sector under consideration. The well-known marine charts for coastal waters, based on the measurements of the depths from step 1′, not suitable for the given task because we need the depths measurements with a step not bigger than 100 m. The matrix of the measurements of the sea depths available on the Internet cannot be used, because their origin and authenticity, as a rule, is not legally confirmed, and often even unknown.

11.4. The reconnaissance of the effects of the damaging and devastating tsunami on the port and coastal structures, which must be classify according to different degree of seismic and tsunami vulnerability, may allow to improve the scale of tsunami intensity [33]. That in turn will lead to the possibility of constructing the simplified THM based on the concept of "tsunami intensity".

11.5. As we know from the basic statements of the IDNDR, the earthquakes and tsunami phenomena cannot be managed by people. In fact, however, in relation to the tsunami, these statements are not so unambiguous: a reasonable, target city planning can and must prevent the presence of “debris” in the second and subsequent tsunami runup and, for example, the creation of the coastal protection zone with breakwaters directly reduces the tsunami impact on the shore. Thus, application and implementation into practice of the chapter “City planning” measures of TDC can mitigate tsunami impact on the urban areas within the zone of the horizontal runup. The successful experience of city planning of Ust-Kamchatsk (Russia), Kodiak Island (USA) and the other~~s~~ urbanized THA are summarized in this chapter.

11.6 On the coastal urban areas formed by the saturated silky sand (as, for example in Poronaysk), the secondary geotechnical problems of erosion and liquefaction of soils under the tsunami impact can additionally appear~~ed~~, a special discussion of these issues is required, but is beyond this article.

11.7. A very significant and prospective issue which was not sufficiently covered in the TDC is to increase tsunami safety by means of reducing the vulnerability of buildings and structures under tsunami impact. This important and technically meaningful direction includes the activities such as usage of the streamlined and permeable structures, application of energy absorption, of dynamic dampers and dissipative connections, and also the design solutions that prevent the progressive collapse, as well as the implementation of new advanced construction materials, etc. This area of R&D requires experimental support (full-scale and simulation) as well as mathematical modeling.

11.8. Early classification of seismic vulnerability of buildings and structures under the threat of a tsunami is absolutely necessary to evaluate EQ-resistance of existing structures and for development of the appropriate disaster scenarios in case of the “no far|” tsunami (in the mixed designing situation “EQ+Ts”).

11.9. The issues of tsunami warning system and of effective evacuation (besides the recommendations for the support of engineering activities for vertical evacuation of the population) in the TDC are not under consideration. Meanwhile, learning from the lessons of Navels EQ (Sakhalin Island, 02.08.07, M=6.4), which has caused tsunami of height above 3 m, the threshold of tsunami warning system is proposed to be reduced from M=7 to M=6.3 for some THA.

11.10. If we believe in the timely and successful evacuation, in development of the disaster scenarios the main effort falls on the assessment of economic losses and damages. For that matter an index of relative human vulnerability (p), and the magnitude of the disaster (M_d), together with index of economic capacity applied to characterize the disaster. By means of managing these parameters, the tsunami disaster should be reduced to permissible risk level (PERIL), which enacted in this or that country/state.

11.11. In the case of a powerful "no far" tsunami the tsunami disaster mitigation strategy even for developed countries cannot be fruitful without insurance, popularity/attractiveness of which depends of various factors, among which are a degree of state participation/support (New Zealand is a positive example) and national mentality (Japan is a negative/fatalistic example). Insurance of critical infrastructures and of potentially dangerous objects against the tsunami impact should be mandatory. In any case, the foundation of an effective insurance should be well - grounded scenarios of disasters.

11.12. Taking in consideration the indicated above difficulties, it is necessary to pay attention to some relevant hardships when we have to assign "the minimum tsunami load" (or better-PERIL!) in the national TDC, which must be obligatory met.

11.13. For developing the well-grounded tsunami disaster scenarios it is offered to improve well-known GIS "Extremum" (Russia) and GIS "HAZUS" (USA), as well as to use an advanced achievement of computer modeling, the comprehensive risk analysis, which have "Happy End" as a final aim.

11.14. The 23 berthing facilities of the seaports of Korsakov and Kholmsk on Sakhalin Island were under consideration as a test example. In accordance with construction type the mooring quays were presented by "artificial giant arrays" (type A), laying from large size regular concrete blocs or massive masonry (type B) and "the bulwark" (type C), which were chosen for calculating the test during the TDC verification.

11.14. From the results of the testing of berthing structures on the subject of tsunami impact, it follows that all three types of objects-representatives of the berthing structures have sufficient load bearing capacity, like shear, and overturning.

11.16. In accordance with the Russian national hydrotechnic structures code [29] the class of seaport depends on the amount of annual passenger traffic and/or cargo turnover of the port. Class of the berthing structure depends on its height. According to [29] the port of Korsakov and the port of Kholmsk have been classified as a class of 3. This classification needs to be adjusted to select the ports or the separated berthing structure of higher class of liability, serviceability of which is necessary for functioning in extreme situations.

11.17. Berthing quays built from the layers of large-size/massive concrete blocks of regular form (B) and structures composed of arrays-giants (A) are the most tsunami resistant. Berthing facilities of the type B in spite of their good quality from the standpoint of earthquake resistance are more sensitive than structures type A. The vulnerability of berthing structures of type A and B to tsunami wave containing pieces of ice or "debris" is also assessed as approx. "light" class (according to vulnerability classification [24, 27]). The tsunami resistance of berthing facilities of types A and B is considered as sufficient, even if a class of the port will increase from 3 until highest 1. These conclusions are supported by nearly a century of operating experience of berthing facilities of type A and B in the port of Korsakov on Sakhalin Island. Bearing capacity of the berthing quay (type C) in port of Kholmsk is sufficient, but it is reaching the ultimately permissible class.

11.18. Because 11 of the 15 berthing facilities (over 70%) in the port of Korsakov are constructed from arrays-giant (type A), this port has been classified as tsunami resistant as a whole, i.e.–port of Korsakov has been considered as serviceable port on Sakhalin Island in case of emergencies. Regarding to the desire of holders to perform the dredging near the berthing wall for servicing the vessels with a greater draught, this issue requires a special consideration and additional comprehensive consultations.

11.19. It should be emphasized that the notable cause of sufficient estimate of tsunami resistance of berthing facilities was their location in THA with low values of the tsunami height, as well as a very high value of wave period in port of Korsakov, which practically led to quasi-static loading on test of the berths.

11.20. Testing of the TDC for different types of offshore, coastal and onshore facilities should be continued by joint efforts worldwide. According to the results of a sufficiently large number of calculations the assistive tables containing, for example, the size limitation of coastal structures of different design types can be made on basis of their tsunami resistance, taking into account both tsunami height and (that is very important) wave period. The engineering community is invited to join efforts in order to create a global directory of the protecting methods and technologies against tsunami impact. Directory has to be supplemented by examples of successful applications.

11.21. Testing examples have demonstrated that the developed TDC allows to build the port hydrotechnic structures with a given tsunami resistant and to evaluate a serviceability of existing berthing structures exposed to tsunami. However, we clearly understand that our draft of the TDC is only first step and we have a long way until last mile. Moreover, approbation of the TDC has confirmed the correctness of simplified design approach. Thus we adopt the quasi-static interpretation of dynamic interaction as sufficiently reliable solution for a large number of marine hydraulic structures of different structural type (in broad range of the tsunami vulnerability), but with ordinary reliability. This allows us to avoid the complex problem of dynamic analysis in a nonlinear formulation. Due to this, our TDC became easier and more suitable for practical engineers (from the rapid evaluation of behavior & condition of the existing berths until the designing of the new hydraulic structures under the tsunami impact). The tsunami resistance of highly important structures (life-support facilities, potentially dangerous objects, etc.) should be estimated, of course, in a nonlinear dynamic formulation.

12. References

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