PARI

Annual Report 2019

Port and Airport Research Institute Annual Report 2019

Creating Technologies That Contribute to the World

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Yoshiaki KURIYAMA, Director General, PARI

In April 2016, the Port and Airport Research Institute (PARI) restarted as a member institute of the National Institute of Maritime, Port and Aviation Technology, which had been established after the integration of PARI, National Maritime Research Institute and Electronic Navigation Research Institute. PARI serves as a research institute responsible for developing technology related to construction and maintenance of ports and airports, and coastal zone management. The Port and Harbour Research Institute (PHRI), the predecessor of PARI, was established in 1962 as an independent institution of the Ministry of Transport. Since then, we have provided technical support for various port and airport projects, including the development of Kashima Port and the construction of Kansai International Airport, and have made research achievements that are highly regarded throughout the world. In order to maximize the achievements in research and development, we further expand and strengthen our cooperation and interaction with researchers in different fields including the two other institutes.

This annual report summarizes PARI's track record in FY 2018, the third year of the first mid-term plan (from FY 2016 through FY 2022). In this plan, PARI is focusing on the following four research and development challenges: Coastal Disaster Mitigation and Restoration, Formation of Infrastructure for Vigorous Economy and Society, Preservation of Marine Interests and Utilization of Oceans, and Creation and Utilization of Coastal Environment.

Our specific approaches to the four research and development challenges taken during the FY 2018 included the following. 1. "Coastal Disaster Mitigation and Restoration": We continued developing techniques to enable the diagnosis of earthquake and tsunami resistance and so forth "while using existing facilities". We also proposed testing methods to rapidly evaluate damage levels on offshore structures and facilities near breakwaters. Moreover we proceeded with research on post-earthquake restoration of port and harbour structures. 2. "Formation of Infrastructure for Vigorous Economy and Society": In order to maintain and manage port structures efficiently, we developed a device that collects images to help diagnose deterioration degree on the underside of the superstructures of open-type wharves by a ROV (Remotely Operated Vehicle) from land. In addition to above and preparing to applying findings in our social settings, we carefully reviewed unit labor costs while starting device-lending program. 3. "Preservation of Marine Interests and Utilization of Oceans": We reduced the weight of the shallow underwater acoustic video cameras and made an operations manual for the cameras and the video image presentation system. 4. "Creation and Utilization of Coastal Environment": We constructed a new coastal ecosystem model that achieves both blue-carbon (the carbon stored in marine and coastal ecosystems) quantification in various coastal areas and predictor models of ocean-wave attenuation (adaptation effect) that take the ecosystem into account.

In executing the above research, PARI pursued its two major goals of maintaining PARI's research levels at the highest global standards and assisting working projects with PARI's research results. PARI also promoted government-led strategic international activities including contributing to the expansion of infrastructure overseas and providing technical assistance to overseas countries.

2018 witnessed several notable natural disasters, including the passage of Typhoon Jebi and Typhoon Trami across Honshu on September 4 and 30, respectively, and the Hokkaido Eastern Iburi earthquake on September 6, as well as earthquakes and high waves that struck Indonesia. We offer emergency responses and restoration support at the time of coastal disaster including earthquakes, tsunamis and storm surges and conduct awareness activities regarding disaster prevention.

We would greatly appreciate your continued support.

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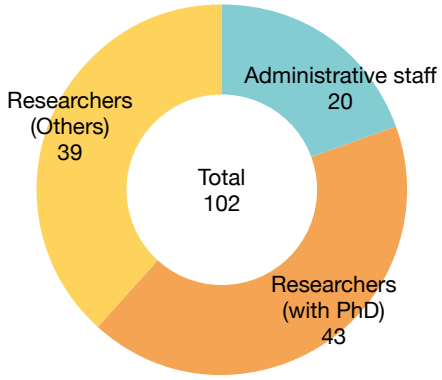
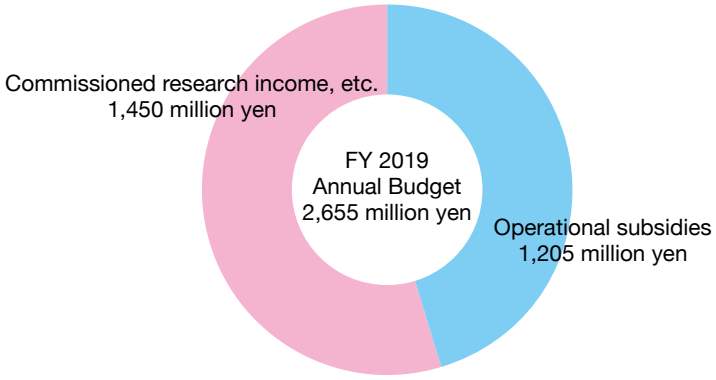
Administrative Staff and Researchers, and Budget

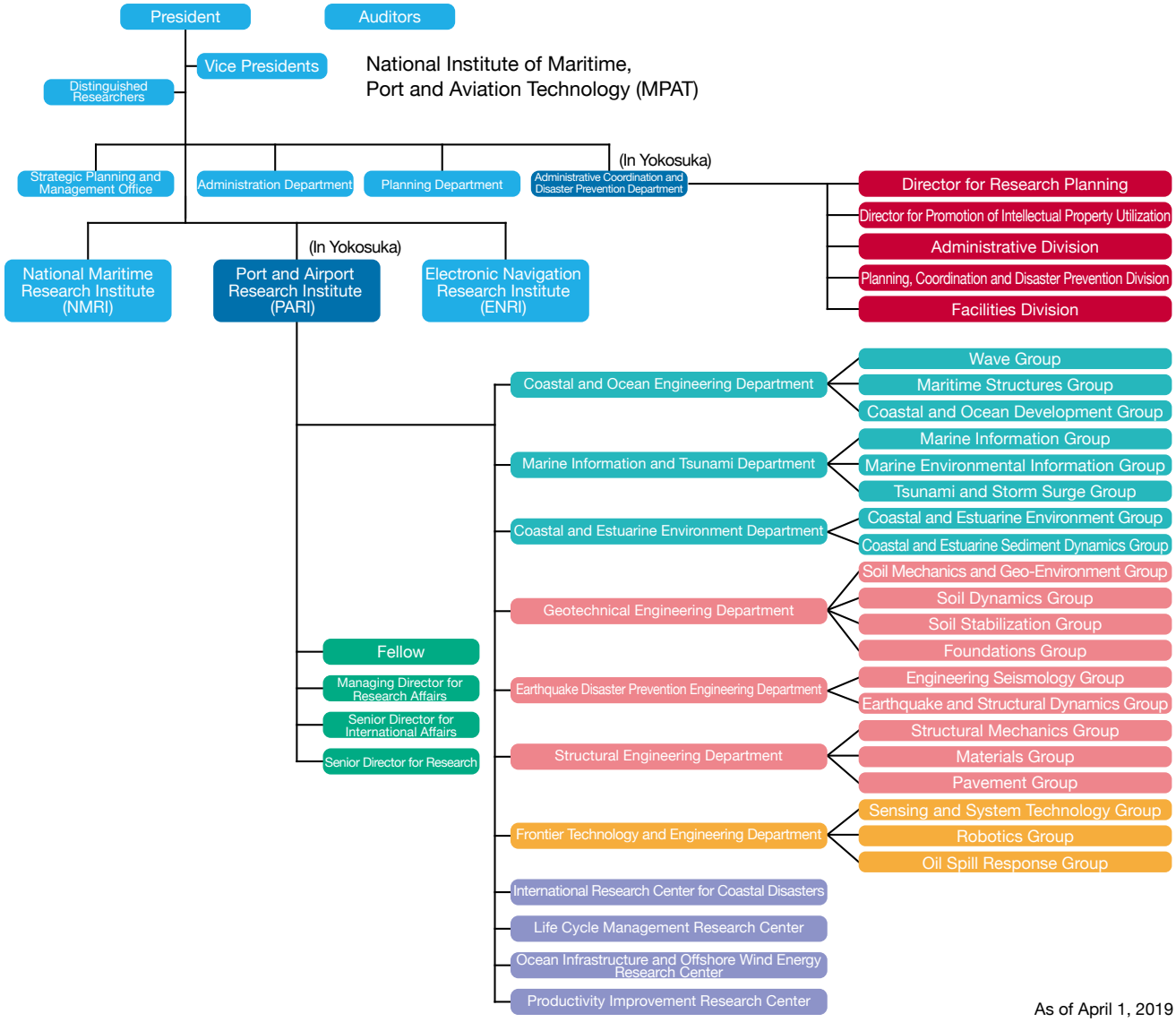


As of April 1, 2019 (In Yokosuka)



* The graph above shows the budget for technical fields related to ports, waterways, coasts, and airports.

Organizational Structure



As of April 1, 2019

Mid- and Long-Term Objectives (FY 2016 to FY 2022)

The Minister of Land, Infrastructure, Transport and Tourism (MLIT) sets mid- and long-term business goals for the National Research and Development Agency, National Institute of Maritime, Port and Aviation Technology to achieve. These goals stipulate our operations as follows.

Basic Policies for Structural Reform of Independent Administrative Institutions were decided in a Cabinet decision on December 24, 2013 (hereafter called "Basic Policies for Reform"). Based on these policies, the National Maritime Research Institute (NMRI), Port and Airport Research Institute (PARI), and Electronic Navigation Research Institute (ENRI), which were National Research and Development Agencies operated under the jurisdiction of the MLIT, were integrated into the National Institute of Maritime, Port and Aviation Technology (hereafter called "MPAT") to implement the policies.

Article 2, paragraph 1 of the Act on General Rules stipulates as follows: some clerical tasks and business require sound implementation from the viewpoint of general welfare including stabilization of people's life and socioeconomy, but at the same time do not require government-led implementation. Some of these clerical tasks and businesses face the risk of neglect when their operation is entrusted to private entities, so MPAT was established to effectively and efficiently conduct their operation.

In consideration of the previous roles of each institute, MPAT is required to continue to make full use of its accumulated wealth of knowledge and stature, and to proceed with research and development according to the Basic Policies for Reform. In addition, MPAT will constantly review research contents and select research areas to address changes in the social environment. At the same time, MPAT will more actively engage in research and development activities to solve policy challenges in each field, such as conducting research in emerging fields.

MPAT has promoted research and development in each field, cultivated technological seeds, and accumulated specialized knowledge. Thanks to MPAT's legacy, such multidisciplinary research became viable. In consideration of this background, MPAT will efficiently and effectively implement multidisciplinary research including "Promoting the protection of maritime interests and the utilization and application of marine-resource/marine-renewable-energy development and other projects". Through such implementation, MPAT will help put national policies into practice.

Furthermore, MPAT considers that it is important to return the benefits achieved through research and development to society, as well as to cooperate with external institutes and to widely disseminate research results. In addition, MPAT is committed to strategically implementing international activities as follows: active participation in projects to formulate international criteria and standards; international promotion of Japanese technologies and systems through international cooperation; and other activities.

As outlined above, MPAT's missions are based on the MLIT's Basic Plan for putting MLIT-recommended policies into practice. Today, Japan faces various important challenges. By realizing these policies, we can solve such challenges.

Mid- and Long-Term Plans (FY 2016 to FY 2022)

The MLIT sets mid- and long-term goals. In response to such goals, MPAT sets mid- and long-term plans to achieve the goals. Among such plans, important points in maximizing research and development results and improving the quality of other projects are outlined below.

1. Promotion of multidisciplinary research and other activities

MPAT will efficiently and effectively implement multidisciplinary research spanning research fields of the three pre-integration institutions to contribute to putting the following policies into practice: promotion of ocean utilization, enforcement of international industrial competitiveness, and other policies.

2. Research and development of technologies associated with ports, water ways, coasts, and airports and other activities

MPAT will focus on the research and development challenges detailed in the following pages, to devise the following MLIT-recommended initiatives: disaster-prevention and disaster-reduction countermeasures for port and airport facilities; countermeasures for facility obsolescence of existing structures; and initiatives to create maritime-development hubs.

Among basic research, MPAT also actively engages in research to understand the mechanisms of ocean waves and beach transformation and principles and phenomena regarding the dynamic behavior of the ground and structures.

MPAT also uses its foresight and flexibility to accurately address emerging research which might lead to new research results.

3. Returning benefits from research and development results to society

MPAT will try to resolve technological policy challenges, to address disasters and accidents, to enforce bridging functions, to promote and utilize intellectual property right, and to enhance the transmission of information and publication.

4. Promotion of strategic international activities

MPAT will contribute to international standardization and cooperate with overseas institutions.

MPAT Operation Management

MPAT will focus on rapid decision-making to engage in strategic institutional operations.

MPAT will also hold the following meetings for multi-faceted investigation of various operational agendas from a broad perspective:

1. Management strategy meetings: In-house meetings for making decisions on important issues related to the core principles of MPAT management
2. Board of Directors meetings: Weekly meetings involving all executives and division managers as well as the three directors of the Administrative, Coordination and Disaster Prevention Department
3. Board of Councilors meetings: Meetings to gather insights from independent experts who have broad and deep knowledge
4. External Evaluation Board: An external body in which third parties objectively and technically evaluate MPAT's research

Structure of Research Themes in FY 2018

Research Field	Research Theme	Research Subtheme	Type of Research		Item on the Research Agenda (☆indicates special research)
1. Coastal Disaster Mitigation and Restoration	1A Research on Mitigation of and Restoration from Earthquake Disasters	① Research on strong ground motions and damage predictions in the case of the greatest earthquakes	Fundamental Research		Strong Motion Earthquake Observation in Port and Airport Area (2A②)
			Fundamental Research		Investigation of Earthquake Disaster (2A②)
			Fundamental Research		Development of strong motion estimation method for scenario earthquakes beneath metropolitan area
			Fundamental Research		Study on the evaluation and analysis of liquefied ground behavior and effective countermeasures under sequenced earthquake motions
		② Research on damage-reduction techniques against the greatest earthquakes	Applied Research		Development of technologies for assessing and improving seismic safety of coastal industrial complex consisting of a wide variety of facilities
			Applied Research		Development of method to seismic peformance evaluation for offshore structure against the largest earthquake motions
		③ Research on the interaction of earthquakes, tsunamis, and high waves with ground dynamics	Fundamental Research		Study from geotechnical view-point on stability evaluation method of coastal structure subjected to high waves (1C②)
			Fundamental Research	☆	Stability evaluation of offshore structures against washout, cavity formation, etc. and development of countermeasure techniques (1C②)
	1B Research on Mitigation and Restoration of Tsunami Disasters	① Research on ICT-based decision support systems	Development Research		Development of a tsunami-fire model for ports
			Development Research		Development of multi-observation based tsunami forecasting method
		② Research on the development of tsunami-resistant ports	Applied Research		Development of an advanced 3-dimentional simulation model for tsunami inundation
			Fundamental Research		Development of the estimation method for local scour around coastal structures due to tsunami
			Fundamental Research		Application of the particle method to the large deformation of port structures due to tsunami
	1C Research on Mitigation and Restoration of Storm Surge and Wave Disasters	① Research on storm surge,wave and maximum damage estimation	Fundamental Research		Elucidation of oceanographic phenomena based on central processing and analysis of observation data
			Applied Research		A study of seasonal and regional statistics on swell observed in Japanese coast
			Development Research		Development of a harbor tranquility analysis method for local wind waves and ship waves in a harbor
			Fundamental Research		Proposal for improvement of prediction accuracy of swell
			Applied Research		Estimation of wave transformation around damaged structures to evaluate remaining performance for sheltering
			Fundamental Research		Assessment of possible maximum storm surge hazard by using storm-surge-wave coupled model
		② Research on the technology to reduce maximum storm surge and wave disasters	Applied Research	☆	Study on wave forces on the structural members of protective facilities under storm surges, high waves, and tsunami (1B②)
2. Formation of Infrastructure for Vigorous Economy and Society	2A Research on Enhancement of Port and Airport Performance for Industrial Competitiveness	① Research and development for enhancing the operations of ports, harbors, and airports	Development Research		Development and suggestion of efficient and suitable use which contains automated cargo systems through container terminal numerical simulations for multi berths
		② Research on efficient and effective improvement of ports and airports			(All research items marked “2A②” in this Table)
	2B Research on Life Cycle Management of Infrastructures	① Research on technologies for prolonging the life of infrastructure	Fundamental Research		Evaluation of longterm durability of concrete, steel and various materials based on exposure test
			Fundamental Research		Development of the performance evaluation method in protective coating for marine structures
			Fundamental Research		Evaluation of the durability of various materials under severe environments
			Applied Research		A study on the improvement of airfield pavement material to prolong the pavement life (2A②)
			Applied Research		Development of structural design method for strategic maintenance of port and harbour structures
			Applied Research	☆	Systematization of repair and strengthening of marine concrete structures
		② Research on systems for inspecting and diagnosing infrastructure	Development Research		Development of the structural health monitoring system for port structures
			Development Research		Enhancement of ROV system for inspection of concrete superstructures of open-type wharves (2A①)
		③ Research on maintenance and management systems for infrastructure	Applied Research		Study on maintenance planning of port facilities in term of LCC optimization
	2C Research on Effective Use of Existing Infrastructure Facilities	① Research on techniques to improve or renew existing facilities	Fundamental Research		Improvement method to non-uniform ground and its effect as a measure against liquefaction (2A②)
			Applied Research		Development of a method for evaluating the performance of reclaimed grounds of airports that takes into account the differences in ground improvement method and landfill material (2A②)
			Applied Research		Study on method for evaluation of bearing capacity of piles for upgrade of port and airport facilities (2A②)
		② Research on effective use and techniques of treating construction byproducts	Fundamental Research	☆	Enhancement of accuracy of method for evaluating mechanical properties of composite geomaterials based on microstructural feature
			Applied Research		Development of technique increasing capacity of disposal site for dredged soil
		③ Research on management and utilization of waste disposal sites at sea	Applied Research		Structure foundation for high-degree land-utilization at confined disposal facilities
3. Preservation of Marine Interests and Utilization of Oceans	3A Research on Development and Utilization of Oceans	① Research on port construction and management in remote islands	Development Research		Innovation for using berthing and mooring facilities constructed in isolated coral reef sea
			Development Research		Technological development on advanced ship mooring system in port
			Development Research		Research on maintenance inspection and investigation technology for remote island ports (2A①)
		② Research on infrastructure technology for utilization and development of oceans	Development Research		Development of next-generation acoustic imaging system (2A①)
			Development Research		Research on adaptation of the machine guidance for an underwater excavator (2A①)
			Fundamental Research		Study on floating breakwater equipped with wave power generation device
			Fundamental Research	☆	Development of analytical methods for the topographic dynamics of carbonate islands
4. Creation and Utilization of Coastal Environment	4A Research on Enhancement and Utilization of Coastal Ecology	① Research on coastal-ecosystem utilization	Fundamental Research	☆	Global estimates of the efficacy of blue carbon as a means of mitigation and adaptation to climate change
			Fundamental Research		Development of integrated prediction and assessment method of coastal benthic ecology and geoenvironmental dynamics
		② Research on the water-environment simulation and analysis in inner-bay	Fundamental Research	☆	Cross-sectional observation and analysis of atmospheric and oceanographic issues at bay mouths
			Fundamental Research		Analytical study of macro-organisms dynamics on a coastal ecosystem simulation
			Fundamental Research		Development of evaluating procedure for biodiversity referring to spatial scale in coastal areas
			Fundamental Research		Study on the mechanisms of coastal current and water environment using data assimilation
		③ Research on countermeasure technologies against sea oil spill	Development Research		Novel oil spill response technology to cope with various sources including natural disaster triggered oil spills
	4B Research on Coastal and Estuarine Processes	① Research on coastal protection and maintenance of waterways and mooring basins	Fundamental Research		Observation of coastal geographical feature change and malfunction of sedimentation control system in considered with influence of global warming
			Fundamental Research	☆	Study on sediment transport in estuary and deposition process in navigation channel
			Fundamental Research	☆	Study on applicability of airborne laser bathymetry for topographic monitoring in coastal zone of sea shore

1A Research on Mitigation of and Restoration from Earthquake Disasters

Background and Objectives

- In the event of large-scale disasters including Nankai megathrust earthquakes and earthquakes in the greater Tokyo area, it is required to secure necessary trunk line cargo transportation soon after an earthquake and to quickly secure the requisite minimum transportation of key emergency supplies for recovery and reconstruction. In addition, the interaction of earthquakes, tsunamis, and high waves with the ground might cause coastal disasters, so it is necessary to reduce such risks.
- Therefore, the themes of this research cover research and development which simultaneously achieves the two goals of improving earthquake resistance and reducing construction costs. These two goals can be achieved through diagnosis and performance verification of earthquake-resistance of facilities which address the properties of long-period and long-duration earthquake ground motion, which is expected to occur during a subduction-zone megathrust earthquake, as well as the properties of earthquake ground motion caused by local ground characteristics. Research and development are being conducted mainly on methods for investigating and diagnosing earthquake resistance as well as construction methods that improve the resistance of existing facilities with limited design life that were erected during the era of rapid economic growth without disturbing their use.

Research Topics

Research and development comprises the following three subthemes:

i) Research on strong ground motions and damage predictions in the case of the greatest earthquakes

Subduction-zone megathrust earthquakes may cause the greatest and long-duration earthquake motions, so we will develop techniques for predicting such motions. Also, we will develop techniques for predicting liquefaction and structural damage caused by such motions.

ii) Research on damage-reduction techniques against the greatest earthquakes

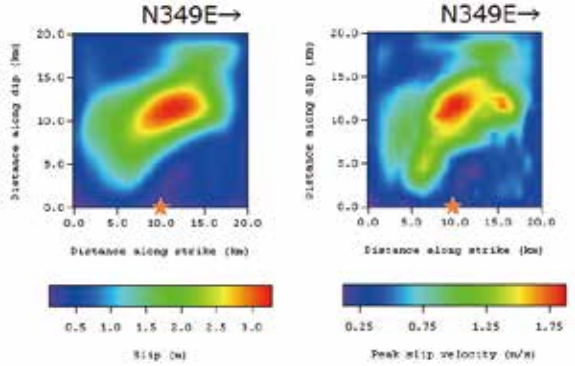
We will suggest the most effective countermeasures under given limitations to effectively promote seismic strengthening of existing structures. In doing so, we will actively utilize damage reduction and strengthening techniques that use novel materials, structures, and construction methods. Especially, as measures for improving earthquake resistance of industrial complexes, we will consider maintaining the functions while reducing costs for overall plants, and then develop investigation, diagnosis and countermeasure techniques which minimize usage limitations of plants. In addition, we will develop methods to rapidly evaluate damage levels on site immediately after a disaster as well as emergency restoration techniques.

iii) Research on the interaction of earthquakes, tsunamis, and high waves with ground dynamics

We will proceed with research on the following interaction problems of earthquakes and ocean waves with the ground: stability evaluation against seabed liquefaction, washout, cavity formation and collapse under earthquakes or under ocean waves; a mechanism in which a breakwater foundation loses its bearing capacity in the presence of tsunami; and other interaction problems. Also, we will use numerical simulation models, model experiments (on a centrifuge and a large-scale fluid tank), and other methods to investigate earthquake-induced submarine landslides, the resulting tsunamis, ground dynamics including deformation and failure under the influence of tsunami and high waves, as well as their countermeasures.

Activities in FY 2018

- We obtained 2,378 strong motion earthquake records during the period between January to December 2018. Of these data, the strong motion earthquake record with the maximum amplitude was measured at the Port of Tomakomai, which resulted from the Hokkaido Eastern Iburi earthquake that occurred on September 6, the maximum acceleration of which was 349 Gal. For strong motion earthquake observation at ports and harbors, we have been gradually implementing a system that automatically sends an email containing quickly estimated values of detected earthquake motions after their record is obtained. Although the earthquake that struck the Port of Tomakomai occurred in the middle of the night, a preliminary estimate of the earthquake data was quickly sent out about 10 minutes after the earthquake struck.
- As for the Hokkaido Eastern Iburi earthquake that occurred on September 6, 2018, PARI was requested by the Hokkaido Regional Development Bureau to cooperate, so we dispatched a joint investigation team together with the National Institute for Land and Infrastructure Management (NILIM) to the Port of Tomakomai on September 7 and 8 and conducted a study on the status of soil liquefaction, etc.
- After the Hokkaido Eastern Iburi earthquake on September 6, we estimated the rupture process of the earthquake, and estimated the earthquake motions that might have occurred at ports and harbors where no strong ground motion record could be obtained, etc.
- We evaluated and analyzed the liquefaction behavior of grounds that had fine content or grounds subject to successive earthquake motions, and obtained new knowledge that will be useful for suppressing the amount of internal ground flow and boiling that occur with the propagation of liquefied zones.
- We examined the residual performance of piled piers concerning their overall stability following their structural damage caused by earthquakes, and proposed a model for quantitatively evaluating the effects of the plate thickness and yield strength of steel pipes, etc., and organized information concerning evaluation of the seismic performance of existing piled piers.
- We examined the shake table test results obtained by using the large-scale earthquake simulator 'E-Defense' at the National Research Institute for Earth Science and Disaster Resilience (NIED) for 1/8-scale models of actual petroleum tanks, piled piers, and seawalls at a petrochemical complex in Keihin Port. We compared the behavior of two different cross sections with and without earthquake-resistance measures.
- We conducted stability evaluation and analyses concerning washout, cavity formation, etc. that occur under various dynamic external forces such as earthquakes, waves, and water flow to elucidate their characteristics and mechanisms, and also suggested new countermeasure techniques that can effectively suppress washout and cavity formation.
- We conducted centrifugal model experiments to study the ground stability against waves and found that ground stress and pore water pressure affect ground stability.



Estimated distribution of slip and slip velocity on the fault surface during the Hokkaido Eastern Iburi earthquake

1B Research on Mitigation and Restoration of Tsunami Disasters

Background and Objectives

- Since the Great East Japan Earthquake in 2011, we have studied stable structures against tsunami overflows and developed a numerical simulation model to predict the drifting of debris generated by the destruction of buildings. However, complex behaviors of tsunami run-up on land and the resulting damages are not fully understood and modeled yet. In addition, regarding a technique for real-time inundation forecast, which is expected to be utilized for evacuation and other purposes, only data from GPS-mounted wave buoys is used; other valuable data is not fully utilized yet.
- Therefore, we are aimed for changing disaster prevention and reduction countermeasures into a pre-disaster stage from post-disaster one, and will conduct research to establish resilient coastal zones which can withstand the most severe tsunamis, i.e., to protect lives against the most severe tsunami, to avoid catastrophic socioeconomic damages, and to enable early recovery and reconstruction.

Research Topics

Research and development comprise the following two sub-themes:

i) Research on ICT-based decision support systems

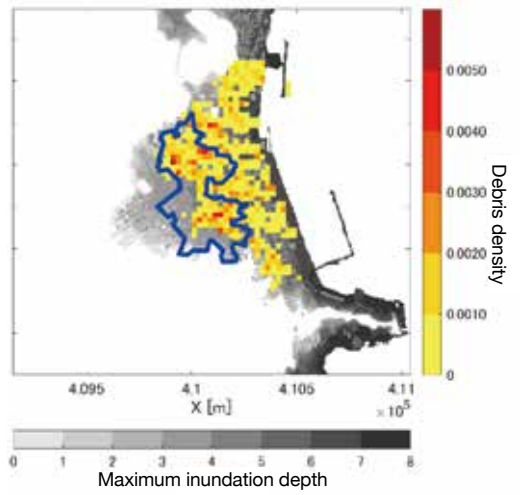
We have previously developed a system for rapid forecasting of tsunami inundation, which utilizes offshore-tsunami waveforms observed by GPS-mounted wave buoys. For highly reliable tsunami prediction, we will additionally utilize ground deformation data obtained by on-land GPS base stations and remote-sensing information including ocean HF radars, and will refine the system. To ensure the safety of evacuation sites, it is necessary to assess not only tsunami-induced inundation depth but also the tsunami velocity and floating objects to determine the resistance of structures and even to assess fires, which are associated with floating objects. So, we establish an integrated simulation system which can assess these risks.

ii) Research on the development of tsunami-resistant ports

We will clarify the structures of violent flows, scours around structures induced by large tsunami-overflows, and the influence of drifting objects including ships and vessels on the damages. Then, we will develop a method of designing tsunami-resistant breakwaters and other facilities as well as a method of planning tsunami-resistant ports. We will develop a three-dimensional multi-physics numerical model based on a particle method with fluid-solid interaction, and utilize it as a tool for the design and planning in addition to numerical models we have developed so far. Moreover, we will conduct a large-scale model experiment to validate the robustness and accuracy of the numerical model, and will understand complex tsunami phenomena in port cities.

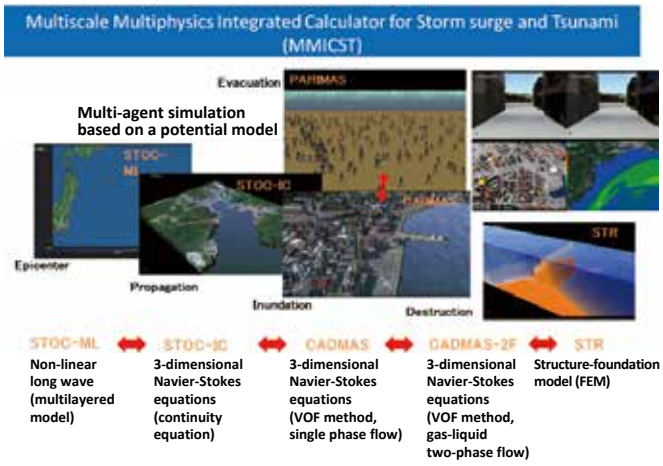
Activities in FY 2018

- For developing a tsunami-fire model for ports, we used the debris behavior model that we had been improving through flume experiments until the previous fiscal year to calculate the inundation and debris drifting that occurred in Yamada Town, Iwate Prefecture as a result of the 2011 Great East Japan Earthquake Tsunami. Improving the calculation accuracy of debris behavior is important for better reproducibility of tsunami run-up areas.



Calculation of tsunami inundation and debris drift

- For developing the tsunami forecasting method based on multi-observation data, we analyzed the characteristics of the noise of ocean HF radars and also GPS-mounted wave buoys. In addition, we introduced weighting algorithm for multiple data sets in inverse analysis of tsunami sources, and examined the applicability of this method using synthetic data with obverted noises.
- As for the advanced 3-dimensional tsunami inundation simulator, we completed the simulator to calculate the inundation in the hinterland, while taking into account the deformation of protection facilities. We conducted a trial calculation for Otsuchi Town flooded by the 2011 Great East Japan Earthquake Tsunami and the coast of Urado Bay by the Nankai Trough Tsunami. And we also improved the computational efficiency of this simulator and enhanced the visualization function.



Overview of multiscale multiphysics integrated simulator

- For developing the method for estimating local scouring around coastal structures caused by tsunamis, we improved a pressure gradient model that makes up the particle-based simulator, and added a sedimentation model that considers the attachment of sand particles floating in the water to the seabed. As a result, we improved the reproducibility of the simulator for overflows on breakwaters and scouring of the ground behind them.
- For applying the particle-based method to the deformation of port and harbor structures caused by tsunamis, we improved the pressure model and also enhanced the precision of the multi-resolution structure model, and also started developing a new coupling model for them. As a result, we enhanced the accuracy of the evaluation of the pressure distribution in plunging breakers and also the impact force that occurs when marine vessels and other floating objects hit the water surface.

1C Research on Mitigation and Restoration of Storm Surge and Wave Disasters

Background and Objectives

- Since Typhoon Vera struck in September 1959, there have been no devastating storm surge and wave disasters in Japan. However, the U.S. suffered severe damages due to Hurricane Katrina in September 2005, and so did the Philippines due to Typhoon Haiyan in November 2013. In future, global warming might bring higher storm surges and waves than those we have expected in Japan.
- Therefore, this research is aimed for changing disaster prevention and mitigation measures into a pre-disaster stage from post-disaster one and focuses on how to mitigate damage by the maximum storm surge and wave conditions and how to rapidly recover and reconstruct after the damage has occurred. Therefore, we conduct research to encourage hard and soft measures. Specifically, we will develop a numerical model to estimate the maximum storm surge and wave and their damage and will also develop design methods to build robust structures.

Research Topics

Research and development comprises the following two subthemes:

i) Research on storm surge, wave and maximum damage estimation

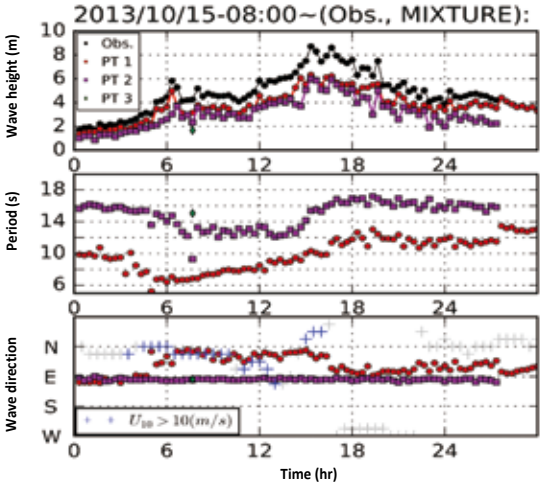
We will develop the following to determine the characteristics of the damage due to the maximum storm surge and wave: an accurate storm surge prediction model, which incorporates a weather model; and a new method based on a 3-D fluid model to simulate tidal levels and flows at the time of storm surge. Also, we will employ a high statistical analysis to estimate the effects of global warming on the maximum storm surge and wave and long-term variations in these statistics. In addition, we will establish a calculation technique to estimate the following wave transformations: the wave sheltering effects of breakwaters damaged through sliding, depression and others; and overtopping prevention effects of seawall having collapsed parapet, dispersed wave-dissipating blocks and other damages.

ii) Research on the technology to reduce maximum storm surge and wave disasters

We will elucidate structural stability under complex conditions in which unexpectedly high water level due to storm surge coincides with high waves. In addition, we will investigate methods of estimating the damage on structures due to storm surge and waves and countermeasure against such damages, and develop a method to design robust structures.

Activities in FY 2018

- For the elucidation of the characteristics of oceanographic phenomena based on central processing and analysis of observation data, we organized the wave observation data measured in 2017 through the Nationwide Ocean Wave Information Network for Ports and Harbours (NOWPHAS) into the annual report, and also analyzed the waves caused during Typhoons Jebi and Trami. In addition, we observed sea surface winds and ocean surface turbulence at the Hiratsuka observation tower.
- For the study of the seasonal and regional characteristics of swells observed along the coast of Japan and the mechanism through which they emerge, we used the method that was developed during the previous fiscal year to estimate two-dimensional wave spectrum with high precision, developed a new method to identify wind waves and swells with different predominant periods and wave directions based on the wind direction and the wave age, and applied the new method to in-situ data for several stations.



Temporal change in the three main components (PT1, 2, and 3)

- For the development of the wave generation and tranquility analysis method for waves created by strong wind and ship waves in a harbor, we studied the wave development process in a wind-wave flume, and also improved the Boussinesq model called as NOWT-PARI, which is used to perform harbor tranquility analysis, so that wave development can be also expressed in line with Miles's theory.
- For the proposal of the improvement in the prediction accuracy of swell, we confirmed that there was no significant difference between WAM and WW3 in terms of their precision of wave estimation in the open ocean, and developed a WW3-based wave estimation system applicable to the coast of Japan. We also proved that it would be difficult for these models to recreate the '*Yori-mawari-nami*' swell that uniquely occurs in Toyama Bay, for which the phase interference of waves is important.
- For the evaluation of the wave transformation and propagation characteristics around damaged structures, we improved the Boussinesq model called as NOWT-PARI so that it can be applied to types of submarine topography such as rectangular cross sections where the depth suddenly changes. We also reviewed data from the disaster caused by Typhoon Jebi and attempted to compute wave overtopping and runup over quaywalls submerged under water due to a high sea level.
- For the study on the maximum storm surge hazard using a coupled model of storm surges and waves, we conducted statistical analyses of the parameters of the typhoons that have occurred since 1951 (including their extratropical transition) and examined what might be the optimal gradient wind velocity reduction factors for the parametric typhoon model. We also performed computations to recreate the storm surges that occurred in Osaka Bay during Typhoon Jebi, 2018.
- For the study on the effects of wave forces on the structural members of costal structures during storm surges, high waves, and tsunamis, we conducted experiments to observe the abrasion of geotextile sheets and the stability of wave-dissipating blocks. We also examined ways to improve the efficiency of UAV-based disaster damage surveys by utilizing data from the surveys in the damaged area by Typhoon Jebi. In addition, we collected experiment data to develop a program for evaluating wave pressure using ANN.

Experiment on the abrasion of geotextile sheets

2A Research on Enhancement of Port and Airport Performance for Industrial Competitiveness

Background and Objectives

- Focused approaches on the following two matters are required: 1. The population is decreasing, society is graying, and accumulated infrastructure is aging in Japan. In view of such problems, studies should be conducted on how to secure port and airport functions, which support the international competitiveness of Japanese industry and the vitality of the nation, and people's lives. 2. With limited financial resources and workforce, studies should be conducted on how to efficiently and effectively implement maintenance, renewal, and repair works while efficiently using existing infrastructure and prolonging the life of overall facilities themselves.
- Therefore, we decided to engage in research and development and other activities which are associated with improving the functions of ports and airports. In these activities, we are conducting comprehensive research and development throughout PARI on subthemes associated with international competitiveness including internationally strategic port policies and improvement of metropolitan airport functions (improvement of Haneda Airport).
- The themes of this research address the development of specific technologies associated with international competitiveness including automated cargo handling and construction information modeling (CIM). Regarding development of technologies which efficiently and effectively implement the following matters for port and airport facilities, the themes of other studies (1A, 2B, and 2C) address: improvement of largescale facilities, improvement of the quake resistance of facilities, maintenance and management after facility construction, and improvement of existing facilities.

Research Topics

i) Development and suggestion of efficient and suitable use which contains automated cargo systems through container terminal numerical simulations for multi berths

Focusing on the strategic international container ports, we aim to establish methods for effectively utilizing container terminals that are typically limited in space in Japan. To achieve this goal, we will quantitatively evaluate the benefits of on-dock depots, how streamlined operations could prevent traffic congestion in front of the gates, and handling of large quantities of containers, and propose strategies to effectively utilize the container terminals in a comprehensive manner, using simulation-based quantitative evaluation.

ii) Saving labor, shortening the work period, and reducing costs by using CIM

As part of the use of construction information modeling (CIM), we will provide technical assistance concerning the construction inspection method based on construction management data utilizing multibeam sonar.

Activities in FY 2018

i) Development and suggestion of efficient and suitable use which contains automated cargo systems through container terminal numerical simulations for multi berths

The operators of large-scale terminals overseas have been able to reduce costs by leveraging their scale, and have extended their technical advantages, while their general requirements are also becoming increasingly advanced, such as the reduction of negative environmental effects and the expansion and improvement of their dynamic storage capacity. Meanwhile, Japan is faced with a number of challenges that must be overcome, including limited storage space, short berth extension, comb-shaped pier arrangement, and insufficient road capacity.

To address these issues, we conducted studies on the following items with a view toward introducing ICT and other new technology:

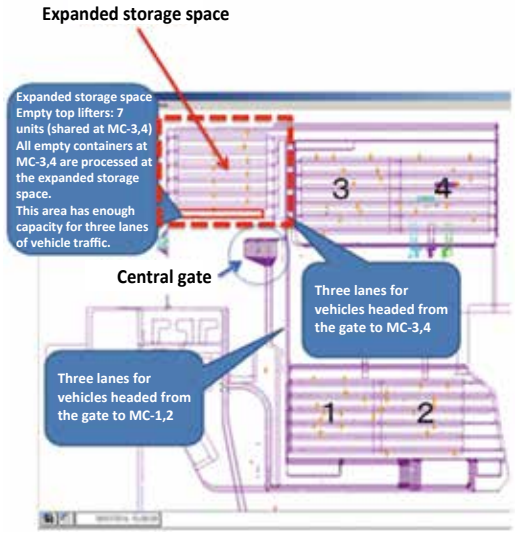
1) Evaluation of the processing capacity of gates

2) Estimation of the effects of improving operation efficiency by utilizing ICT, etc., and the effects of introducing a reservation system and a prior gate processing system

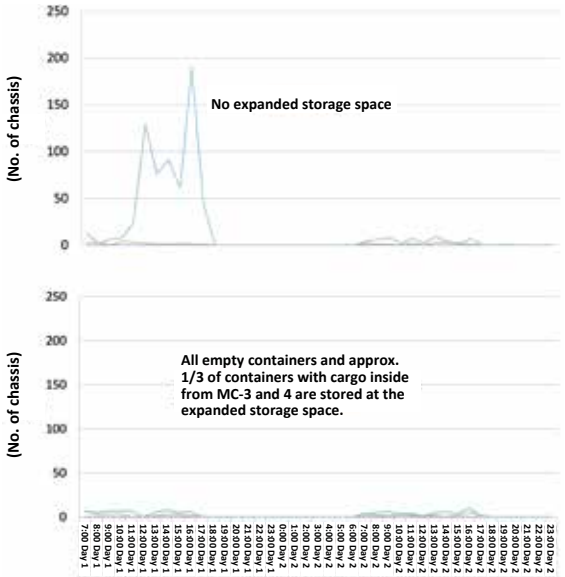
3) Rational handling of cargo quantities that exceed plans

Proposal to utilize expanded storage space (empty containers, containers with cargo inside, on-dock)

We selected Minami Honmoku Pier MC-1 through 4 of Yokohama Port to conduct a simulation-based quantitative evaluation. In the expanded storage space, we were able to confirm significant benefits already on day 1 (on which there was a relatively large number of chassis from outside entering the pier), in terms of the number of chassis standing by in the machinery parking area in front of the gate.



Typical case of the simulation model



On Day 1, which had a large number of chassis from outside entering the pier, a maximum of about 200 chassis were seen standing by at times, in the absence of an expanded storage space. However, once the expanded storage space was set up, the number of chassis standing by disappeared almost completely. Therefore, the provision of such expanded storage space is highly beneficial.

2B Research on Life Cycle Management of Infrastructures

Background and Objectives

- The ports, airports and coastal infrastructures that have been in service for a long time are increasing, but financial resources and the number of engineers for facility maintenance are limited. As important port, airport, and coastal infrastructure functions should be maintained, the strategic maintenance, renewal, and other measures to maintain such functions are strongly required.
- Therefore, we are trying to establish methods for structure design and material selection which are excellent in terms of maintenance, and will develop techniques and technologies regarding various countermeasures for maintenance phase.

Research Topics

Research and development comprises the following three subthemes:

i) Research on technologies for prolonging the life of infrastructure

Regarding various construction materials in marine environments, we will conduct research on the following: evaluation of long-term durability, understanding of deterioration mechanisms, and investigation of the prevention effects of protective methods for steel structures. Especially, assuming that infrastructure is used overseas and on remote islands in Japan, we will investigate material characteristics for durability improvement under severe environments and under conditions in which low-quality material is used, and will investigate environmental-load reduction, durability improvement, and environmental harmonization. Regarding airport pavement, we will investigate methods for detecting the stripping of asphalt mixtures, measures to prevent such stripping, how the durability performance of airport pavement can be improved, and quick repair and rehabilitation techniques while construction quality, is still assured.

ii) Research on systems for inspecting and diagnosing infrastructure

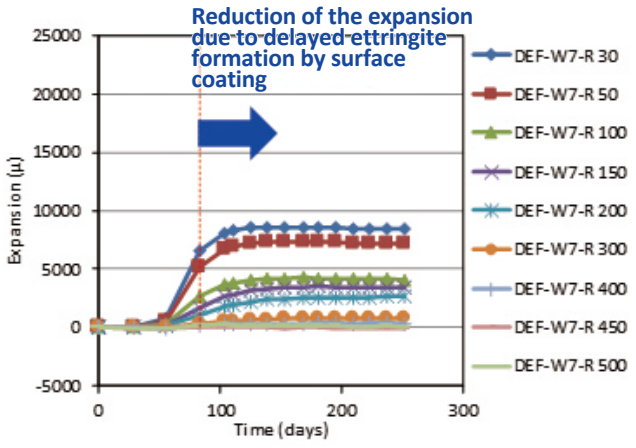
We will research and develop the following: inspection and diagnosing techniques using non-destructive and semi-destructive inspection methods and sensors, unmanned investigation devices including ROVs, non-contact thickness measurement system, and others. Especially, we will propose a health-monitoring system which utilizes sensors, as well as monitoring methods specialized for each member type.

iii) Research on maintenance and management systems for infrastructure

We will conduct accelerated deterioration tests of members of port structures, investigate performance deterioration models which cover the entire lifecycle of structures, and validate such models through exposure tests in actual environments and through on-site investigation. We will also take into account the required properties and utilization of individual structures, budgets, and various limitations, and then suggest strategies of management of port-based and district-based groups of port structures.

Activities in FY 2018

- We used long-term exposure facilities to study how to predict chloride-induced concrete deterioration, the electrolytic protection characteristics of steel bars in reinforced concrete, and the concentrated corrosion mechanism that affects steel materials. We also obtained data on the durability of various wood materials and reinforced concrete that utilized recycled frame materials.
- We aimed to establish a method for predicting the deterioration of protective coating methods against corrosion. To achieve this goal, we conducted continuous experiments at Hazaki Observational Pier, including exposure tests on steel pipe piles to which anti-corrosion protective coating had been applied. We also conducted accelerated deterioration trials and exposure tests to further elucidate the deterioration mechanism of petrolatum coating methods.
- We evaluated the durability of concrete, in which low-grade aggregate (coral aggregate) and seawater as mixing water had been used, and conducted exposure tests to develop a concrete-curing technique using seawater. We also evaluated the durability of highly corrosion-resistant reinforcing steel and surface coating materials through exposure testing.
- We conducted a comparative evaluation of the aggregate gradation of airfield asphalt mixtures by indoor tests on their rutting resistance, moisture susceptibility, water permeability, and other characteristics, aiming to prolong the life of airfield asphalt pavement.
- We studied the solidification of filling material in caisson-type outer walls as a preventive measure against local failure due to repeated collisions of wave-dissipating blocks, focusing on how such solidification work, strength of filling materials, and thickness of solidification would affect the load-bearing and impact-resistant capacities of those outer walls. In addition, we examined a method for monitoring the effects of repairs performed on prestressed concrete (PC) members that are prone to chloride-induced corrosion, in order to improve the repair techniques. We experimentally examined the feasibility of performing repairs by applying surface coating to protect expansion due to alkali-silica reaction and/or delayed ettringite formation, evaluated the effects of the method, and improved the existing model.
- We organized points that must be considered while designing steel and concrete members for future maintenance purposes, and reflected some of them in revised technical standards. We also proposed a flow chart for determining use-conversion of existing caissons. In addition, we examined methods for inspecting and diagnosing PC hollow girders that utilize high-durability materials.
- We conducted monitoring verification tests using an IoT-enabled inspection and diagnosis system and investigated optimal threshold values for the maintenance and management of sensors for checking the corrosion prevention effects of petrolatum lining method. We also examined what points should be monitored that would be useful for determining the usability of the superstructures of PC open-type wharves when major earthquakes occur. Also, the applicability of performing inspections using underwater drones was examined.
- We introduced new operational support functions including a shooting-omission prevention function and an autonomous collision-avoidance function into the ROV for inspecting the superstructures of piers and then conducted on-site demonstration test.
- To advance the process of formulating preventive and maintenance plans for port and harbor facilities, we performed case studies on model piled piers, while formulating renovation scenarios (selection of an optimal renovation method and timing) based on which those piled piers can be converted into a preventive maintenance, using LCC and NPV as evaluation indicators.



Effect of suppressing DEF expansion using surface coating

2C Research on Effective Use of Existing Infrastructure Facilities

Background and Objectives

- There is strong demand to improve the functions of existing infrastructure and use them effectively as possible. Requests include measures to handle increasing cargo volume and larger ships and vessels, diversification of airport functions, and countermeasures to deal with existing facilities which can no longer be used due to increased external forces and other reasons. In addition, regarding waste disposal sites at ports which accept industrial and non-industrial waste, there is social demand for the highly effective use of them. On the other hand, it has become difficult to secure disposal sites which accept soil dredged from water channels for shipping routes. Accordingly, it is necessary to prolong the life of soil disposal sites.
- Therefore, we will develop the following: techniques to improve the functions of existing infrastructure and to renew and efficiently change the intended use of existing infrastructure; techniques to reduce or effectively utilize construction byproducts; and techniques to effectively utilize waste disposal sites at ports.

Research Topics

Research and development comprises the following three subthemes:

i) Research on techniques to improve or renew existing facilities

We have already conducted research and development on improving existing facilities including deepening existing quaywalls. However, such improvements were made using techniques for newly-built structures. Hereafter, we will investigate methods of evaluating ground characteristics, design methods, and geotechnical survey methods to improve and renew existing facilities. In such methods, the construction history, effects from neighboring structures, and other factors will be taken into account. We will also investigate ground evaluation methods and geotechnical information databases, both of which cover residual settlement and other phenomena, with the aim of long-term facility maintenance and management.

ii) Research on effective use and techniques of treating construction byproducts

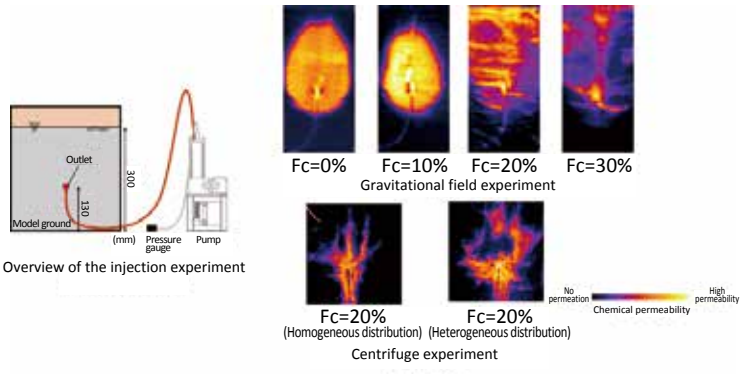
We will investigate the following techniques regarding dredged soil: improvement techniques to transform dredged soil into high-value added materials including composite soil, which provides habitats for benthic creatures, and solidified soil with high water permeability; and new volume reduction techniques. We will also investigate durability when solidified soil and slag composite soil are used in sea areas, the mechanical characteristics of composite ground materials containing various byproducts, crushable materials, and other contents, and methods of evaluating and managing the quality of these materials.

iii) Research on management and utilization of waste disposal sites at sea

Regarding disposal sites at sea, technologies for seepage control works for site development have been progressed. However, research on post-construction utilization of such sites has not been conducted. Therefore, we will investigate the following which are necessary for utilization: foundations, construction methods, effects on impermeable layers, management methods of the internal water level at low cost, techniques to detoxify waste before land reclamation, and the medium- to long-term strength and elution characteristics of solidified soil.

Activities in FY 2018

- Based on measurements of unequal settlement of reclaimed land at airports, we continued to estimate settlement as we did in the previous fiscal year. As the undulating shape of the surface had not changed significantly from the previous year, and the coefficients of the estimated settlement curves almost converged, we judged that the prediction method using data accumulated over a set period of time and the curves that approximated those data was effective.
- We used transparent soil to visualize the process of grout injection into different sandy grounds with varying fine particle fraction contents. Such grout injection experiments were conducted in a gravitational field and a centrifuge, where we evaluated the status of grout permeation around areas of the ground that had uneven contents, the effects on the ground in the surrounding area, under various conditions such as confining pressure, fine particle fraction content, and fine particle fraction distribution.
- We examined the method of ground improvement to be applied to the ground between the piles at existing sheet-pile-type mooring wharves with coupled pile anchorage, which is intended to improve durability, by conducting 3-dimensional model experiments and numerical analyses. Then, we developed a numerical analysis method for application to actual cross sections, and used the method to design actual structures. In addition, we conducted 3-dimensional measurements on breakwaters built directly on soft ground, and confirmed that their point group data were useful for detecting any change in behavior, etc.
- To be able to perform X-ray CT scanning of the ground on-site and understand various engineering characteristics from the acquired images, we developed equipment that enables X-ray CT scanning of a core sampled from the ground on-site, focusing on gravel grounds, and also conducted model-based verification experiments including various indoor CT scanning tests.
- We used model cross sections and conducted numerical analyses to examine how increasing the height of a levee would alter its conditions, by using parameters such as the height of dredged soil, distance of a temporary bank from the bulkhead, structural and mechanical properties of temporary banks, and countermeasures for bulkhead bodies.
- We also summarized the results of pile-installation and pile-removal experiments at a waste site that had been filled with incinerated ash. We started to investigate an insolubilization of contaminants by cement improvement technique and investigated deterioration promotion methods to study the deterioration of solidification-treated soil and eluviation of contaminant. As a result, regarding high-early-strength cement, we achieved homogeneous deterioration of the specimens by compulsory permeation.



Example of a chemical injection process visualized during the model-based centrifuge experiment
(Potential effect of different ground conditions on the creation of improved areas)

3A Research on Development and Utilization of Oceans

Background and Objectives

- Since the 1960s, the importance of marine utilization and development has been pointed out. Various approaches for this purpose have been taken, but the progress remains inadequate. One of the reasons is the lack of infrastructure at sea as a hub. Therefore, marine hub ports should be constructed on remote islands including Minamitorishima Island and Okinotorishima Island to promote marine utilization and development.
- However, these remote islands are surrounded by severe sea wave environment and severe sea climate for port construction which are different from those of general ports in main islands. Further technological development is required to ensure smooth ship berthing, cargo-handling, and port construction.
- Therefore, in this research theme, we will make maximum use of previously accumulated knowledge regarding waves, sea-bed soils, port structures, and port construction to construct ports on remote islands, and will also promote marine utilization and development. Specifically, we will clarify the characteristics of waves in isolated reef areas, and will develop a new mooring system for ships. We will also develop technologies for downsizing and reducing the weight of underwater acoustic video cameras, as well as utilization and development.

Research Topics

Research and development comprises the following two subthemes:

i) Research on port construction and management in remote islands

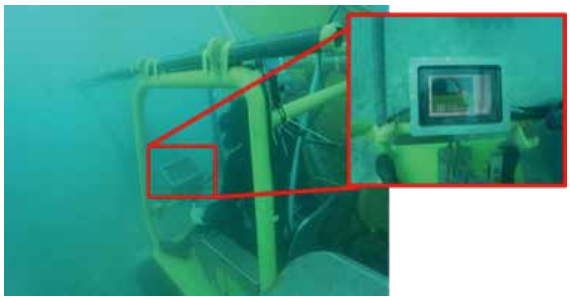
We will develop a numerical model for wave transformations on continental shelf boundaries and around isolated islands. We will also propose a technology to create calm water areas against wave propagation and long-period waves around isolated reefs. At the same time, we will develop a new mooring system applicable to remote islands to improve cargo-handling efficiency for ships.

ii) Research on infrastructure technology for utilization and development of oceans

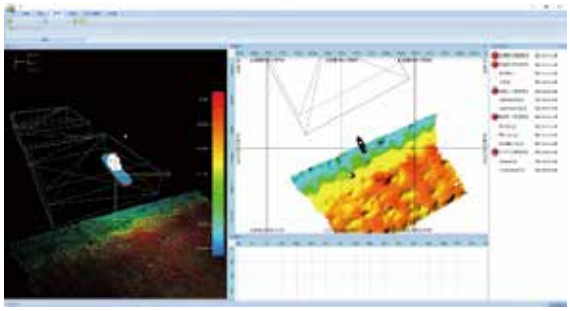
We are trying to downsize and lighten underwater acoustic video cameras, and will also develop an unmanned underwater construction system to construct marine infrastructure. In addition, we will propose environmental conservation technologies utilizing calcifiers.

Activities in FY 2018

- For the development of techniques that can be utilized on mooring facilities constructed in isolated coral reef sea areas, we created a wave height estimation tool that can be applied to the quay walls at Minamidaito Port and Kitadaito Port, using NOWPHAS data observed around Okinawa Island. In addition, we measured the magnitude of motions and the mooring force on vessel models that were moored above an isolated reef in a model experiment, under various mooring and wave conditions; supplemented the results of the model experiment using the improved version of CADMAS-SURF/3D that was developed during the previous fiscal year; and clarified what mooring and wave conditions would allow safe mooring and cargo handling in such sea areas.
- For the technological development of a new mooring system for ships in ports, we computed the motions of a ship moored by using the new mooring system utilizing high-strength wire ropes. In the computation, we calculated the maximum wave heights for ship cargo-handling, and verified the effectiveness of the new mooring system by comparing to the conventional mooring method.
- For the research on maintenance inspection and investigation technology for remote island ports, we proposed a data management method through which inspection photos captured underwater would be embedded with geotags indicating where those photos were taken and other metadata. In addition, to measure the location data of an underwater vehicle that would be necessary for the management purpose, we proposed a method that would use acoustic positioning equipment, GNSS, a seabed altimeter, and wave pressure gauges in combination. Furthermore, we adapted operation support software and tested it in the actual sea, performing the entire task cycle of deployment, inspection, and recovery, and confirmed that it could be operated with only a small number of workers.
- For the research on adaptation of the machine guidance for an underwater excavator, we conducted operation tests at an actual construction site, and identified issues that must be resolved before the technology could be applied to actual use. In addition, we improved external measurement and conducted element testing of attachments for mound leveling. Our aim is to be able to remotely operate underwater backhoes by integrating these technology elements.
- For the development of a next-generation acoustic imaging system, we enhanced the performance of an acoustic video camera for shallow sea and achieved water-pressure resistance of 30 m and in-air weight of 32 kg. In addition, we developed / supported to develop a viewing system with additional value something extra, which is chart, blueprint, traverse course, etc., for monitoring construction work, focusing on dredging works, bottom mud replacement works and diver works. Furthermore, we prepared manuals for operating the acoustic video camera and the viewing system.
- For the development of analytical methods for the topographic dynamics of carbonate islands, we conducted in situ surveys of Minamitorishima, Naha Port, Hirara Port, and Ishigaki Port, including GNSS survey, photographic survey using drones, multi-beam sounding, water sampling, and aerial photography combining visible light and NDVI cameras. In addition, we collected the geographical feature data of Minamitorishima and analyzed its topographical changes. Furthermore, we examined the relationship between coral growth and environmental conditions, and investigated methods to automatically recognize the distribution of coral-forming organisms and their levels of activity.
- As for the study on floating breakwater equipped with wave power generation device, we surveyed the cases of technology development on floating-type wave power generation devices and also the cases of installation of floating breakwaters. We then created the fundamental concept of a floating breakwater equipped with a wave power generation device, based on the results of those surveys.



Operation test at actual construction site in Hirara Port



Audiovisual presentation system

4A Research on Enhancement and Utilization of Coastal Ecology

Background and Objectives

- Rich ecosystems in coastal zones include tidal flats, seagrass meadows, and coral reefs. Coastal zones are valuable places for the global environment. However, during the era of rapid economic growth, intense socio-economic activities caused the deterioration of water quality in coastal inner bays and enclosed waters, resulting in ecosystem damage. Thanks to subsequent countermeasures, water quality has gradually been improving in some coastal zones; however, recovery of the coastal zone environment including ecosystems remains a formidable challenge.
- On the other hand, new challenges include the utilization of coastal zone functions for mitigating climate change, as well as countermeasures against large-scale oil spill incidents from maritime industrial complexes and other facilities.
- Therefore, in the themes of this research, we will conduct research and development with the following goals: further restoration of the coastal zone environment, coastal zone utilization for climate change mitigation, and establishment of technologies to counter large-scale oil spill incidents.

Research Topics

Research and development comprises the following three subthemes:

i) Research on coastal-ecosystem utilization

Regarding ecosystem-based countermeasures against the impacts of climate change, we will conduct research on climate change mitigation including carbon and atmospheric CO_2 uptake, both of which utilize ecosystems (blue carbon) under various conditions including remote islands such as Minamitorishima Island. In addition, we will expand our technological development internationally. We will also develop a technology to create coastal ecosystems which suffer less damage due to earthquakes and tsunamis and which recover rapidly. Through such technologies, we can continuously reap the benefits of the ecosystem.

ii) Research on the water-environment simulation and analysis in inner-bay

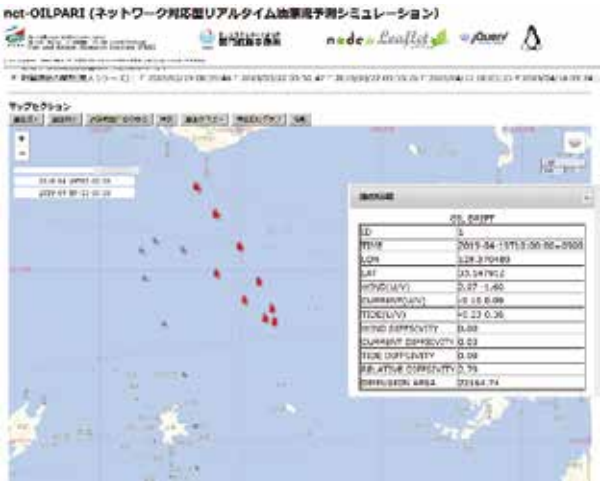
We will develop the following methods regarding the acquisition and utilization of environment observation data: a new method of analyzing marine monitoring data covering currently operating ferries and monitoring posts and others; and a new method of observing parameters for which common methods cannot obtain adequate results. We will also re-analyze existing underutilized environmental data, and will use multi-functionalized GPS wave-observation buoys to continuously observe areas for which environmental data has not been obtained. In addition, we will integrate weather/marine/ecosystem models and utilize in real time the environmental observation data. Through these means, we will develop a system which comprehensively predicts problems that frequently occur in inner bays, including red tides, blue tides, and hypoxia.

iii) Research on countermeasure technologies against sea oil spill

Regarding technologies for dealing with spilled oil, in addition to developing technologies to resolve conventional on-site challenges, we will conduct new research and development on the following: oil-gathering equipment loaded on next-generation oil-recovery ships; and systems which comprehensively recover or treat oil and which can address large-scale oil spill incidents. In addition, we will establish an information system for the risk management of oil pollution based on simulation technology, understand the behavior and mechanisms of oil spilled from dangerous facilities in waterfront areas due to natural disasters including earthquakes and tsunamis, and conduct research and development of quantitative prediction techniques and mitigation techniques for spilled oil. Through such approaches, we will develop innovative countermeasure techniques against oil pollution and improve the ability to respond oil pollution.

Activities in FY 2018

- For the global estimates of the efficacy of blue carbon as a means of mitigation and adaptation to climate change, we estimated the amounts of current CO_2 absorption by blue-carbon ecosystems and other shallow coastal ecosystems, on a global scale for the first time in the world, and also for the whole of Japan, that is crucial for developing government policies on this topic. We also presented these findings at the side event of the 24th Conference of the Parties (COP24) of the United Nations Framework Convention on Climate Change (UNFCCC).
- For the development of integrated prediction and assessment method of coastal benthic ecology and geoenvironmental dynamics, we improved and further developed the chart for diagnosing the habitat environment of organisms, and used it to obtain the results of integrated assessment and prediction of the link between coastal benthic ecology and geoenvironmental dynamics then compared them to the data acquired during on-site surveys, and verified that the developed integrated methods can consistently assess and predict the relationship between biodiversity and geoenvironmental dynamics as well as the changes in areas where various organisms are distributed.
- For the research on cross-sectional observation and analysis of atmospheric and oceanographic issues at bay mouths, we obtained and examined wind direction and velocity data from Kanaya-maru for atmospheric observation. As for oceanographic observation, we developed a new marine observation system for use aboard Kanaya-maru.
- For the development of evaluating procedure for biodiversity referring to spatial scale in coastal areas, we organized information on the characteristics of diversity evaluation methods, and compiled evaluation guidelines that would be suitable for ports and harbors.
- For the analytical study of macro-organisms dynamics on a coastal ecosystem simulation, we added a new model applicable to fishes and verified that their data could be computed.
- For the study on the mechanisms of coastal current and water environment using data assimilation, we programmed a new data assimilation model into the Ise Bay simulator and verified it through numerical experiments.
- We conducted an experimental examination of the feasibility of applying bubble curtains to oil collection equipment, and elucidated that bubble curtains alone would be able to collect spilled oil floating on the surface in an arbitrary location and keep it there, without using conventional-type solid damming elements. We also examined a dispersed fire extinguishing method for extinguishing a fire burning on drifting oil. As for the development of real-time hazard maps indicating oil spills, we converted the server-side scripts into Node.js to enhance scalability, and released them on the PARI website for trial operation as RC.



Real-time hazard map of oil spills

4B Research on Coastal and Estuarine Processes

Background and Objectives

- PARI's research activity of littoral drift was started to examine the critical water depth of sediment movement for harbor planning. Now, prevention methods against sedimentation and also siltation are proposed. However, in Japan, sedimentation and siltation are still progressing in some ports, and in other countries which aim to expand their infrastructure overseas, a much greater amount of siltation than in Japan is projected. Countermeasures against such sedimentation and siltation problem have been inadequate.
- On the other hand, beaches are valuable as they provide protection, environment and utilization functions. However, the area of beaches has been decreasing since the era of rapid economic growth, and is still shrinking at a rate of 1.6 km^2 per year. Various countermeasures have been taken to prevent such coastal erosion, and as a result, the beach area has increased at some coasts. Nevertheless, global warming is expected to cause more severe coastal erosion. In addition, when remote islands and overseas are taken into account, it is important to maintain not only beaches but also coral-reef coasts.
- Therefore, in the themes of this study, we aim to maintain the following under future climate change: natural coastline geometry including beaches, mangrove coasts, and coral-reef coasts; and artificial coastline geometry including navigation channels and harbor basins, which support logistics. We will also estimate changes in coastal-erosion and sedimentation phenomena assuming the progress of global warming, and then propose countermeasures against those changes. Also, we will clarify siltation processes in the estuaries of large rivers, mangroves and intertidal zone in the Asian countries, and then propose countermeasures against such phenomena.

Research Topics

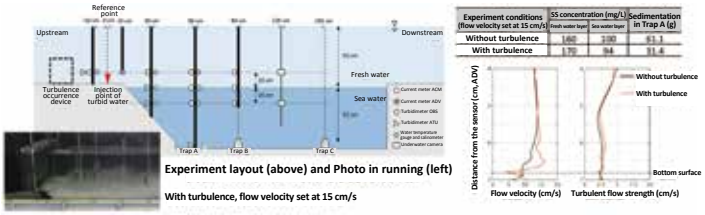
Our researches and developments for coastal protection and maintenance of waterways and mooring basins are as follows:

We will analyze long-term measurement data of the Hasaki coast and conduct short-term, intensive, on-site observation of how beaches respond to different sea levels. Through this, we will understand beach-response mechanisms to sea level rise, and will develop methods of predicting future beach morphology. We will take into consideration the spatial scale of not only the Hasaki coast but also global, and predict long-term coastal changes (including natural sand coasts, sand coasts protected by structures, coral-reef coasts, and pebble coasts) along with variations of coastal disaster risks. In addition, we will develop hybrid beach-maintenance methods, which minimize structure volume and actively introduce sand bypasses, and propose effective beach maintenance methods that account for the disaster risks.

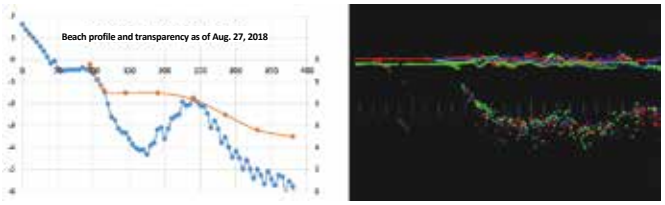
Regarding sediment transport which accompanies port utilization, we will expand the scope of our research to include estuaries of large rivers, mangroves, and intertidal zones over-seas. Then, we will develop monitoring method for topographic change which address regional characteristics and understand the dynamics of topographic changes. In addition, we will examine strategies to reduce siltation and sedimentation and will develop the efficient maintenance methods of navigation channels and harbor basins as well as conservation of the surrounding environment of port and harbor facilities.

Activities in FY 2018

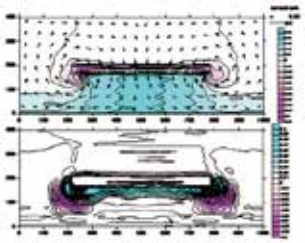
- We conducted an on-site investigation of the characteristics of sediments in areas of with a sudden change of depth in Niigatanishi Port (in December). We also conducted experiments to understand the behavior of turbid water in dredged areas of a port and examined how effective turbulence control would be for suppressing sedimentation and siltation. We also conducted a joint investigation with BPPT, an Indonesian government agency, pursuant to the research cooperation agreement that had been executed between the parties.
- As for the applicability of airborne laser bathymetry for topographic monitoring in coastal zones along the seashore, we conducted aerial surveys of the area encompassing Hasaki Oceanographical Research Station (HORS), the surrounding seashore, and Hasaki fishing port using green laser (on August 27th), checked the status of acquiring sea floor topography data under turbid seawater conditions and also surveyed the sea floor topography around structures along the coastline. In addition, we surveyed the same area at different times with varying sea levels and have been using the acquired data to examine analytical methods that utilize different breaking points of waves to reduce missing survey data that is caused by the white foam that forms as waves break.
- For the observation of coastal geographical feature change and malfunction of sedimentation control system in considered with influence of global warming, we carried out continuous on-site observations of the wind, waves, flow, and topographical changes at HORS. In addition, we used beach morphological data of the U.S. West Coast to examine the applicability of the shoreline change model. We also improved the computation model for predicting topographical changes around submerged breakwaters, around which the fields of waves and flow shift in a complex manner due to sudden wave-breaking phenomena.



Experiment on the behavior of turbid water flowing into a dredged area inside a port



Distribution of seafloor topography and transparency data from the shore into the ocean (left) and aerial laser survey data taken at different times with varying sea levels (right), as observed from HORS



Observation of ocean upper wind at the tip of the observation pier (left) and computation data indicating the mean sea level, nearshore currents, and numerical result of topographical changes near submerged breakwaters (right)

Fundamental Research in FY 2018

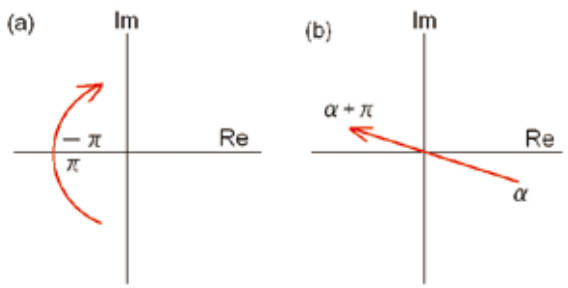
The fundamental research of waves, beaches, ground, earthquakes, environments, etc., is the basis of every study conducted by PARI, and therefore we are actively working on clarifying principles and phenomena, such as the mechanisms of natural phenomena and dynamic behavior of the ground and structures.

	Research theme (Fundamental research)
1	Strong Motion Earthquake Observation in Port and Airport Area
2	Investigation of Earthquake Disaster
3	Development of strong motion estimation method for scenario earthquakes beneath metropolitan area
4	Study on the evaluation and analysis of liquefied ground behavior and effective countermeasures under sequenced earthquake motions
5	Study from geotechnical view-point on stability evaluation method of coastal structure subjected to high waves
6	Stability evaluation of offshore structures against washout, cavity formation, etc. and development of countermeasure techniques
7	Development of the estimation method for local scour around coastal structures due to tsunami
8	Application of the particle method to the large deformation of port structures due to tsunami
9	Elucidation of oceanographic phenomena based on central processing and analysis of observation data
10	Proposal for improvement of prediction accuracy of swell
11	Assessment of possible maximum storm surge hazard by using storm-surge-wave coupled model
12	Evaluation of longterm durability of concrete, steel and various materials based on exposure test
13	Development of the performance evaluation method in protective coating for marine structures
14	Evaluation of the durability of various materials under severe environments
15	Improvement method to non-uniform ground and its effect as a measure against liquefaction
16	Enhancement of accuracy of method for evaluating mechanical properties of composite geomaterials based on microstructural feature
17	Study on floating breakwater equipped with wave power generation device
18	Development of analytical methods for the topographic dynamics of carbonate islands
19	Global estimates of the efficacy of blue carbon as a means of mitigation and adaptation to climate change
20	Development of integrated prediction and assessment method of coastal benthic ecology and geoenvironmental dynamics
21	Cross-sectional observation and analysis of atmospheric and oceanographic issues at bay mouths
22	Analytical study of macro-organisms dynamics on a coastal ecosystem simulation
23	Development of evaluating procedure for biodiversity referring to spatial scale in coastal areas
24	Study on the mechanisms of coastal current and water environment using data assimilation
25	Observation of coastal geographical feature change and malfunction of sedimentation control system in considered with influence of global warming
26	Study on sediment transport in estuary and deposition process in navigation channel
27	Study on applicability of airborne laser bathymetry for topographic monitoring in coastal zone of sea shore

Cases of Fundamental Research

Development of strong motion estimation method for scenario earthquakes beneath metropolitan area

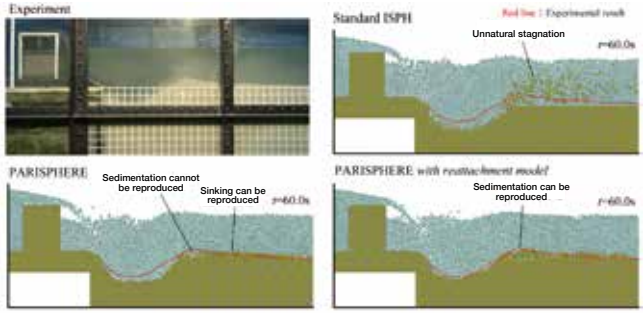
- As part of efforts to develop a method for predicting strong ground motions caused by major earthquakes that may occur directly underneath metropolitan areas, we conducted fundamental research on the phase characteristics of seismic motions.
- The Fourier phase of seismic motions (hereinafter referred to as “seismic motion phase”) differentiated by the circular frequency is called group delay time, which is known to be related to the temporal characteristics of seismic motions. In many studies, this relationship is used for waveform synthesis, where waveforms with appropriate temporal characteristics are synthesized by imposing appropriate group delay time. The results of those studies are also used to define design ground motions in a practical manner. However, as the statistical characteristics of seismic motion phase and group delay time are not yet fully understood, studies are still underway for full comprehension. In some of those studies, it is claimed that seismic motion phase cannot be differentiated by the circular frequency anywhere and, therefore, group delay time cannot be defined, as it is a first-order differentiation of seismic motion phase with respect to the circular frequency. If such claim turns out to be true, the very foundation of previous studies that relied on the concept of group delay time as a differentiation of seismic motion phase will come into doubt, threatening any application of the concept for practical use.
- Therefore, in this study, we revisited the definition of seismic motion phase. We first examined the differentiability of the Fourier transform of seismic motions, and then used the results of the examination to study the differentiability of seismic motion phase. Through the study, we discovered that seismic motion phase cannot be differentiated under limited conditions; not everywhere.
- The figure below illustrates the conditions in which it is impossible to differentiate seismic motion phase. The arrows indicate the trajectory of the Fourier transform of seismic motions F(ω) on a complex plane. (a) indicates a case where F(ω) moves from the third quadrant to the second quadrant on the complex plane, as ω increases. Here, discontinuity of 2π is seen occurring to the seismic motion phase. Meanwhile, (b) is a case where F(ω) passes through the origin on the complex plane, as ω increases. Here, discontinuity of π is seen occurring to the seismic motion phase. The former issue can be avoided if so-called “unwrapping” is performed properly, while the latter cannot be resolved even with proper unwrapping.
- From a theoretical standpoint, the only case when phase cannot be differentiated is where F(ω) passes through the origin on a complex plane. However, in numerical computation, we discovered that phase suddenly changes in response to a change in ω when F(ω) passes near the origin, even if it does not pass through the origin, and at such point Δθ/Δω, which is a finite difference approximation of group delay time, becomes numerically unstable. We also identified a method for avoiding such numerical instability.



Conditions in which it is impossible to differentiate seismic motion phase

Development of the estimation method for local scour around structures due to tsunami

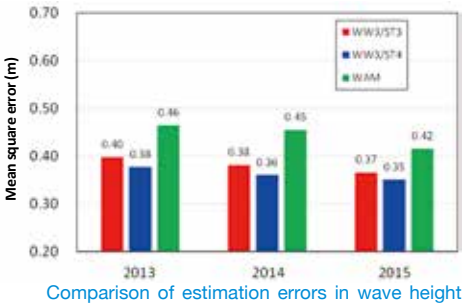
- The local scouring behind breakwaters and in a sandy ground around breakwater heads is critical to structural stability for a tsunami, but the amount of scouring remains difficult to estimate.
- Therefore, in this study, we will elucidate the mechanism of local scouring by conducting hydraulic experiments, and establish a model for estimating the amount of scouring by applying a particle-based method, etc.
- During FY 2018, we continuously worked on the project from the previous fiscal year to develop a model for the scouring process in the ground behind breakwaters as tsunami overtops them. This was done by applying a particle-based numerical wave flume (PARISPHERE). While it had achieved the reproduction of the detaching process of sand particles from the seabed under tsunami overflows, issues remained: the sand particles would become stationary in an unnatural manner after floating, and they would not become attached to the seabed upon reaching it.
- In order to resolve such issues, we first performed solid-liquid multiphase flow simulations of the sedimentation process of high specific-gravity particles under water and discovered that, when the standard ISPH model was applied, an unnatural decrease in the fluidity of fluids would occur along with the unphysical phenomenon whereby high specific-gravity particles became stationary. In addition, we improved the fluid pressure gradient term model and made it possible to reproduce the physical fluidity of fluids with suppressing the pressure noises.
- We then developed a model with sand particles reattached after their floating around, and confirmed that sedimentation of the floating sand helped better reproduction of the natural phenomena.
- Our future plan for this research project includes conducting experiments on the local scouring that occurs near breakwater heads and establishing a method to estimate the amount of such local scouring, in addition to ongoing experiments on the scouring that occurs along breakwater trunks.



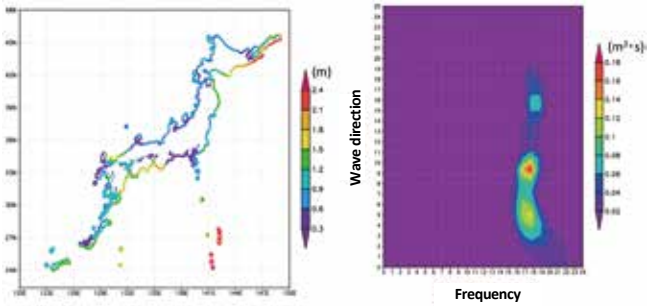
Comparison of the experiment and the particle-based model of scouring behind breakwaters

Proposal for improvement of prediction accuracy of swell

- The design of port and harbor facilities basically uses observed wave data. We need to estimate waves with a wave hindcasting model if there is no available observation data. However, the third-generation wave hindcasting model WAM, which has been used in practice for many years, may fail to estimate wave periods with sufficient precision in certain cases. *The Technical Standards and Commentaries for Port and Harbor Facilities in Japan* was revised in May 2018. As a result, we also needed to consider only swells in addition to the conventional wave conditions that do not distinguish between wind waves and swells. In the future, it is required to improve the estimation accuracy of swell.
- Therefore, in this study, we will examine the estimation precision of the third-generation wave hindcasting model WAM and WW3 by comparing the model output to observed wave data at multiple NOWPHAS stations, and develop a wave hindcasting system that will be applicable to the coast of Japan.
- In FY 2018, we compared the wave statistics estimated using WAM and WW3 in previous fiscal years to actual observation data collected from several NOWPHAS locations, and saw that WW3 had a slightly better precision on average between those locations, but WAM was more accurate in certain cases.
- In addition, we focused on swells (*Yori-mawari-nami*) in Toyama Bay and examined the estimation accuracy, which suggested that it would be difficult to perform high-precision estimation using the third-generation wave hindcasting models that are currently available.
- Furthermore, we developed a wave hindcasting system for the coast of Japan based on WW3, which automatically performs all required computational tasks including pre-processing of ocean wind and other input data, execution of wave estimation, creation of graphs, etc. to illustrate the estimation result, and all other post-processing, by simply specifying an estimation period.
- We plan to continuously improve the accuracy of wave estimation and hope that it will help create better designs of port, harbor, and coastal facilities and also prevent disasters in coastal areas.



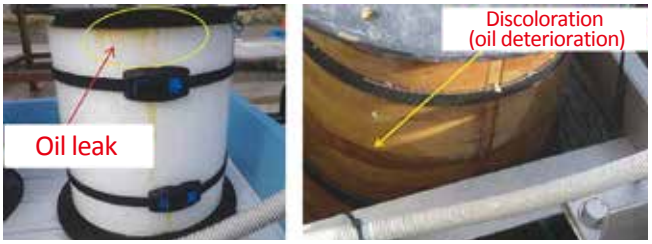
Comparison of estimation errors in wave height among 25 locations between WAM and WW3



WW3-based wave hindcasting system
(left: wave height, right: directional wave spectrum)

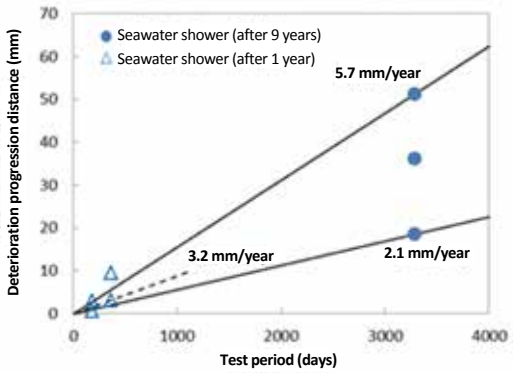
Development of the performance evaluation method in protective coating for marine structures

- The combination of two types of prevention methods, namely cathodic protection and protective coating, has been used for marine steel structures, ensuring their long-term durability. Regarding the protective coating method, deterioration characteristics including expected durable years have been clarified from the past exposure test results. However, methods of checking the performance of each protective coating method at the design stage, methods of evaluating current protective performance at the maintenance stage, and methods of predicting future situations have not yet been established.
- Maintenance costs remain high and there are not enough technicians, so more efficient methods of maintaining the above social capital urgently need to be developed.
- In this theme, we are working on establishing the following methods: a method to check the performance of each protective coating method at the design stage, a method to evaluate the current protective performance at the maintenance stage, and a method to predict the future situation.
- Investigation (1): We studied the deterioration mechanism of the petrolatum coating method and conducted accelerated deterioration tests to establish a method for evaluating the performance of petrolatum material, and organized information on the factors that affect the deterioration process. We then narrowed down the influential factors based on our findings and started conducting outdoor exposure tests.



Outdoor exposure tests to establish a method for evaluating the performance of anti-corrosion petrolatum material
(after one month of exposure to the marine atmosphere and the tidal-environment)

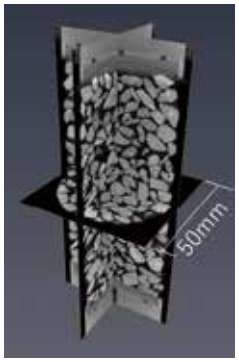
- Investigation (2): As continuous outdoor exposure tests have been conducted to establish a method for predicting the deterioration of hat-shaped steel sheet piles with heavy duty coating (urethane elastomer coating) applied, we verified the method of predicting deterioration after about 10 years of the exposure testing.



Relationship between the test period and the deterioration progression distance measured between the ends of each coated area
(in case of exposure to seawater shower)

Enhancement of accuracy of method for evaluating mechanical properties of composite geomaterials based on microstructural feature

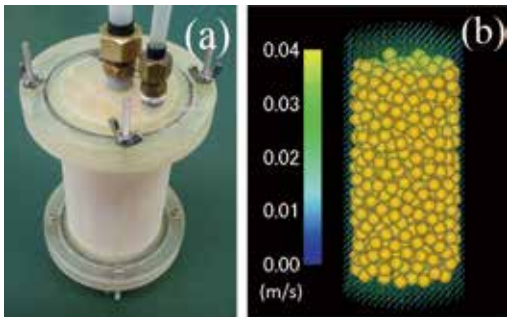
- Geomaterials with different grain size distribution, particle shape, and other micro-structural features exhibit various mechanical properties due to those features. In addition, even if soil specimens are sampled from the same geological stratum or prepared in a similar manner, the test result may vary depending on their micro-structural differences. Therefore, evaluating the effects of such micro-structural features will lead to advances in methods for evaluating the mechanical properties of the ground. In the conventional geotechnical investigation method, undisturbed samples (i.e., cores) are taken from the original ground, after which various types of laboratory tests must be performed to measure their properties, etc. depending on the purpose. On the other hand, if it were possible to use an X-ray CT scanner to acquire images of the micro-structural features of the ground, perform CT image and numerical analyses, and conduct simulated soil tests using 3D printing technology, it would enable the evaluation of the various mechanical properties of the core samples, which would be highly useful in practice.
- We 3D-printed the micro-structural data detected in CT images, and performed triaxial compression tests of such simulated test specimens, and thus were able to prove that the unique behaviors as the granular materials (such as stress dependency and dilatancy behavior), which the original gravel material resembles, could be recreated, confirming its applicability as an appropriate soil testing method.



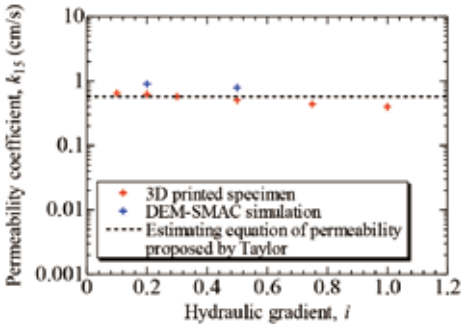
Sample CT images of triaxial compression test specimens utilizing gravel

Simulated test specimen that has been 3D-printed using gravel material

- In addition, we conducted DEM-SMAC coupled analyses (in which models are created by DEM from particle structures, and the flow of pore fluids is computed) to address the issue of water permeation in the ground, and were able to confirm that the findings were highly consistent with the results of the constant head permeability tests in which simulated test specimens were used.



(a) simulated test specimen and (b) numerical model, with equal particle shapes and arrangements

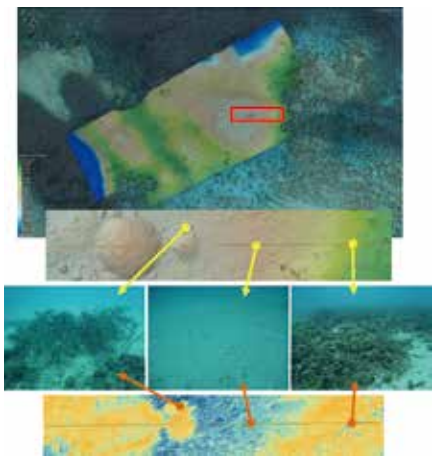


Comparison of permeability coefficients

- In this study, we have been developing equipment that will be able to perform X-ray CT scanning of core specimens on site. We are analyzing the images acquired in experiments, and examining the discrete element method and the mechanical property evaluation method that utilizes 3D printing technology.

Development of analytical methods for the topographic dynamics of carbonate islands

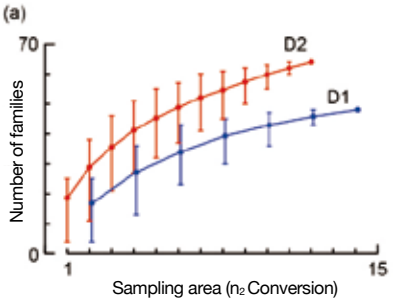
- Most remote islands located on the southern edge of Japan, such as Okinotorishima and Minamitorishima Islands, mainly consist of carbonates formed by corals, foraminifers, and other reef-forming organisms, unlike Honshu and other parts of Japan, which are mainly comprised of silicates.
- External stresses such as climate change and the environmental changes caused by large typhoons ravaging remote islands pose threats to the conservation of those remote islands as national land.
- When investigating the current status of those threats and formulating countermeasures against them, there are constraints specific to remote islands, such as scarcity of goods, supplies, and labor.
- Therefore, in this study, we aim to develop and present methods for analyzing topographical dynamics that can cover wide areas for an extended period of time in a resource-efficient manner, while taking into account the constraints that are typical of remote islands.
- During the fiscal year, we conducted in situ observations of model sites, and analyzed existing core sample specimens. In addition, we examined the relationship of coral coverage with the environmental conditions at the Urasoe breakwater in Naha Port.



Simultaneous multi-beam measurement of seafloor topography and bottom soil quality at model sites

Development of evaluating procedure for biodiversity referring to spatial scale in coastal areas

- As the conservation of biodiversity also helps preserve the benefits of the ecosystem that are reaped by humans, it is an important part of Japan's key national strategy. Also in port and harbor operations, protection of biodiversity is one of the most crucial goals, and it is expected that biodiversity will be maintained and enhanced through the restoration of intertidal flats, seagrass beds, etc. However, the concept of biodiversity is abstract yet complex. Therefore, in order to decide policies on future projects and evaluate completed projects effectively, it is necessary to find some methods through which we can clearly define what biodiversity means.
- In this study, we focus on diversity indices as one of the means of defining biodiversity and aim to develop evaluation criteria that can be used to assess how various types of environmental consideration in port and harbor operations might contribute to conserving biodiversity.
- As this will be the last fiscal year of this particular research item, we have organized the research findings from the past three years. We decided that the main objective of this research project is to standardize diversity indices, which are highly dependent on the extent of sampling efforts made by observers, using simple methods that are scientifically error-free yet useful enough for practical application. More specifically, we organized views on how to factor in the extent of sampling efforts made by observers, used data obtained from actual sea areas, and identified the types of diversity indices that would be suitable for port and harbor operations. Going forward, we plan to organize the findings from this research and promote the dissemination of related technical knowledge among engineers involved in port and harbor operations, while continuously developing technology and techniques that are more clearly geared toward protecting biodiversity in port and harbor operations.



Change in diversity indices in relation to the extent of sampling efforts made

Study on sediment transport in estuary and deposition process in navigation channel

- In ports located around estuaries, sedimentation of navigation channels and harbor basins occurs due to the deposition of discharged sediments from rivers. Reduction of such sedimentation as well as siltation has become an important research topic, for resolving the issue of insufficient sites for disposing of dredged sediments and also for meeting the need to reduce the cost of maintenance dredging. Maintenance and management of navigation channels and harbor basins are more serious problems in Southeast Asian and other countries that have ports located in the estuaries of large rivers.
- In this research, which focuses on estuaries not only in Japan but also in Southeast Asian and other countries, we aim to understand the transport dynamics of sediments supplied by rivers, including the transport of highly concentrated fluid mud and its seasonal variations, and develop a model for simulating bottom sediment transport, focusing on coastal areas near estuaries.
- During FY 2018, we conducted an on-site survey of sediment characteristics in the areas with a sudden change of depth in Niigatanishi Port (in December 2018). In addition, we conducted experiments to observe the behavior of the turbid water flowing into the dredged areas of the port, and evaluated the effectiveness of turbulence control to suppress sedimentation and siltation. We also conducted a collaborative study with BPPT, an Indonesian government agency, under a joint research agreement.

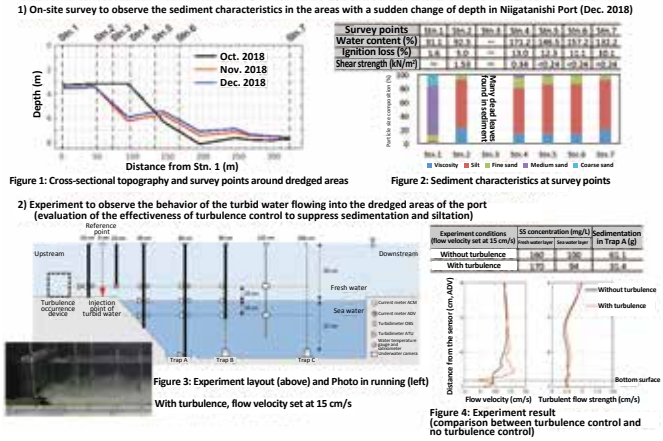


Figure 1: Cross-sectional topography and survey points around dredged areas

Figure 2: Sediment characteristics at survey points

Figure 3: Experiment layout (above) and Photo in running (left)
With turbulence, flow velocity set at 15 cm/s

Figure 4: Experiment result (comparison between turbulence control and no turbulence control)

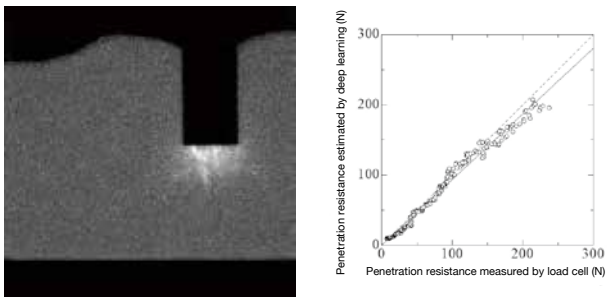
Survey of sediment characteristics in the areas with a sudden change of depth in Niigatanishi Port and experiment to suppress sedimentation and siltation

Exploratory Research in FY 2018

In FY 2018, exploratory research projects based on ingenious and/or advanced ideas that could potentially lead to new research fields for PARI in the future were carried out.

Strength estimation of granular materials using deep learning based on the learning of particle motion and force chain

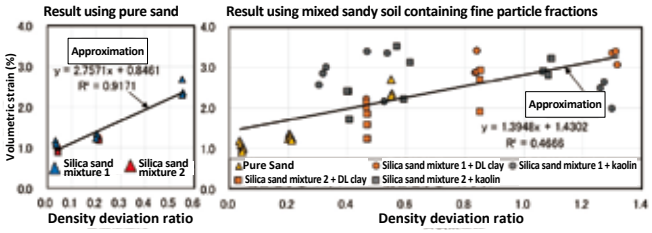
- In this study, we focused on estimating the penetration resistance of closed end pile by deep learning using visualized images of penetration resistance with force chain and particle motion during pile penetration.
- The learning data of the visualized images were collected through the process of pile penetration into the mechanoluminescent-coated particle assemblages that emitting the force-induced luminance. The wedge-shaped higher luminance intensity area were obtained under the pile shown in left side figure.
- We developed deep learning model of following two types: generating the estimation image of force distribution during pile penetration based on the learning of the visualized images, estimate penetration resistance based on the force visualized images. These estimated results was verified through the captured images and measured value using load cell.
- The result of verification for generated images shows the higher luminance intensity area under the pile end. The result of verification for estimating penetration resistance was shown in right side figure. The estimated value shows good agreement with measured value, whose error was around 10%.



(Left) Learning data of visualized penetration resistance with force chain and particle motion
(Right) Verification through the comparison between estimated penetration resistance and measured values

Prediction method of quantitative distribution of ground subsidence caused by liquefaction for improving tsunami inundation analysis

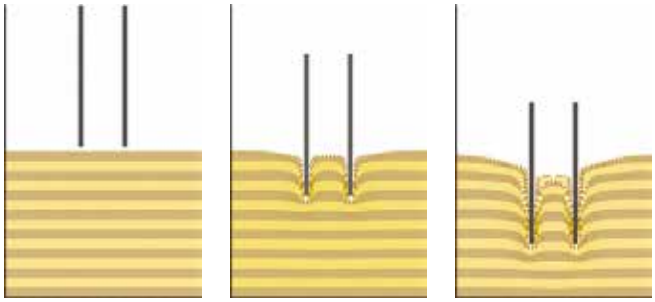
- One of the factors that has a significant effect on the tsunami inundation process in coastal areas with soft soil is ground subsidence caused by liquefaction, which must be taken into account when analyzing tsunami inundation.
- Focusing on mixed sandy soil containing fine contents, which is the type of soil found in many coastal areas, we examined methods for predicting the amount of ground subsidence caused by liquefaction.
- We conducted undrained cyclic torsional shear tests while varying the uniformity coefficient of the sandy base material and fine contents (content rate(Fc) and type), and observed which parameters had a high correlation to volumetric strain following liquefaction. We chose two different types of mixed silica sand with different uniformity coefficients (silica sand 1: uniformity coefficient of 3.891, silica sand 2: uniformity coefficient of 2.286) as base materials, and used sandy soil blended with DL clay, which is non-plastic silt, and kaolin, which is a type of plastic clay, as test specimens.
- We applied the following three parameters and measured their correlation coefficients to volumetric strain: 1) Void ratio, 2) Skeletal void ratio, and 3) Density deviation ratio [$(\rho_{dmax}-\rho_d) / (\rho_{dmax}-\rho_{dmin})$, ρ_d: The dry density of sandy base material, ρ_{dmax}: The maximum dry density of sandy base material, ρ_{dmin}: The minimum dry density of sandy base material]. The comparisons showed that the correlation coefficient would become higher in the following order: 3) Density deviation ratio > 2) Skeletal void ratio > 1) Void ratio. The correlation between density deviation ratio and volumetric strain is illustrated in the figure below. In the case where pure sand was used as base material, it can be seen that there is a consistent high correlation, unaffected by the variance caused by the different uniformity coefficient of the sandy base material. In the other case where the base materials contained fine particle fractions, a positive correlation is observed, while the degree of data scattering is relatively large.
- In the cases of the mixed sandy soil, volumetric strains tend to be larger than the results of pure sand. To improve prediction accuracy, it is necessary to further analyze the effects on volumetric strain following liquefaction, focusing on how the physical properties of fine contents act in such process.



Correlation between density deviation ratio and volumetric strain

Development of a numerical method independent of the objective stress rate for large deformation of the ground due to pullout of driven piles

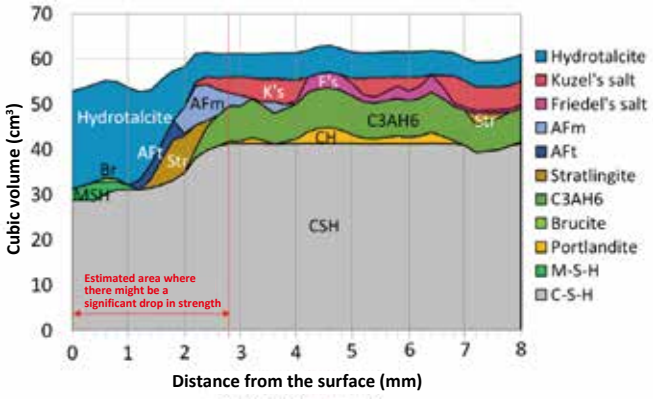
- For open-ended piles of port and harbor foundations, pull-out resistance is not sufficiently taken into account in design. However, in order to develop and improve facilities more efficiently, the pullout capacity needs to be evaluated properly.
- To evaluate the pullout resistance of the pile analytically, it is necessary to first understand the changes in mechanical characteristics of the ground during pile driving. Therefore, the continuum analysis using the constitutive law for soils is more suitable than DEM analysis. However, due to the difficulty of performing such numerical computations, ground deformation caused by pile driving has never been successfully simulated. Therefore, in this study, we developed a numerical method that can simulate the ground deformation from pile driving to pulltout.
- The material point method (MPM) was used for numerical method, which can track extremely large deformation that cannot be simulated in a commonly-used finite element method due to the distortion of mesh. By considering the frictional contact between pile and ground, we were able to successfully simulate the pile driving process.



Simulation of the pile driving process

Development of next-generation concrete deterioration simulation model utilizing geochemistry phase-equilibrium calculations

- In view of the lack of human resources and financial budget that will be needed to maintain and manage Japan's infrastructure in the future, many facilities might have to continue to be used beyond their initially designed period of use. While it is necessary to examine the long-term durability of concrete materials to address this issue, there is a concern that long-term exposure tests alone may be insufficient.
- Deterioration acceleration testing is an existing method for estimating long-term durability. However, the usefulness of acceleration testing is yet to be determined, as it also requires some long-term exposure testing to define an appropriate acceleration rate, and it also remains unclear how differences between the testing environment and the actual environment affect the deterioration process.
- Therefore, we believe the next reasonable step is to perform simulations based on the actual deterioration mechanism in order to accurately predict the long-term durability of concrete materials in the future. In this study, we observed cement compositions and changes in the concentration distribution of various ions in concrete materials, and obtained their phase constitution through geochemistry phase-equilibrium calculation (GEMS; D.Kulik, 2013), and created simulations that indicate the areas where the concrete materials would become vulnerable (reduction in strength).
- The figure illustrates a sample phase composite calculation based on the distribution of various ions found in a concrete material (cement: BB), the surface of which has actually lost strength. As a reduced CSH level, which affects strength, was observed for the area approx. 3 mm from the surface, it can be seen that the strength of the area has significantly deteriorated. However, as the composition of CSH is considered to be affected by CH becoming extremely low, and it starts losing strength, the actual drop in strength may be far deeper.
- We measured Vickers hardness data on actual concrete material and determined that the area where strength deteriorated was 5.1 mm from the surface. Taking into account that Vickers hardness measurement data tend to fluctuate widely, we believe this method is capable of predicting strength deterioration roughly yet sufficiently at this point.
- In future, we plan to conduct chemical analysis, etc. of the border regions where strength deterioration of concrete occurs, in order to properly define border conditions and enhance prediction accuracy.



Relationship between the composition change of hydrates and the area of strength deterioration in the direction of depth

Number of Peer-reviewed papers in FY 2018

Number of papers in Japanese	Number of papers in non-Japanese languages	Total	Rate of papers in non-Japanese language
58 (47)	55 (30)	113 (77)	48.7% (39.0%)

* The above numbers contain proceedings that only reviewed the abstract. (Numbers in parentheses indicate the number of journals.)

Papers Published in PARI Reports in FY 2018

No.	Title	Author(s)	Language	Month/Year
57-2	Field measurements and analyses of carbonate production by a coral reef ecosystem: towards the low-water line protection of remote islands	Toko TANAYA, Tatsuki TOKORO, Yoichi WATABE, Tomohiro KUWAE	Japanese	June 2018
57-4-1	Regulating factors of organic carbon accumulation rate in coastal vegetated habitats	Kenta WATANABE, Tatsuki TOKORO, Kazufumi TADA, Shigeru MONTANI, Tomohiro KUWAE	Japanese	March 2019
57-4-2	An analysis of Ocean Waves along the Japanese Coast Based on Swell Index	Hitoshi TAMURA, Takashi FUJIKI, Koji KAWAGUCHI	Japanese	March 2019

Papers Published in PARI Technical Notes in FY 2018

No.	Title	Author(s)	Language	Month/Year
No.1342	Annual Report on Nationwide Ocean Wave Information Network for Ports and Harbours (NOWPHAS2016)	Koji KAWAGUCHI, Fumikazu SUEHIRO, Takashi FUJIKI, Hitoshi TAMURA	Japanese	June 2018
No.1343	Seismic coefficients of coastal parapet levees considering the dynamic response characteristics and applicability to performance verification	Eiji KOHAMA, Ryota NATSUSAKA, Hirofumi FUKAWA	Japanese	June 2018
No.1344	Applicability of pile foundations at confined disposal facilities in coastal area – Part 2: in situ demonstration for pile-driving and impermeable performance at the landfill for waste incineration residue	Takaaki MIZUTANI, Yoshiyuki MORIKAWA, Yoichi WATABE, Yukio TSUDA, Yuji MIYAHARA, Takayuki MATSUMOTO, Jun MATSUO, Yu ICHIKAWA, Nobuharu MATSUMOTO, Teiji TAKAGI, Kazuhiro UENAKA	Japanese	June 2018
No.1345	Modeling of Ship Wave Generation for NOWT-PARI and Its Verification - To Apply the Model for Port and Harbor Operation -	Katsuya HIRAYAMA, Naoto HIGUCHI, Junya NAGANUMA	Japanese	June 2018
No.1346	Accuracy verification of Airborne Laser Bathymetry in the surf zone	Satoshi NAKAMURA, Masayuki BANNO, Taichi KOSAKO, Shin-ichi YANAGISHIMA, Hideto YASUDA	Japanese	June 2018
No.1347	Annual Report on Strong-Motion Earthquake Records in Japanese Ports (2016)	Atsushi NOZU, Yosuke NAGASAKA	Japanese	June 2018
No.1348	Damage to Port and Airport Facilities during the 2016 Kumamoto Earthquake Sequence	Atsushi NOZU, Futoshi IZU, Shinji SASSA, Eiji KOHAMA, Yousuke OHYA, Ryuji TERADA, Takaaki KOBAYASHI, Akihiko KONDO, Yosuke NAGASAKA, Takeshi SUZUKI, Yukitomo TSUBOKAWA, Ryoji NAITO, Masahiro TAKENOBU, Yusuke FUKUNAGA, Takashi KIDOU	Japanese	July 2018
No.1349	Analysis on Chloride Induced Deterioration Progress in Superstructure of Open-type Wharf with Statistical Methods	Yutaka TANAKA, Yuichiro KAWABATA, Ema KATO	Japanese	December 2018
No.1350	Survey on aggregate gradation of asphalt mixture for surface course of Airfield pavement	Futoshi IZU	Japanese	December 2018
No.1351	A field-experimental study on solidification of filling material in caisson toward enhanced resistance of caisson against repeated collision of concrete block	Yuichiro KAWABATA, Kenichi KUROKI, Ema KATO, Yoshiyuki MORIKAWA, Tetsushi HAYAKAWA	Japanese	March 2019
No.1352	INVESTIGATION ON REINFORCEMENT OF A PIER WITH STEEL PIPE PILES USING SUPPLEMENTAL DAMPING DEVICES	Eiji KOHAMA, Shingo AWAZU, Yousuke OHYA, Yoshio SHIOZAKI	Japanese	March 2019

Annual Report, Technical Journals, and Website

The Annual Report 2018 (Japanese version) and the PARI Annual Report 2018 (English version), which summarized the activities in FY 2017, were produced as a record of achievements, and were distributed to the parties concerned and published on PARI's website.

Regarding the PARI Technical Journal, we selected special articles for each study theme for every issue to introduce utilization situations of study results and PARI's experiment and on-site observation facilities. Approximately 2,000 copies of the PARI Technical Journal were distributed to approximately 1,700 places.

The PARI Technical Journal

On PARI's website, we provided various information on events and news including PARI's summarized information, achievements, facilities, symposiums on a real time basis; we got approximately 140,000 accesses in this fiscal year.

Lectures for the General Public

Port and Airport Technology Lecture

Aiming to present and disseminate the achievements of investigations, research, and technical developments carried out at PARI, we held a Port and Airport Technology Lecture in Tokyo on October 9, 2018 in cooperation with the National Institute for Land and Infrastructure Management, which was attended by 174 participants.

Port and Airport Technology Special Lecture in Region

Aiming to widely provide information on the research activities and achievements of PARI and collect information such as research needs in each region of Japan, we held 4 lecture meetings throughout Japan in cooperation with the National Institute for Land and Infrastructure Management, Regional Development Bureaus, and others, gathering approximately 650 participants.

Port and Airport Research Symposium

We held the Port and Airport Research Symposium in cooperation with the National Institute for Land and Infrastructure Management in Yokosuka City on January 11, 2019, which was attended by more than 100 people.

Open House

Open House

During the Open House event held on Saturday, July 21, 2018, we conducted a variety of demonstration experiments such as "Let's find out the powerful force of tsunami!", hands-on events including "Let's touch tidal flat creatures!", and exhibitions including "Let's try a flight simulator!". A total of 980 people visited PARI for the event.



Open House set-up

Other Facility Tours

Other than the Open House, we held 71 facility tours, with 2,144 visitors. We introduced PARI facilities and PARI-associated research to visitors from private companies, the government, municipalities, and educational institutions to broaden understanding of PARI's activities and the social importance of researchers. We also carried out activities to increase understanding of disaster prevention, such as providing various information on earthquakes and tsunamis.

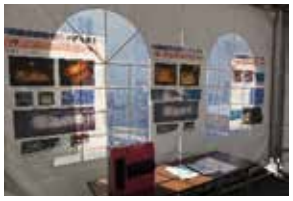
Other Outreach Activities

Cooperation with Super Science High school (SSH) Projects

For first-year students from Kanagawa Prefectural Yokosuka High School which is SSHs designated by the Ministry of Education, Culture, Sports, Science and Technology, we explained our studies and organized tours to PARI's facilities to enhance students' interest in science and math.

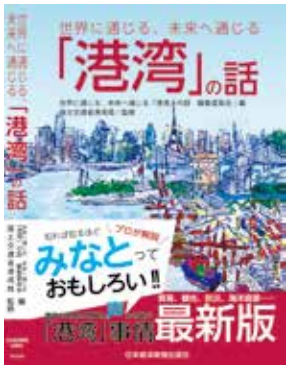
Exhibition at Tokyo-wan Daikanshasai 2018 [Tokyo-Bay Thanksgiving Day 2018]

Tokyo-wan Daikanshasai 2018 was held in the vicinity of the Yokohama Red Brick Warehouse in October 2018. We explained to many visitors underwater imaging technology along with demonstrations by marine divers as part of PR activities at the Keihin Port Dock, designated as a Civil Engineering Heritage site by the Japan Society of Civil Engineers.



Presentation at the Keihin Port dock

Media Appearances

We distributed information via media outlets, including experimental films explaining the dangers of tsunamis and other materials broadcast on news shows and other programs of Japanese TV stations. In addition, articles on various activities of PARI appeared in newspapers, technical journals, and other printed media, a total of 58 times.



Presentation of cases where PARI's research findings are applied to port, harbor, and airport operations

Awards for Papers and Others in FY 2018

	Name		Award	Institution	Date	Remarks
1	Shinji SASSA	Head, Soil Dynamics Group	Outstanding Reviewer of Coastal Engineering	ELSEVIER The Editors of COASTAL ENGINEERING	April 12, 2018	
2	Shinji SASSA	Head, Soil Dynamics Group	Outstanding Reviewer of Journal of Rock Mechanics and Geotechnical Engineering	ELSEVIER The Editors of JOURNAL OF ROCK MECHANICS AND GEOTECHNICAL ENGINEERING	April 12, 2018	
3	Yuichiro KAWABATA Kazuhide YONAMINE	Senior Researcher, Structural Mechanics Group Researcher, Materials Group	Japan Cement Association, Distinguished Paper Award	Japan Cement Association	May 9, 2018	
4	Hidenori TAKAHASHI and three others	Head, Soil Stabilization Group	Ports & Harbours Association of Japan, FY2018 Distinguished Paper Award	The Ports & Harbours Association of Japan	May 23, 2018	Design method of reinforcing embankment for breakwaters and sensitivity analysis by its scale
5	Isamu FUJITA Yoshitaka MATSUZAKI	Director, Frontier Technology and Engineering Department Senior Researcher, Oil Spill Response Group	Ports & Harbours Association of Japan, FY2018 Distinguished Paper Award	The Ports & Harbours Association of Japan	May 23, 2018	A simulation model of oil transport on the water surface
6	Yuri SUGIYAMA	Researcher, Soil Mechanics and Geo-Environment Group	The Maeda Engineering Foundation Yamada Kazuie Award	The Maeda Engineering Foundation	June 1, 2018	Basic research on dynamic properties of seabeds
7	Daiki TAKANO and seven others	Senior Researcher, Soil Stabilization Group	Japanese Geotechnical Society, Operation Plan Award	Japanese Geotechnical Society	June 6, 2018	Electronic publication series including collections of papers presented at international conferences hosted by the Japanese Geotechnical Society
8	Keita NAKAMURA	Researcher, Foundations Group	International Conference, Japanese Geotechnical Society, Distinguished Young Paper Author Award	Japanese Geotechnical Society	June 6, 2018	
9	Eiichi MIYOSHI	Research Specialist, Coastal and Estuarine Environment Research Group	Japan Society of Civil Engineering, FY2017 Distinguished Technical Contribution Award	Japan Society of Civil Engineers	June 8, 2018	
10	Shinji SASSA	Head, Soil Dynamics Group	Outstanding Reviewer of Applied Ocean Research	ELSEVIER The Editors of Applied Ocean Research	June 25, 2018	
11	Yuri SUGIYAMA	Researcher, Soil Mechanics and Geo-Environment Group	53rd Geotechnology Research Presentation, Excellent Presentation Award	Japanese Geotechnical Society	September 6, 2018	Analytical study of methods for estimating in-situ strength of seabeds
12	Takashi FUJIKI Koji KAWAGUCHI Fumikazu SUEHIRO and one other	Researcher, Marine Information Group Head, Marine Information Group Researcher, Marine Information Group	FY2018 Distinguished Coastal Engineering Paper Award	Coastal Engineering Committee, Japan Society of Civil Engineers	November 16, 2018	Automated partitioning of directional wave spectrum with Gaussian mixture model
13	Tomohiro KUWAE and four others	Head, Coastal and Estuarine Environment Research Group	Ecological Research Award	The Ecological Society of Japan	March 19, 2019	Seasonal linkage between stocked sweetfish and great cormorants as predators and prey
14	Takaaki MIZUTANI	Head, Foundations Group	Letter of Appreciation	Bureau of Port and Harbor, Tokyo Metropolitan Government	March 22, 2019	Technical assistance provided in a study of the supporting force of piles at the new wharf for passenger ships in Tokyo Bay

Active Commitment in International Meetings, Workshops, and Other Projects

In December 2015, the United Nations General Assembly officially designated November 5th, which has already been designated as Tsunami Prevention Day in Japan, as World Tsunami Awareness Day. In response, we established the Hamaguchi Award (Minister of Land, Infrastructure, Transport and Tourism Award) in 2016 in order to reward persons who have made remarkable contributions in the field of coastal disaster prevention technology including tsunami disasters. In November 2018, the award was given to the following two persons and one group: Hajime Mase, Professor Emeritus / Research Professor at Kyoto University; Harry Yeh, Professor at Oregon State University; and the DONET Development Team.

A prize awarding ceremony and commemorative lecture of the Hamaguchi Award (November 7, 2018, Tokyo)

In September 2018, PARI researchers participated in HYDRALAB+Meeting and the Workshop International Collaboration outside Europe held in Catania, Italy and introduced PARI's research facilities of marine and hydraulic engineering and presented our studies on global warming.

In addition, PARI representatives also traveled to Ghent, Belgium in October 2018 to attend the Sixth International Symposium on Life-Cycle Engineering. We gave a presentation of our research findings of maintenance technologies on port facilities and deepened interactions through vigorously exchange of opinions.

Broad Research Exchange with Japanese and Overseas Research Institutes

To improve the quality and efficiency of research, we actively collaborated on research with domestic and overseas research instituties and signed a total of 39 research cooperation agreements with 12 Japanese and 27 overseas institutes as of FY 2018. During FY 2018, PARI executed research cooperation agreements with the International Partnership for Blue Carbon (secretariat: the Government of Australia), the Japan Agency for Marine-Earth Science and Technology, etc.

Conclusion of Education and Research Collaboration Agreements

We signed agreements with national, public and private universities. Under these agreements, PARI researchers serve as grad-school professors or take other positions at the universities. Under the graduate school linking system, in which postgraduate students receive instructions at research institutions, we concluded collaboration agreements with 9 universities including the Tokyo Institute of Technology, Nagoya University, and Nagaoka University of Technology. In FY 2018, we dispatched 9 researchers as lecturers. We also dispatched a total of three researchers to universities which are not under the graduate school linking system, including the University of Tokyo.

Promotion of Administrative Support

Dispatching of Researchers to Disaster Sites

In order to investigate the status of the damage caused by storm surges during Typhoon Jebi on September 4, 2018, PARI, in conjunction with the National Institute for Land and Infrastructure Management (NILIM) Yokosuka branch, dispatched four researchers (including two from PARI) to Wakayama-Shimotsu Port and two researchers (including one from PARI) to Amagasaki-Nishinomiya-Ashiya Port.

In addition, PARI, in conjunction with NILIM Yokosuka branch, sent four experts (including three from PARI) to Tomakomai Port to investigate the status of damage caused by the major earthquake that occurred on September 6, 2018, an epicenter of which was located in the central and eastern Iburi region in Hokkaido.

Furthermore, 2018 Sulawesi earthquake and tsunami struck in Central Sulawesi Island, Indonesia on September 28, 2018 caused enormous damage due to liquefaction-induced tsunamis. As the government of Indonesia requested JICA to help developing a master plan for post-disaster recovery, PARI dispatched two researchers as part of the investigation team to conduct a field survey on the disaster area so that the plan would be completed based on the survey.

Investigation of the status of damage at Tomakomai Port

Dispatching of Researchers to Various Technical Committees

We dispatched a total of 40 researchers to various technical committees organized by governments and other organizations to solve technical issues concerning the execution of port, coastal, and airport public works by national and municipal governments and local administrations. Including technical committees on improving ports, coasts and airports established by various institutions, a total of 307 researchers were dispatched by PARI, and actively tackled technical issues faced by governments and other organizations.

Dispatching of Lecturers to Training Courses for Domestic Engineers

Training courses for national and other public service engineers are held by NILIM. We actively participate from the planning stage and have dispatched a total of 35 researchers to 12 training courses as lecturers.

Providing Operational Support for Technical Standards for Ports, Airports, etc.

Regarding technical standards for port facilities, our researchers took part in technical committees set up by the Ports and Harbours Bureau of the Ministry of Land, Infrastructure, Transport and Tourism. Our researchers also gave lectures at NILIM, conferences, and seminars organized by other relevant organizations, and contributed to the spread of technical standards. Regarding airport facilities, our researchers participated in various investigative commissions in preparation for the smooth introduction and operation of technical standards for airport civil engineering facilities.

Support for Evaluation of New Technologies

In response to a request of the Ministry of Land, Infrastructure, Transport and Tourism (including regional development bureaus), PARI offered technical support by dispatching researchers to the New Technology Utilization Evaluation Conference established by each organization for evaluating the practicality and applicability of the technologies to be registered in the New Technology Information System (NETIS) in order to promote the application of useful new technologies.

July 2019

—Creating Technologies that Contribute to the World—

National Institute of Maritime, Port and Aviation Technology

Port and Airport Research Institute

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