Advancement of design technology for port facilities

1. Outline of Studies and Activities

Event	Research background	Research	Reflection of results and policies
1995 **WTO TBT Agreement** **2005** **ISO 2394 Published (General Principles on the Reliability of Structures)** **2015** **ISO 2394 Revised (Risk-based design, etc.)** **2020** **JSI Version of ISO 2394 (JISA3305) Published**	■Need for harmonization of domestic standards with international standards ■Need for a shift from specification-based to performance-based design methods ■Need for design methods that take into account maintenance, management, and construction	**■Introduction and advancement of performance-based and reliability-based design methods** ・Study on Performance-Based and Reliability-Based Design Methods (2001-2006) ・Study on Systematization of Performance Verification Methods for Port and Harbor Facilities (2007-2011) ・Study on Rationalization of Port Facility Design (2001-) ・Study on Port Survey and Design Guidelines (2014-2016) ・Study on Design Methodology Based on Maintenance and Management (2012-2018) ・Study for the Development of Future Port Standards (2018-)	**○Reflection on the Technical Standards and Commentaries for Port and Harbor Facilities (2007)** [Part 2, Chapter 1 General rules] ・2 Performance-based design method ・3 Reliability-based design method [Part 2, Chapter 4 Earthquakes] ・1.2 Level 1 earthquake ground motions used in performance verification of facilities [Part 4, Facilities] ・Chapter 4: Protective facilities for harbors ・Chapter 5: Mooring facilities *Updated overall **○Partial Revision of the Technical Standards and Commentaries for Port and Harbor Facilities (2007) (2012-2014)** ・Design seismic coefficient of various structures ・Partial factors for various structures ・Correction method for site amplification factors ・Revision of tsunami design method (Tenacious breakwater structure, etc.) ・Others
1995 **Great Hanshin Earthquake** **2011** **Great East Japan Earthquake** **2016** **Kumamoto Earthquake** **2018** **Hokkaido Eastern Iburi Earthquake** **Typhoon No. 21**	■Need for more advanced design methods using Level 1 and Level 2 earthquake motions ■Need for the design of tenacious breakwaters in light of the tsunami disaster caused by the 2011 Great East Japan Earthquake and other disasters ■Need to cope with typhoon damage, climate change, and the impending threat of large-scale earthquakes and other disasters	**■Advanced seismic and tsunami resistance** ・Study on Seismic Design Method Using Probabilistic Time History Waveforms Considering Site Amplification factors (2005-) ・Study on the Rational Setting of Site Amplification Characteristics Using Microtremor Observations Records (2005-) ・Analysis of the Damage from the Great East Japan Earthquake and Study on the Design Tsunami Response (2011-2014) ・Study on Upgrade of Technical Standards for Port Facilities (2016-) ・Study of Methodology for Immediate Damage Estimation of Large-Scale Earthquakes (2018-2020) ・Compilation of damage records (List of damaged breakwaters (2013)) (2011 Great East Japan Earthquake Port Facility Damage Report)	**○Reflection on the Technical Standards and Commentaries for Port and Harbor Facilities (2018)** [General] ・Chapter 1 2. Performance-based design systems ・Chapter 2 1. Flow to ensure performance of facilities 2. Design of facilities (Including improvement) [Facilities] ・Chapter 4: Protective facilities for harbors (Partial factors, etc.) ・Chapter 5: Mooring facilities (Partial factors, etc.) [Reference Materials] ・Fundamentals of the reliability-based design method ・Surveys and tests after a large earthquake and tsunami ・Basics of design seismic coefficients ・Others
2013 **Infrastructure Export Strategy** **2016** **Action Plan for Overseas Deployment of Infrastructure Systems** **Memorandum between Vietnam and Japan on cooperation in development of the National Technical Standards (Signed in 2014, extended in 2017, re-extended in 2020)**	■Growing need for overseas development of domestic standards as logistical support for infrastructure export strategies ■Response to Vietnam's request for cooperation in developing national port standards ■Response to "High-quality infrastructure investment"	**■Internationalization of technical standards for port and harbor facilities of Japan** ・Study on Internationalization of Standards and ISO Compliance (2001-2005) ・Research and Study on Internationalization of Technical Standards (2006-2010) ・Study on International Deployment of Technical Standards in the Port and Harbor Sector (2011-)	**○English Translation of the Technical Standards and Commentaries (2009, 2020)** **○Publication of Vietnamese Port Standards (2017-) (Six chapters)**

Since the ratification of the WTO (World Trade Organization)/TBT (Technical Barriers to Trade Agreement) in 1995, domestic technical standards are required to be consistent with ISO international standards, and in response to the government's deregulation trend, a change from specification-based to performance-based technical standards is sought. In addition, the introduction of reliability-based design in accordance with ISO 2394 (General Principles on Reliability for Structures) is also required. On the other hand, disasters caused by earthquakes, tsunamis, and typhoons (e.g., the 1995 Great Hanshin Earthquake, the 2011 Great East Japan Earthquake, and Typhoon No. 21 in 2018) have continuously occurred, requiring constant improvements in seismic design, wave resistance design, and tsunami resistance design for breakwaters and mooring facilities. Furthermore, in the 2010s, there was a growing need for overseas export and deployment of infrastructure systems due to concerns about a declining domestic population and shrinking markets, as well as the need for design improvement and life extension of aging facilities in Japan.

We have conducted research on these needs and reflected the results in the "Technical Standards and Commentaries for Port and Harbor Facilities" (fully revised in 2007 and 2018, and partially revised in other years), which is a compilation of the best design technology for domestic ports and harbors. In addition, we have been working to improve the environment for further deepening performance-based design by developing technical documents (NILIM Technical Notes, etc.) on which these standards are based. We have also contributed to the maintenance and improvement of the technical status of Japan's port and harbor sector overseas through dissemination of the design standards.

■Introduction and advancement of performance-based and reliability-based design methods

(Background/Issues) The introduction of performance-based design and reliability-based design methods was necessary for the advancement and international harmonization of port facility design. Performance-based design was an unprecedented concept, and it was necessary to appropriately incorporate it into the legal and practical design systems. It was also necessary to develop a Level 1 reliability-based design method (partial factor method) that would be rational in design practices.

(Research Outline and Results Implementation) The research results on performance-based design systems were reflected in the 2007 full revision of the "Technical Standards for Port and Harbor Facilities." In addition, partial factors for various structures have been continuously developed, and the results have been reflected twice in the "Technical Standards and Commentaries for Port and Harbor Facilities," and are directly used in port design practices throughout Japan.

■Advanced seismic and tsunami resistance design methods

(Background/Issues) After the Great Hanshin Earthquake in 1995, the introduction of Level 2 earthquake motions (the largest class of earthquake motions) and other advanced seismic design features were called for; after the Great East Japan Earthquake in 2011, tsunami resistant design was introduced for breakwaters and "tenacious structuring" was called for.

(Research Outline and Results Implementation) For the advancement of seismic design, research was conducted on design input earthquake motion with a time history waveform that takes into account the design site amplification factors, and on a new seismic coefficient method (introduction of design seismic coefficient for verification) for Level 1 earthquake motion (probabilistic time histories) that can indirectly verify the amount of deformation of quay walls. For tsunami resistance design, research was conducted on reinforcement design methods for breakwaters against tsunamis and other disasters. The results of these studies are reflected in the "Technical Standards and Commentaries for Port and Harbor Facilities" and are directly used in port and harbor design practices throughout Japan.

■Internationalization of technical standards for port and harbor facilities in Japan

(Background/Issues) Japanese port standards (Technical Standards and Commentaries for Port and Harbor Facilities in Japan) have been translated into English and are used in Japan's official development assistance (ODA) projects. Due to the advancement of seismic design in Japan, however, there had been a noticeable difference in the technical level of developing countries, making it difficult in some cases to apply the content to local design as is. Meanwhile, Vietnam requested technical assistance for the development of their new port standards.

(Research Outline and Results Implementation) In response to the request for technical assistance from Vietnam, we conducted research on a methodology to develop locally applicable standards by modifying (customizing) Japanese port standards (design, construction, and maintenance) to suit the natural conditions of the host country, etc. The results were compiled in NILIM Technical Notes and other publications. In Vietnam, cooperation between the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the Vietnamese Ministry of Transport (MOT) has been promoted since 2014 based on a Memorandum of Cooperation, and as a result, the national port standards (six chapters) have been officially put into effect.

2. Main Research Results

■ Introduction and advancement of performance-based and reliability-based design methods

- In the 2007 "Technical Standards and Commentaries for Port and Harbor Facilities in Japan," the results of research on partial factors (Level 1 reliability-based design method) using the performance-based design system and the material factor design were adopted.
- In 2018, the "Technical Standards and Commentaries for Port and Harbor Facilities in Japan" adopted the results of research on partial factors (Level 1 reliability-based design method) using the load and resistance factor design via reliability analysis using a Monte Carlo simulation (MCS). In addition, the results of research analyzing examples of improvements to existing facilities were also adopted, and fundamentals and consideration regarding improvement design were newly incorporated.

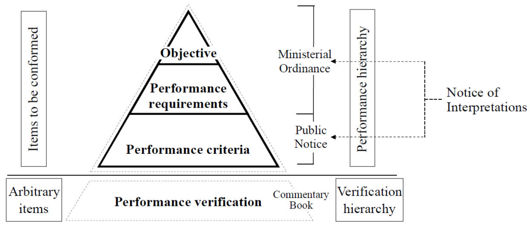

Figure-1 Performance-based design system of port and harbor facilities

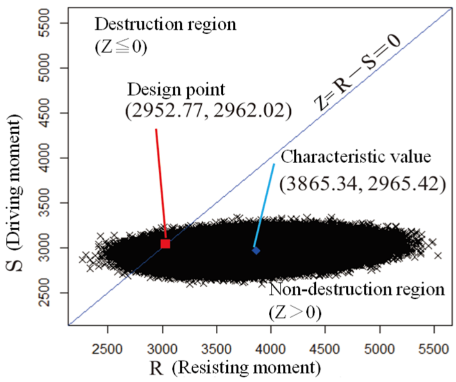

Figure-2 Calculating the failure probability in a circular slip analysis using the MCS method (Failure probability is calculated by dividing the number of MCS attempts in the failure region by the total number of attempts.)

■Advanced seismic and tsunami resistance design methods

- A new seismic coefficient method (design seismic coefficient) was studied for mooring facilities of various structural types to control the amount of deformation so that the facility can continue to be used after a Level 1 earthquake, thereby improving the seismic design. The research results have been reflected in the Standards and Commentaries.
- The research was conducted on design methods for reinforcing caisson breakwaters against tsunamis and waves with embankment widening work behind the breakwater, and on design methods considering the influence of tsunami seepage flow generated in the foundation mound on the reduction of the bearing capacity, in order

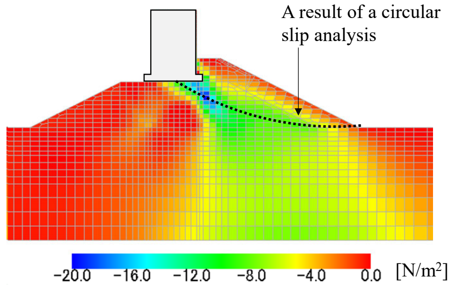

Figure-3 Bearing capacity analysis considering the seepage flow of a breakwater with embankment widening work (Image of shear stress at failure by FEM analysis) to improve tsunami resistance design methods. The research results have been reflected in the Standards and Commentary.

■Internationalization of technical standards for port and harbor facilities of Japan

- A methodology was studied to develop locally available standards by modifying (customizing) Japanese port standards to suit the natural conditions and other factors in the partner country. The results were then applied to Vietnam to develop their port standards. In Vietnam, the National Port Standards (five design standards and one construction and acceptance standard), which were reviewed by the Ministry of Transport and the Ministry of Science and Technology, were officially put into effect by the Ministry of Science and Technology.
- As a basic study to promote the overseas use of Japanese port standards, a comparative study of pier designs based on Japanese port standards and British port standards (BS6349) was conducted and the results were compiled as a NILIM Technical Note.

Photo-1 Technical meeting with Japanese and Vietnamese code writers

Figure-4 Status of issues and work on Vietnamese port standards

As of April 2021

	Progress			
	Research	draft-TCVN	Evaluation of TCVN	Issue of TCVN* *Vietnamese Standards
■ Design Standards				
Part 1 : General Principles	→	→	→	May 2017
Part 2 : Loads and Actions	→	→	→	May 2017
Part 3 : Material Requirements	→	→	→	November 2019
Part 4-1 : Foundation	→	→	→	March 2020
Part 4-2 : Soil Improvement	→	→	→	March 2020
Part 5 : Wharves	→	→	→	
Part 6 : Breakwater	→	→		
Part 7 : Channels and Harbours				
Part 8 : Dry Dock, Lock, Slipway and Shipbuilding Berths				
Part 9 : Dredging and Reclamation	→	→		
Part 10 : Other Marine Facilities				
■ Constructions and Acceptance Standard				
Constructions and Acceptances	→	→	→	September 2017
■ Maintenance Standard				

3. List of Related Reports and Technical Documents

■Introduction and advancement of performance-based and reliability-based design methods (typical)

1) NILIM Research Report No. 20 http://www.nilim.go.jp/lab/bcg/siryou/rpn/rpn0020.htm
2) NILIM Technical Note No. 956 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0956.pdf
3) NILIM Technical Note No. 955 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0955.pdf
4) NILIM Technical Note No. 944 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0944.pdf
5) NILIM Technical Note No. 931 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0931.pdf
6) NILIM Technical Note No. 922 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0922.pdf
7) NILIM Technical Note No. 880 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0880.htm
8) NILIM Technical Note No. 373 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0373.htm
9) NILIM Technical Note No. 377 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0377.htm
10) NILIM Technical Note No. 350 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0350.htm
11) NILIM Technical Note No. 217 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0217.htm

■Advanced seismic and tsunami resistance design methods (typical)

1) NILIM Technical Note No. 1065 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks1082.pdf
2) NILIM Technical Note No. 994 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0994.pdf
3) NILIM Technical Note No. 979 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0979.pdf
4) NILIM Technical Note No. 954 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0954.pdf
5) NILIM Technical Note No. 920 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0920.pdf
6) NILIM Technical Note No. 836 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0836.htm
7) NILIM Technical Note No. 812 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0812.htm
8) NILIM Technical Note No. 800 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0800.htm
9) NILIM Technical Note No. 798 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0798.htm

10) NILIM Technical Note No. 717 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0717.htm

11) NILIM Technical Note No. 310 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0310.htm

■Internationalization of technical standards for port and harbor facilities of Japan (typical)

1) NILIM Project Research Report No. 61 http://www.nilim.go.jp/lab/bcg/siryou/kpr/prn0061.htm

2) NILIM Technical Note No. 1117 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks1117.pdf

3) NILIM Technical Note No. 915 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0915.pdf

4) NILIM Technical Note No. 800 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0800.htm

5) NILIM Technical Note No. 769 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0769.htm

*There are approximately 50 additional NILIM technical reports and notes on the above three studies.

4. Future Outlook

In order to further deepen performance-based design in the port field and to respond to various social needs that may change in the future, there are still many issues to be addressed. For example, research needs to be conducted on design systems that consider user needs and productivity, improvement of disaster response, sustainability, overall optimization using numerical analysis and various data, and conversion to the versatile Level 1 reliability-based design method (partial coefficient method). In addition, as ports and harbors will be required to improve their disaster response capabilities even more than before, it is necessary to conduct research on design systems that enable verification of performance and functionality not only by confirming the performance of individual facilities, but also by considering the system of ports and harbors as a whole. Another major issue is how to cope with extreme sea level rise and waves due to climate change. It is also necessary for port facilities to promptly respond to various technological innovations (e.g., autonomous navigation of ships, automatic mooring systems, conversion to hydrogen energy, etc.). It is necessary to conduct research on these various issues and continue to study the results so that they can be reflected in design practice.