PARI

Annual Report 2021

Port and Airport Research Institute Annual Report 2021

Creating Port and Airport Technologies That Contribute to the World

港湾空港技術研究所長
（うみそら研理事）　高野誠紀

Seiki TAKANO
Director General, Port and Airport Research Institute
(Executive Director, National Institute of Maritime, Port and Aviation Technology “Umisora Institute”)

In April 2016, three research institutes – the National Maritime Research Institute (NMRI), the Port and Airport Research Institute (PARI), and the Electronic Navigation Research Institute (ENRI) – were integrated, the National Institute of Maritime, Port and Aviation Technology (MPAT), (commonly known as “Umisora Institute.”) was launched. We, the Port and Airport Research Institute (PARI), are going to play a role in the Umisora Institute as a research institute responsible for survey, research and technological development related to the maintenance of ports and airports, while inheriting our past steps. Our predecessor institute, the Port and Harbor Research Institute (PHRI) of the Ministry of Transport (MOT) has been supporting technically numerous port and airport projects such as Kashima Port development, and Haneda/Kansai International Airport construction since its birth in 1962, and has achieved research results that are highly evaluated worldwide. We, the Port and Airport Research Institute will further expand, deepen the cooperation and integration of research in different fields by the cooperation with other two integrated institutes (NMRI and ENRI), and maximize the results of research and development by demonstrating the synergistic effect, in addition to the close cooperation with the National Institute for Land and Infrastructure Management (NILIM), Ministry of Land, Infrastructure, Transport and Tourism (MLIT) from now on.

This annual report summarizes the results for FY2020, the fifth year of the first medium- to long-term plan (FY2016 to FY2022).

In the first medium-to long-term plan, we will focus on the four R & D issues; "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".

In "Coastal Disaster Mitigation and Restoration", we are proceeding research of a development of predicting method of strong vibrations near the epicenter, Tsunami predicting techniques based on combined observation information, a method for estimating the amount of local scour structures caused by Tsunamis.

In "Formation of Infrastructure for Vigorous Economy and Society", we are proceeding research is being conducted on the introduction of ICT into container terminals, the improvement and development of inspection equipment for offshore structures, and the development of core-less ground survey methods.

In "Preservation of Marine Interests and Utilization of Oceans", we are proceeding research on analysis methods for topographic dynamics on isolated islands, methods for discriminating the distribution and use of reef-building organisms, and clarification of horizontal resistance characteristics of pile foundations for offshore wind power generation facilities.

In "Creation and Utilization of Coastal Environment", we are proceeding research, such as quantification of blue carbon (mitigation effect) in various coastal areas and practical application of carbon offsetting, the influence of the super-moon on coastal topographical changes.

In carrying out these researches mentioned above, we will be pursing the two major mottos of our institute, “The Research level is the highest in the world” and “The Research results are useful the actual projects”. We will be also promoting strategic international activities such as contributing to the overseas expansion of infrastructure promoted by the national government and technical support to overseas countries. Furthermore, in order to respond to technical issues across research fields, PARI internally set up five centers (International Research Center for Coastal Disasters”, “Life Cycle Management Research Center”, “Ocean Infrastructure and Offshore Wind Energy Research Center”, “Productivity Improvement Center”, and “ Innovation Promotion Center”), and we will be further strengthening cooperation with the Regional Development Bureaus of the Ministry of Land, Infrastructure, Transport and Tourism, which have technology implementation sites, and private companies.

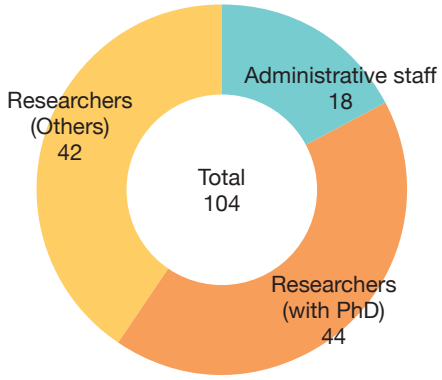
In recent years, natural disasters such as earthquakes, storm surges, and high waves have intensified, occurred frequently, and the acceleration and deepening of National Resilience is an urgent issue. In view of the uniqueness of our institute as research institute that conducts practical research and development closely related to the field under the harsh natural conditions unique to Japan, we will be continuing to utilize the knowledge and human resources of our institute, in addition, we would like to firmly work on emergency response and support for restoration in the event of natural disaster, enlightenment related to disaster prevention.

We would greatly appreciate your continued understanding and support.

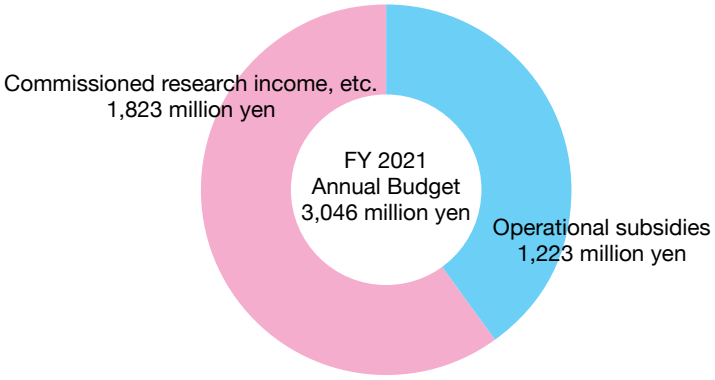
CONTENTS

1 Outline of Organization 02p
2 Management Strategy 03p
3 Structure of Research Themes in FY 2020 04p
4 Research Themes and Activities in FY 2020 05p
5 Fundamental and Exploratory Research 14p
6 Published Research Papers 19p
7 The Open Institute 20p
8 Outstanding Research Activities 21p
9 PARI Events 22p

Administrative Staff and Researchers, and Budget

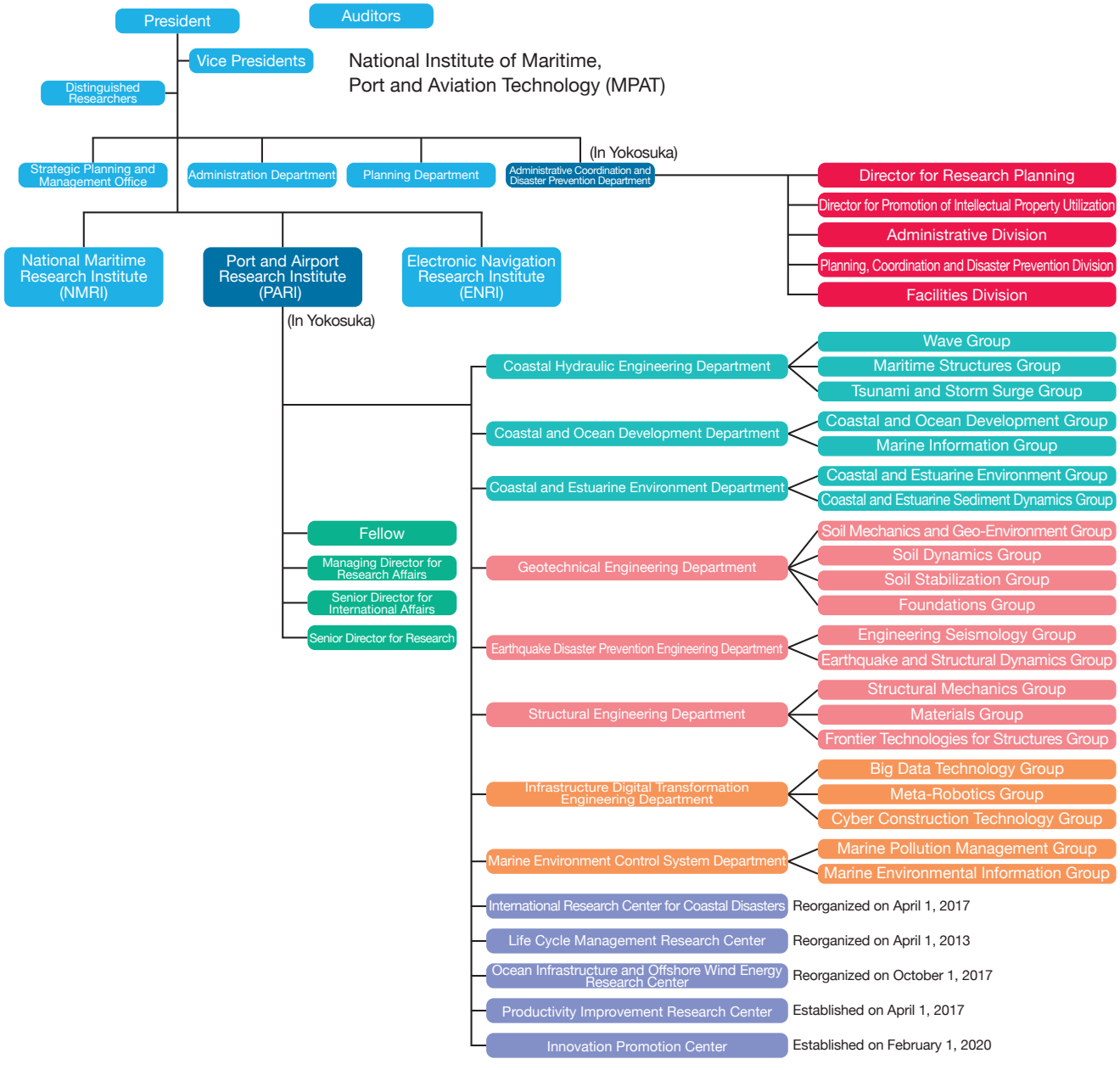


As of April 1, 2021 (In Yokosuka)



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

Organizational Structure



As of July 1, 2021

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 2020

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
			Fundamental Research		Investigation of earthquake disaster
			Fundamental Research		Development of estimation method for near-fault strong ground motions
			Fundamental Research		Development of a new method for predicting liquefaction-induced ground subsidence and flow
		② Research on damage-reduction techniques against the greatest earthquakes	Applied Research	☆	Development of seismic performance evaluation method for offshore wind turbines and coastal structures against the largest earthquake motions
			Applied Research		Development of countermeasures for early exhibition of seismic performance of coastal facilities
		③ Research on the interaction of earthquakes, tsunamis, and high waves with ground dynamics	Applied Research	☆	Stability evaluation of offshore structures against washout, cavity formation, etc. and development of countermeasure techniques
			Fundamental Research		Evaluation of the deformation and fracture characteristics of coastal soil structures in relation to waves and flows, and development of reinforcement technology
	1B Research on Mitigation and Restoration of Tsunami Disasters	① Research on ICT-based decision support systems	Development Research		Development of a 3-dimensional simulation model for drift behavior and its application to a 2-dimensional simulation model
			Development Research		Development of multi-observation based tsunami forecasting method
		② Research on the development of tsunami-resistant ports	Fundamental Research		Development of the estimation method for local scour around coastal structures due to tsunami
			Development 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
			Fundamental Research		Identification of issues and improvement of wave estimation methods applicable to Japan's coastal areas
			Development Research		Development of a pier inundation simulation method that considers seawall overtopping and drainage
			Applied 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
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	Applied Research		Proposal of evaluation method to estimate the productivity of the container terminal system introduced AI and ICT technology or other method
			Applied Research		Proposal of planning method for automated container terminal by quantitative numerical simulation
			Applied Research		Proposal of new technology for container terminal operations
	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 applicability of sustainable materials in the marine environment
			Applied Research		Study of the effects of steel mesh in concrete pavement used at airports from the design and implementation perspectives
			Applied Research	☆	Examination of productivity improvement methods applicable to concrete structures at ports
		② Research on systems for inspecting and diagnosing infrastructure	Fundamental Research		Study on application of inspection and diagnosis systems for improvement of performance evaluation of marine structures
			Development Research		Development of adaptive technique for inspection vehicle to disturbance in operation
	2C Research on Effective Use of Existing Infrastructure Facilities	① Research on techniques to improve or renew existing facilities	Applied Research		Development of quality evaluation method for ground improvement using geophysical exploration
			Fundamental Research		Study on process leading to rupture of pier structure for high definition of performance regulation
		② Research on effective use and techniques of treating construction byproducts	Applied Research		Effect of defective part of solidified body on its internal stability
			Fundamental Research		Basic research to develop coreless ground survey methods and establish digital geotechnical engineering
3. Preservation of Marine Interests and Utilization of Oceans	3A Research on Development and Utilization of Oceans	① Study on the preservation and use of remote islands	Development Research		Development of fender system for automatic ship berthing/unberthing
			Fundamental Research	☆	Development of analytical methods for the topographic dynamics of carbonate islands
		② Research on infrastructure technology for utilization and development of oceans	Development Research		Study on the multi-functional evolution of underwater construction machinery using machine-guidance techniques
			Development Research	☆	Study on the application of acoustic imaging system to ICT-based construction projects
			Applied Research		Study on floating breakwater equipped with wave power generation device
			Applied Research		Research on the estimation method of wave force acting on offshore wind power facilities
			Fundamental Research	☆	Elucidation of the horizontal resistance characteristics of pile foundations for offshore wind power plants under various fluctuating loads
			Applied Research		Research on load setting method for offshore wind power facilities under waves and winds
			Fundamental Research	☆	Evaluation of the mechanical properties and durability of infrastructure materials in the deep sea
4. Creation and Utilization of Coastal Environment	4A Research on Enhancement and Utilization of Coastal Ecology	① Research on coastal-ecosystem utilization	Fundamental Research	☆	Validation of the newly developed global dynamic model for the projection of atmospheric CO_2 uptake rate and inundation control in shallow coastal ecosystems
			Applied Research		Coastal geotechnical/geomorphological design for disaster mitigation and ecological environment
		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		Numerical study on responses of aquatic ecosystem to an environmental change
			Fundamental Research		Development of the methods for increasing ecosystem functions in eelgrass meadow
			Applied Research		Numerical analysis of coastal current by numerical simulation and data assimilation
		③ Research on countermeasure technologies against sea oil spill	Development Research		Development of oil spill response technology for next generation
	4B Research on Coastal and Estuarine Processes	① Research on coastal protection and maintenance of waterways and mooring basins	Fundamental Research		Observation of coastal phenomena at HORS and development of numerical simulation of topography change for port and surrounding beaches
			Fundamental Research		Developing future projection model of coastal change in the context of climate change
			Fundamental Research	☆	Development of sediment transport control method to minimize harbor siltation

* Special research involves high-priority research topics on which PARI must conduct studies intensively. PARI allocates significant human resources and funding to these projects, and also arranges cross-functional research systems extending beyond the basic organizational structure within PARI as needed, in order to accelerate research.

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, this research aims to develop reliable techniques for predicting seismic motions and damage to structures caused by the strongest, long-duration earthquakes. The research also intends to develop new techniques for reinforcing existing structures for improving their anti-seismic capacity, assessing damage during on-site damage surveys, and implementing emergency measures. In addition, the research attempts to elucidate the phenomenon of tsunami caused by submarine landslides, explain soil performance under the effects of tsunami, high waves, and flows, and identify related countermeasures.

Research Topics

Research and development comprise the following subthemes for mitigating earthquake damage and facilitating post-disaster recovery:

① Research on strong ground motions and damage predictions in the case of the greatest earthquakes

We will develop a composite source model for simulating near-source strong ground motions that can consider not only the strong ground motions that are caused by the rupture of deep asperities, which have conventionally been reflected in structural designs, but also the effects of shallow slip as observed during the Kumamoto earthquake, and will examine its validity.

② Research on damage-reduction techniques against the greatest earthquakes

We will develop techniques that will swiftly activate the functions of coastal facilities following earthquakes that involve adding new components to existing facilities and replacing those when damaged by earthquakes.

③ Research on the interaction of earthquakes, tsunamis, and high waves with ground dynamics

We will develop effective design and countermeasure techniques for mitigating washout, cavity formation, etc. that occur to coastal structures under various dynamic external forces.

Activities in FY 2020

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

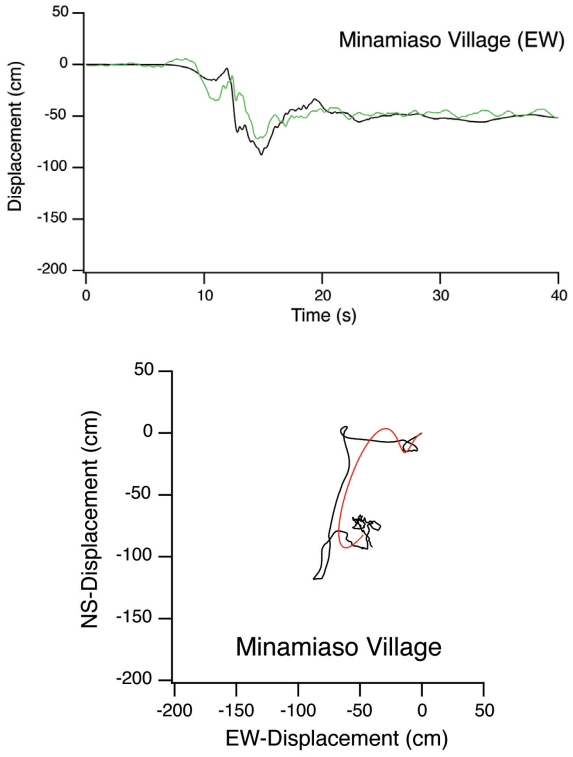
In order to predict seismic motions and damage in the greatest earthquakes, we observed strong ground motions in ports and airports and organized and analyzed their data, investigated earthquake disasters and their causal factors, and worked on the development of novel methods for predicting near-source strong ground motions and liquefaction-induced ground subsidence and flow. In particular, to develop a method for predicting near-source strong ground motions, we conducted fundamental research on fault plane discretization and use of complex frequency to calculate the effects of shallow slip with improved accuracy in order to develop a composite source model that can consider not only the strong ground motions that are caused by the rupture of deep asperities, which have conventionally been reflected in structural designs, but also the effects of shallow slip. We also developed a composite source model applicable to actual earthquakes and verified its validity by comparing the simulated ground motions with the observed ones.

Research on damage-reduction techniques against the greatest earthquakes

We worked on the development of a technique for assessing the seismic performance of offshore wind turbines and coastal structures, and examined techniques that could be implemented to swiftly activate the seismic performance of coastal facilities in the greatest earthquakes. In particular, we used the earthquake response analysis program that was previously developed for use on offshore wind turbines to perform a number of analyses on monopile foundations, and examined the effect of simultaneous action of seismic motions and wind, the effect of the liquefied layer modeling method, and the effect of seabed sloping. Furthermore, we conducted shake table tests and analyses on a seismic reinforcement method that could be applied to vertical-pile wharves that would involve installing additional structural members, and confirmed that the method could reduce the amount of damage and deformation for the overall wharf structures by allowing damage to the additional structural members.

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

Concerning the interaction of earthquakes, tsunamis, and high waves with ground dynamics, we worked on the development of a stability analysis for washout, cavity formation, etc. affecting coastal structures, and examined possible countermeasures. We also worked on techniques for evaluating the deformation and failure of coastal geotechnical structures under wave and flow forces and investigated possible measures for reinforcement.



Simulated ground motions with the composite source model for the Kumamoto earthquake
Black indicates observed ground motions while green and red indicate simulated ground motions

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 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.

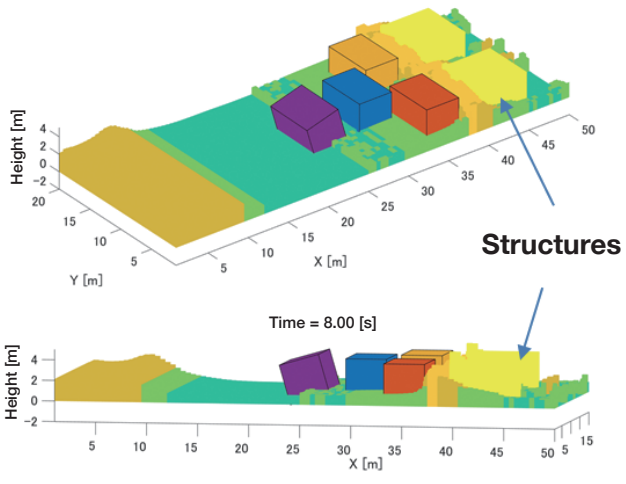
Research Topics

Research and development on this theme cover the following topics for tsunami disaster mitigation and recovery:

- For our research on simulation model for tsunami drift object , we are examining the accuracy of developing 3-D simulation model for the behavior of drift object.
- For our research on multi-observation-based tsunami forecast, we are verifying the efficacy of our prediction method utilizing tsunami-source inversion.
- For our research on the application of particle methods to the deformation of port structures, we developed new boundary models for more accurate and easy simulations.

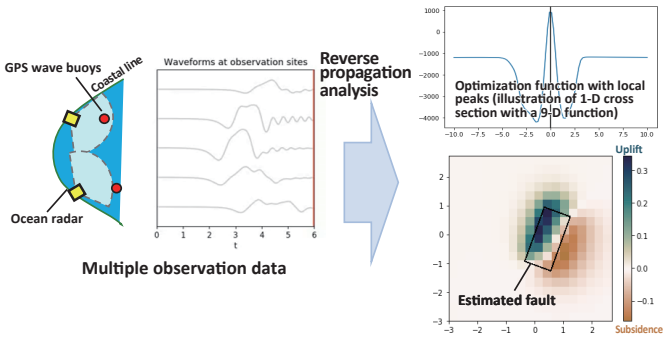
Activities in FY 2020

- We developed a 3-D model to estimate the behavior of the drift object on quay walls, and compared the simulation results of the planar 2-D and 3-D models. We found that the behavior of drift object significantly changes by the rotational movement in 3-D and the contact with the ground surface, which the planar 2-D model was unable to take into account.



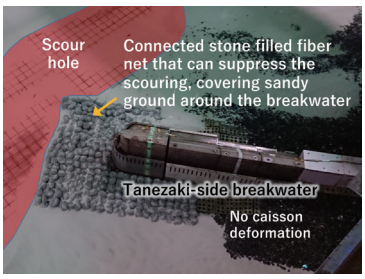
Numerical simulation by 3-D model

- The optimization function used to estimate the tsunami source faults has multiple local peaks, which makes it difficult to find the global optimal solution. We developed an inversion method using the replica exchange Markov Monte Carlo method to overcome this problem.

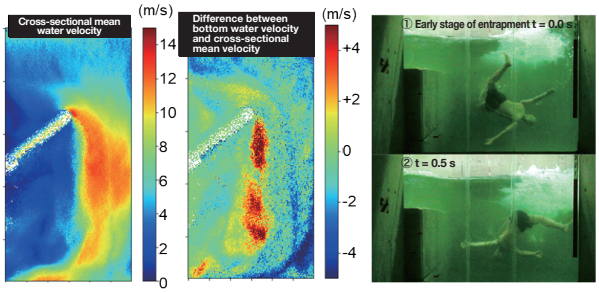


Tsunami-source fault estimated from multiple-point observation data

- We elucidated the process of how a tsunami goes under at the head of a breakwater, increases in velocity near the seafloor, and causes scouring, through model experiments and numerical calculations. Related to this, we identified a set of effective methods for calculating wave forces acting on breakwaters, and verified the stability of a novel scour-suppressing engineering technique, etc. utilizing connected stone filled fiber net. These research findings were used in the design of the breakwaters built near the mouth of Urado Bay, and patents were obtained on the scour-suppression engineering method. We also elucidated the process of how a tsunami-induced swirl could entrap a human body, as well as the buoyancy necessary for suppressing such entrapment.



Scour suppression by installation of connected stone filled fiber net



Calculation of water velocity at the breakwater head Entrapment by tsunami

- We have developed a free-surface boundary model for the particle methods. This model can appropriately treat unphysical voids generated inside the water under the wave breaking, which are inevitably given in the single phase flow simulations by the N-S solvers. In addition, a new wave generation model has been developed for more easy setups of wave boundaries including connection to other planar 2-D simulations. This model works at any given uniform depth but also along a slope facilitating wave deformations. Hence, the method is expected to drastically improve the computation efficiency by focusing its computation area around the target structure.

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

Background and Objectives

While Japan has not experienced a storm more devastating than the Isewan Typhoon that ravaged the nation in September 1959 in terms of severity of damage caused by storm surges and high waves, the United States and the Philippines have also been hit by catastrophic storms more recently, including Hurricane Katrina in September 2005 and Typhoon Haiyan in November 2013. In future, global warming might bring higher storm surges and waves than those we have experienced 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.

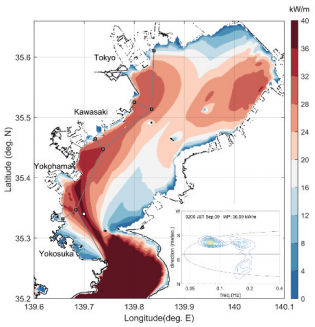
Research Topics

Research and development on the theme of mitigation of disasters caused by storm surges and high waves and disaster recovery cover the following topics:

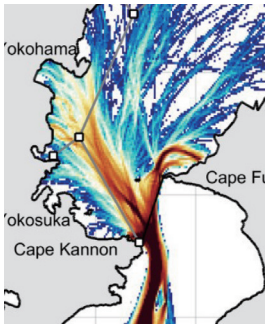
- For our research to elucidate the oceanographic phenomena based on ocean observation data, we are continuously processing and analyzing wave observation data (processing of quick reported and finalized wave data, and analysis of wave statistics).
- For our research on the simulation of inundation caused by waves within ports, we are developing an inundation and drainage model to address the issue of waves overtopping on quay walls.
- For our research on storm surge hazards of the highest magnitude, we are working on storm surge and inundation calculations that take into account the effects of waves, while reviewing sea surface drag coefficients under ultra-high-velocity wind conditions.
- For our research on the wave forces acting on the structural members of protective facilities under storm surges, high waves, and tsunami, we are examining methods of estimating chronological changes in wave forces and also the dynamic behavior of the structural members and the ground using neural networks, etc.

Activities in FY 2020

- We analyzed the wave observation data acquired through the NOWPHAS (Nationwide Ocean Wave information network for Ports and HArbourS) in 2019 and published it in the annual report. We also focused on the wave field of Typhoon Faxai, simulating it using a third-generation wave model and analyzing the wave direction (ray tracing) of the swell coming into the bay. The reproducibility of sea surface winds and Tokyo submarine canyons is crucial for the wave simulation of Tokyo Bay. Our study also indicated that the external swells that entered Yokohama Port during the typhoon might have caused significant damage to the adjacent areas.

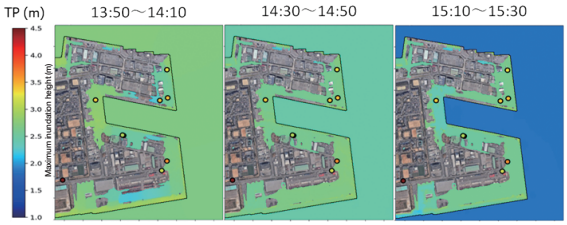


Spatial Distribution of maximum wave power



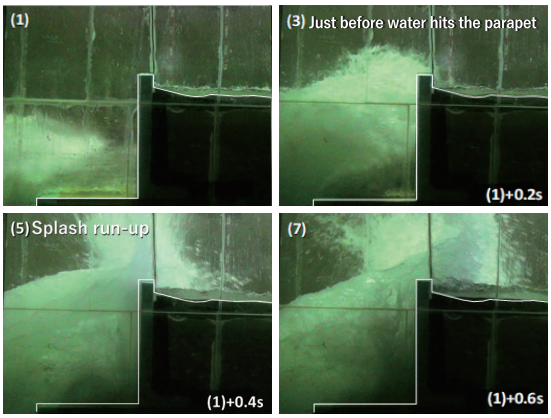
Analysis of the ray tracing of swells entering the bay

- The improved version of NOWT-PARI, which can perform continuous calculations while reflecting the chronological changes in storm surges and high waves, was tested to verify its ability to monitor the inundation process of wharves, which also factored in the natural drainage caused by lowered tidal levels and decreased overtopping waves. As a result, we were also able to confirm the reproducibility of the wharf inundation that occurred in Kobe Port during Typhoon Jebi (2018).

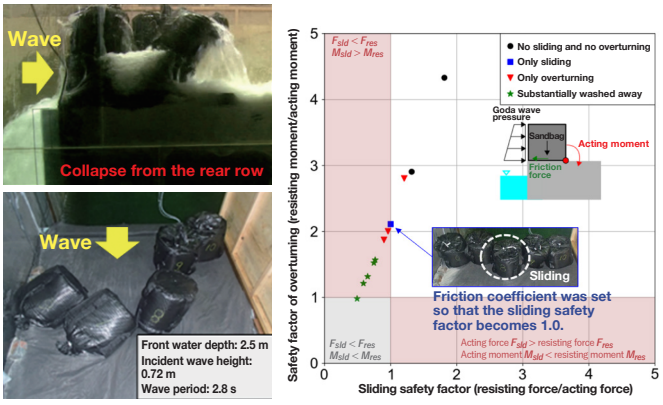


Process of inundation caused by storm surges and high waves during Typhoon Jebi (2018)

- Storm surge simulations considering wave setup were conducted to reproduce the observation data of sea level deviation caused by typhoon Jebi. The effect of typhoon translation speed on the storm surge deviation and the method of setting the sea surface drag coefficient at high wind speed are investigated.
- In view of the disaster that occurred in Yokohama Port during Typhoon Faxai, we conducted a large hydraulic model experiment and performed numerical simulations and elucidated the characteristics of the impulsive wave pressure acting on the setback parapet during storm surge and high waves. Based on this information, we were able to establish a method of evaluating the stability of sandbags against overtopping waves. These findings are supplementary to *Case Studies of Sandbag Installations in Ports and Harbors to Mitigate Damage Caused by Storm Surges and High Waves* (Ports and Harbours Bureau, Ministry of Land, Infrastructure, Transport and Tourism). We were also able to elucidate the mechanism of how energy suppression nets could reduce the wave pressure within the joint of caissons.



Experiment of wave force acting on setback parapet



Experimental results on the stability of sandbags

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

Background and Objectives

PARI is responsible for research and development to help improve the functions of ports, harbors, and airports across Japan, as part of the country's efforts to improve the international competitiveness of its industries and promote port, harbor, and airport development in an efficient and effective manner, as they are vital to the daily activities of the nation's citizens. PARI's research in these areas covers the following subthemes and goals that are relevant to Japan's international competitiveness, encompassing the country's global strategic port and harbor policy, improvement of airport functions in the Metropolitan Area (improvement of Haneda Airport), infrastructure export capability, etc. These topics are comprehensively studied by various departments of PARI as part of its overall R&D policy.

Research Topics

Research and development were conducted on the following topics to improve the port and airport functions in order to ensure their global competitiveness.

For the particular objective of improving container terminal productivity, we are developing a container damage inspection system, evaluating numerical simulations of terminals where ICT, etc. are used, and studying various implementation plans as part of our efforts to promote digital transformation at ports and harbors, improve their operational efficiency, facilitate the implementation of environmental measures, and enhance their overall functions.

Activities in FY 2020

(1) Proposal of evaluation method to estimate the productivity of the container terminal system introduced AI and ICT technology or other method

When the parallel container-stacking layout was examined in FY2019, we observed that many trucks had to wait for their turn on the terminal premises where cargo volumes of 1,500,000 TEU were handled per year. This meant that deploying the number of RTG cranes there in line with MC-3 and MC-4 would significantly fall short of the required actual cargo throughput. As the terminal had adopted an automated damage inspection system in FY2020, its overall cargo-handling machinery capacity improved, and the on-premises wait time of the trucks, which previously had to wait for ten minutes for their turn on average, was reduced to a short queue of five to six trucks. This improvement is likely attributable to the fact that this model of a container terminal had undergone a major expansion of space that increased its depth from 500 m to 700 m, in addition to its vertical layout where an automated transfer crane (ASC) is always deployed at each lane on the incoming chassis side, and it was assumed that such a terminal layout would require a large initial investment. As described above, AutoMod-powered simulations can enable us to examine various future plans by testing different assumptions. As the current port and harbor plan includes a cargo-handling volume of roughly 1,000,000 TEU per year, there should be sufficient excess capacity according to our simulations.

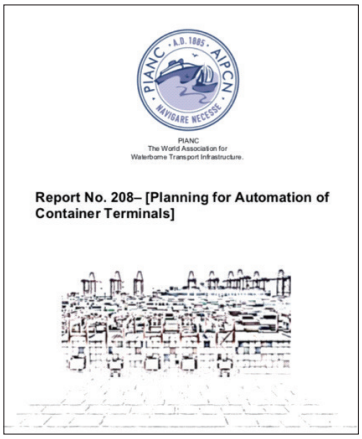
(2) Proposal of planning method for automated container terminal by quantitative numerical simulation

The PIANC finished its WG208 report titled *Planning for Automation of Container Terminals* and was set to publish it in March 2021. This 190-page book contains information on many of the latest cargo-handling machines, and how they could be deployed in combination with various operation systems, etc.

Meanwhile, PARI executed a memorandum of understanding (MOU) with the National University of Singapore (NUS) jointly with the Overseas Coastal Area Development Institute of Japan and the Japan Association of Cargo-Handling Machinery Systems. Under the MOU, PARI will form a research alliance not only with the NUS but also other institutions that have executed similar MOUs with the NUS, including the Singapore Maritime Institute and other research centers and universities from Australia, China, Germany, Korea, and the Netherlands, with a view to establishing unified international standards for smart ports.

Through this research alliance, PARI will function as one of its global partners in the formation of PortML (port mark-up language) standards that will facilitate cooperative interaction and information sharing among various port authorities and users.

When this project is completed, it will facilitate the development of innovative digital twin technologies, which will help enhance the global competitiveness of various parties involved in port and other maritime operations in Japan.



Planning for Automation of Container Terminals

(3) Proposal of new technology for container terminal operations

As part of the PRISM (Public/Private R&D Investment Strategic Expansion PrograM) sponsored by the Cabinet Office, we developed an AI-powered image determination system and conducted its data acquisition test at Daikoku Pier in Yokohama Port during FY2020 with a view to implementing the system in actual port operations in the near future. This system is capable of making determinations using both image processing and laser measurement data. In addition, we examined its applicability to PC-18 on Port Island in Kobe Port and prepared its test manual.

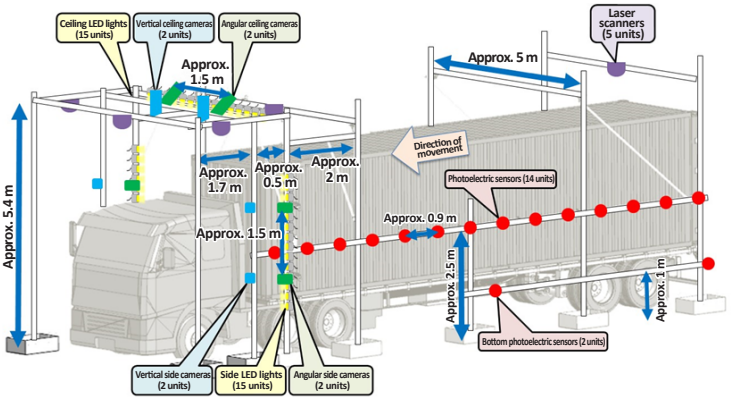


Illustration of the container damage inspection system (prototype installed at Yokohama Port)

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 were conducted on infrastructure life-cycle management with emphasis on the following three subthemes:

- Concerning technology for inspecting and diagnosing port structures, we examined various inspection and diagnosis techniques and inspection systems.
- We conducted exposure tests on concrete, steel and other materials to evaluate their long-term durability.
- We examined methods of evaluating the applicability of sustainable materials to marine environments.

Activities in FY 2020

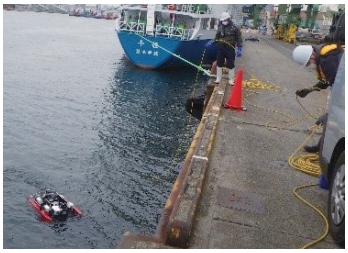
Research on systems for inspecting and diagnosing infrastructure

- Study on the implementation and operation of inspection and diagnosis techniques for developing the evaluation of marine structure performance

To study the use of underwater drones as an alternative to visual inspections, we tested their effectiveness in a survey of anode wear. During the test, we deployed underwater drones to measure the electric currents discharged from anodes while also visually inspecting them, and found that underwater drones could be a viable alternative to the conventional inspection method involving professional divers. However, the test also indicated that the efficiency of water drone surveys greatly depends on the skill of the operator. Another study we conducted focused on a monitoring method using an IoT-based inspection and diagnosis system. As part of this study, we selected a pier to survey the concentration of its salt accumulation and perform numerical analysis of the wind conditions underneath it in order to investigate effective positions for installing sensors on the surrounding marine structures. The results revealed that the spatial distribution of the accumulated salt concentration across the bottom surface of the pier might have been affected by the winds.

- Research and development on techniques to deal with external disturbances affecting inspection equipment operation

As part of our study on the use of ROVs to inspect the superstructures of piers, we developed a prototype of a stationary positioning system (i.e., thrust adjustment, countersteering, etc.) utilizing the positioning function already implemented in the ROVs, which is one of the techniques used to deal with external forces. We also took our ROV designed for inspecting pier superstructures to the Ajigawa and Taisho areas of Osaka Port to conduct on-site surveys of bottom surface of pier superstructures, and successfully tested the effectiveness of the aforementioned stationary positioning function as the ROV hovered in waves in the actual port environment. In this connection, our published report, *Development of a Pier Superstructure Inspection Robot and a Diagnosis Assistance System*, which included the findings from this study, won the 4th Infrastructure Maintenance Award for Excellence (jointly sponsored by the MLIT and six other Ministries) in January 2021.



Inspection ROV surveying the bottom surface of a pier (Taisho, Osaka Port)

Research on technologies for prolonging the life of infrastructure

- Exposure test on concrete, steel, and other materials to evaluate their long-term durability

We set up a long-term exposure test facility to examine a method of predicting concrete corrosion induced by chlorine, the cathodic protection characteristics that affect steel bars in reinforced concrete, the concentrated corrosion mechanism of steel components, and the cathodic protection characteristics present near LWL. We also acquired data on the durability of various wood materials in this study.

- Development of a performance evaluation method applicable to protective coating methods used on marine structures

We have been continuously performing exposure tests (for 36 years) at the Hazaki Oceanographical Research Station (HORS) to examine various coating methods for protecting steel piles in order to establish a method for predicting deterioration applicable to protective-coated steel structures. In addition, we worked on elucidating the deterioration mechanism of petrolatum-coated structures based on the findings from our accelerated weathering and indoor exposure tests along with the aforementioned exposure tests conducted at the HORS. In addition, we conducted a survey on the superstructure of a pier that had been surface-coated 18 years ago to evaluate the durability of the protective coating (surface coating method) applied to concrete structures and to test the effectiveness of our deterioration prediction method.

- Examination of productivity improvement methods applicable to concrete structures at ports

To promote the utilization of precast concrete materials in port structure construction, we created test specimens mimicking joint sections of pier-superstructure beams consisting of precast sleeve tubes and steel-pipe piles in order to perform a peak-to-peak alternating load experiment and numerical analysis. In this examination, we found that such joint sections possessed a superior energy absorption capacity compared to the conventional type of pier superstructure joints while maintaining a similar level of load-bearing capability. In terms of the method of connection between sleeve tubes and main steel bars, the experiment indicated that the stress would mainly occur around the folded sections of those components, and that the stress that was transmitted to the sleeve tubes and RC beams was not affected by the diameter-to-thickness ratio of the steel-pipe piles. In addition, we started performing accelerated deterioration and outdoor exposure experiments on PCa test specimens created by the PC mild-press-joint method in order to evaluate the durability of component joints.

- Study on the effectiveness of the design and implementation of concrete pavement at airports

Steel nets are typically installed on the concrete pavements at airports to prevent the spread of cracks and maintain the integrity of the rebar joints underneath them, while preventing foreign objects from falling into the cracks. However, the effectiveness of this design and implementation method was yet to be proven, so we conducted a study for this purpose. For this study, we constructed a test pavement and compared its areas with and without steel-net covering to see if it would make any difference in terms of crack formation and stress generation, etc., but the comparison showed no significant difference.

Evaluation of the applicability of sustainable materials in marine environments

On this research topic, our studies encompass evaluation of various performance indices of concrete components that utilize recycled materials (i.e., applicability, durability, etc.), organization of information on the performance requirements of port structures made of concrete (mainly unreinforced) and examination of various evaluation methods for assessing their long-term durability, and evaluation of the applicability of eco-friendly materials (especially recycled materials), etc. (While prior research mainly focused on durability, we are conducting a more comprehensive examination including their environmental effects such as CO_2 emissions.)

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 were conducted on the following subthemes for efficient facility renewal, effective use of construction byproduct soil, utilization of waste disposal sites at sea, etc.

Research on techniques to improve or renew existing facilities

To elucidate the fracture process of pier structures and improve our ability to better define the performance requirements of piers, we conducted model experiments to observe how the joint sections of pier superstructures and steel piles failed, and also used the data acquired from the previous year's model experiments to observe their fracture mechanism based on numerical analysis.

We also worked on developing a method of evaluating the quality of improved ground through geophysical surveys, and examined how it could accurately perform detection based on specific resistance differences in indoor experiments, etc.

Research on effective use and techniques of treating construction byproducts

We started conducting basic research to develop coreless ground survey methods. In addition, we started our study on the evaluation of how defects in solidified and improved soils would affect the overall strength of improved ground.

Research on management and utilization of waste disposal sites at sea

Although we had previously halted our new research on this topic due to the lack of need to utilize those sites or to resolve related issues, we decided to keep gathering relevant information to explore such needs in the long term for fundamental research on the future site utilization.

Activities in FY 2020

Research on techniques to improve or renew existing facilities

- Elucidation of the fracture process of pier structures to define the performance requirements of piers in more detail

While the performance requirements of piers can be broken down into different categories such as usability, repairability, and safety, the current performance specifications only cover the locations and amounts of residual displacement and plasticized hinges, etc. and fail to provide rules on their practical usability and repairability. To address such shortcomings, it is crucial to understand the fracture process of entire pier structures in detail, including the behavior of their components following yielding and plasticization. For this purpose, we conducted model experiments to observe the fracture process of the joint sections between pier superstructures and steel piles, and also use the data obtained from the previous year's model experiments on the underground bending behavior of steel piles to reproduce their fracture behavior based on numerical analysis.

- Development of a method to evaluate the quality of improved ground through geophysical surveys

As no effective method currently exists to three-dimensionally observe the status of improved materials underground after chemical grout is injected into inhomogeneous ground to prevent liquefaction, we conducted a study to establish methods of evaluating the quality of improved ground and construction management based on geophysical surveys that would not require soil sampling. The study involved an indoor model experiment to measure the shape of improved ground in 3-D and also a real-scale measurement experiment to verify the method's applicability to coastal areas.

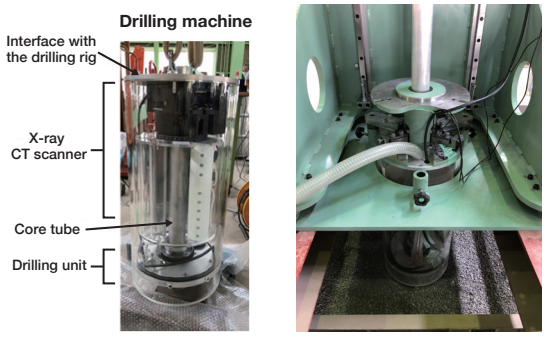
Research on effective use and techniques of treating construction byproducts

- Basic research to develop coreless ground survey methods and establish digital geotechnical engineering

To develop an in-situ digital sampling method that is capable of scanning the core of the original underground soils with an X-ray CT scanner, we operated our internally developed drilling machine, which has a built-in X-ray CT scanner, on a gravel soil model and measured its excavation force, etc.

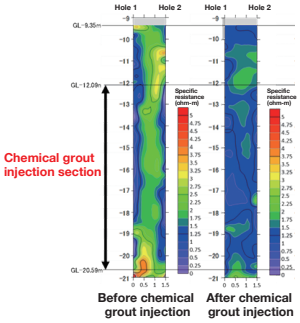
- Evaluation of how defects in solidified and improved soils would affect the overall strength of improved ground

We performed numerical analysis to examine how weak sections would affect the stress-strain relationship of unconfined compression test, with the parameters being the strength ratio of weak and sound sections, weak section size, and the locations of the weak sections within the specimens. The analysis indicated that, if the solidified specimens contained some weak sections, the strain at failure would not increase, while exhibiting the same effects as crack-type disturbances that would only result in decreased strength. The analysis implied that such specimens, which exhibiting the same effects as crack-type disturbances, would not be suitable for the quality control of ground improvement such as cement-treatment. The improved ground with weak sections should be evaluated comprehensively, considering the content rate of the section.



Drilling machine with built-in X-ray CT scanner and drilling experiment

In addition, we examined a method of creating specimens containing weak sections. We were able to confirm that our goal of creating specimens containing unimproved sections could be achieved by placing a clay slurry that had been frozen with liquid nitrogen in a mold, pouring a slurry of cement-improved soil into the mold, and curing it.



Tomography of specific resistance measurement data before and after the chemical grout injection

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. 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 are being conducted on the following subjects for the development and utilization of oceans.

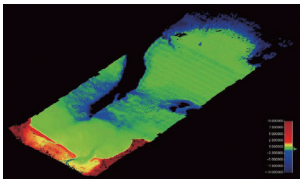
- For our development of analytical methods applicable to the topographic dynamics of carbonate remote islands, we analyzed the processes and mechanisms of topographical change and ground formation and verified the validity of our survey and analysis techniques. Based on our findings, we proposed effective methods of surveying and analyzing low-water lines, shorelines, and other topographical features near port facilities, with a view to their preservation.
- For our research on the equipment of underwater construction machines with multiple functions using machine guidance technology, we used profile sonar to conduct an experiment on its external measurement, tested the accuracy of our acoustic positioning system, and developed a remote operation support system.
- For our research on the acoustic imaging system, we explored ways to install acoustic video cameras on a work vessel, and worked on developing a software program that would enable real-time monitoring of an ongoing construction project.
- For our research on the horizontal resistance characteristics of pile foundations at offshore wind power plants, we performed horizontal cyclic loading tests on piles along with related element tests, worked on enhancing our numerical analysis code for simulating the process of pile penetration, and examined our non-linear spring model of soil that factored in horizontal cyclic loading.
- For our research on the mechanical properties and durability of various infrastructure materials in the deep sea, we designed and produced related testing equipment, and performed durability experiments in a high-pressure water tank using a low-temperature seawater circulation system. We also started conducting an exposure experiment on infrastructure materials in the deep sea, etc.

Activities in FY 2020

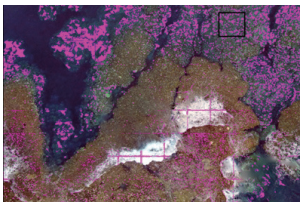
- For the development of a fender system for automatic ship berthing/unberthing, we invented a fender system that has adsorption pads fixed to the front of the fender panel on the fenders to allow automatic and efficient ship berthing/unberthing and also to enable steady mooring and cargo-handling operations. In addition, we studied the optimal adsorption pad structure that could easily cling to the side of a ship, and also examined a prior study on the conceptual structure of a vertical adjuster mechanism that would track a ship's movement along with a change in its draft, which allowed us to create the basic concept of our fender system for automatic ship berthing/unberthing.

- For our development of analytical methods applicable to the topographic dynamics of carbonate remote islands, we were able to achieve the following. We succeeded in developing a monitoring method that combined images shot by drones and stationary cameras and survey data to observe the entire low-water lines and shorelines of remote islands as well as the topographic changes occurring around port facilities. We conducted an on-site experiment on Iriomote Island in Okinawa Prefecture to prove the method's effectiveness. We also developed a method that could automatically determine the distribution and activity levels of reef-forming organisms using aerial photography, AI, etc.

Hybrid drone mounted with a green laser
The manufacturer developed this hybrid drone capable of charging the onboard battery with a gasoline-powered generator, thereby extending the flight time and enhancing the drone's surveying and aerial photography capabilities.



Topographical data acquired by the green-laser-equipped drone



Coral distribution estimated by our coral identification model utilizing machine learning and aerial drone photography

- For our installation of multiple functions in underwater construction machines utilizing machine guidance technology, we enhanced the foundation-leveler attachment that was developed in the previous year by adding a small bucket to it for carrying rocks, and tested it on land to verify its effectiveness. We also conducted an experiment with it on temporary caisson mounds on Miyako-jima Island in Okinawa Prefecture to perform leveling tasks by remote control immediately after crushed stones had been poured in, observed its operational precision and capability, and identified some key issues to be addressed before it can be used in the field. In addition, we explored its application to other types of tasks and proposed a system concept that could be used for dredging in culverts, etc. and conducted a tank test to review the performance of wall detection sensors, etc.

- For our study on the application of an acoustic imaging system to ICT-based construction projects, we improved the task-monitoring application program used in the shallow-water acoustic video cameras including the acoustic image viewing system to increase its effectiveness, especially during leveling, dredging, and replacement tasks. We then trialed it in the Shinmoji (Phase II) construction project, and successfully demonstrated its usability as a construction management system and created an operation manual for it.
- For our study on floating breakwaters equipped with a wave-power generation function, we performed numerical calculations using a motion simulation program for a floating body to examine the optimal shape of such a single-component floating breakwater with wave-power generation devices and its mooring method, and observed how the absorption of wave energy with generation devices affected the breakwater's wave-dissipating capability. We also examined the wave-dissipating capability of a multiple-component floating breakwater with wave-power generation devices by performing simplified numerical calculations viewing it as an elongated version of the aforementioned single-component floating body.
- For our research on methods of estimating the wave forces affecting offshore wind power facilities, we are currently conducting a large-scale movable bed experiment to observe scouring.
- For our study to elucidate the horizontal resistance characteristics of pile foundations for offshore wind power plants under various fluctuating loads, we conducted a cyclic loading test using triaxial testing equipment to apply very small loads, and learned that soil stiffness would be reduced by small repetitive loading. In addition, we conducted a horizontal and cyclic pile-loading experiment in a large soil tank. Furthermore, we developed an analysis method for elucidating the mechanism of the frictional contact between the soil and the rigid bodies installed in it, and applied the method to the phenomenon of pile penetration to demonstrate its validity.
- For our research on load-setting methods for offshore wind turbines in waves and winds, we observed the dynamic response of offshore wind turbines under several different wind and wave combinations is strongly affected not only by the blade pitch control following wind speeds but also by the wave action. In particular, larger bending moments appear in wave conditions where the breaking waves occur in shallow water. In addition, we collected meteorological, oceanographic, and structural specification data on offshore wind turbines, and extracted and sorted necessary data for performing load coupled analysis on actual machine equivalent offshore wind turbines.
- For our evaluation of the mechanical properties and durability of infrastructure materials in the deep sea, we were able to accomplish the following: We designed and produced a device that would be used to conduct a concrete loading experiment under water pressure. We started an experiment to observe the deterioration process of cement-based materials in low-temperature seawater. We placed test specimens on the northern edge of the Nankai Trough and in another sea area at a depth of 1,680 m and analyzed them after exposure and elucidated their deterioration mechanism. We conducted a laboratory test on hardened cement specimens to observe their water pressure resistance characteristics, and also started an in-situ monitoring experiment using same-sized specimens on the northern edge of the Nankai Trough at a depth of 3,500 m.

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 especially 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. Meanwhile, there are new challenges looming, including the need to utilize the coastal zone functions to alleviate climate change and to address the issue of large-scale oil spills from coastal industrial complexes, etc.

Therefore, we are focusing on activities to help restore the coastal environment, alleviate climate change, and develop technologies to better deal with large-scale oil spills. We are also working on elucidating the function of coastal ecosystems in absorbing greenhouse gases (blue carbon) and proposing how their function could be utilized. In addition, we are developing a new system that will be able to predict in real time the status of the aquatic environment in Tokyo Bay, Ise Bay, etc. including the occurrences of red tides and blue tides. Furthermore, we will be developing a next-generation oil recovery system for use by the oil recovery fleet owned by the Ministry of Land, Infrastructure, Transport and Tourism, along with a new technology to deal with oil spills from coastal industrial complexes, etc. that are caused by earthquakes and tsunami.

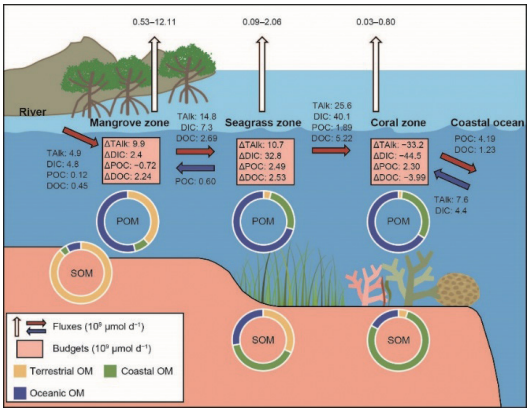
Research Topics

For research and development on the preservation and utilization of coastal ecosystems, we are focusing on the following subthemes.

- For our research on examining the previously developed global dynamics model for predicting the speed of carbon dioxide absorption and inundation suppression effects in shallow sea areas, we are continuously gathering data and knowledge on various factors and processes pertaining to the ecosystems, while integrating and improving its sub-models (i.e., wave model, topography and sediment model, ecosystem model, etc.).
- For our initiative to create coastal topography and geo-designs that would both assist disaster mitigation and ecological environment preservation, we are evaluating and analyzing the characteristics of the types of topographical and soil environment that can maintain resilience during disasters and allow diverse species of organisms to inhabit, while evaluating their disaster mitigating and energy reduction effects against earthquakes, tsunami, and high waves.
- For our research on techniques to improve the functions of seagrass meadow ecosystems, we are developing a model to explain the maintenance and restoration mechanism of seagrass meadows, while also examining methods of facilitating seagrass meadow restoration and assessing their value as a food for fauna inhabiting those meadows in order to evaluate their function as feeding grounds.
- For our research and development on techniques for mitigating oil pollution, we are improving our real-time oil movement prediction system, and continuously examining techniques for mitigating oil pollution, including self-extracting bubble curtains for controlling floating oil, application of such bubble curtains to environment management vessels, and extraction of oil from sunk vessels, etc.

Activities in FY 2020

- For the research on examining the global dynamics model for predicting the speed of carbon dioxide absorption and inundation suppression effects in shallow sea areas, we conducted on-site measurements in large seagrass meadows to observe their CO_2 absorption through dissolved refractory organic carbon discharge. We also conducted in-situ surveys of subtropical blue-carbon ecosystems and quantified the carbon flows among different complex ecosystems inhabited by mangroves, seagrasses, and corals. The findings from these studies have enabled us to examine CO_2 absorption amounts using the aforementioned global model. In addition, we ran simulations to predict future changes in shallow-water ecosystem areas by the RCP scenario and published our findings in a scholarly paper. Furthermore, we conducted in-depth topographical observations of coral reefs to use the data as a basis for our wave-height reduction calculation using a green-laser-equipped drone.



Quantified carbon flow among different complex ecosystems consisting of mangroves, seagrasses, and corals (Iriomote Island)

- For our project to create coastal topography and geo-designs that would both assist disaster mitigation and ecological environment preservation, we further developed our integrated assessment and prediction method applicable to coastal benthic ecosystems and geo-environmental dynamics for a broad area of tidal flats and beaches, and used the developed integrated assessment and prediction model to examine how the major changes in coastal topography and geo-environment caused by meteorological disturbances affected the changes to benthic ecosystems and the distributions, and proved the model's efficacy based on the results of in-situ observations performed in Japan and overseas.
- For the cross-sectional observation and analysis of atmospheric and oceanographic issues at bay mouths, we developed a method to continuously and steadily conduct atmospheric observations over extended periods including particulate matter, and performed statistical analysis of wind conditions at bay mouths. In addition, we maintained steady oceanographic observation operations including pH and other marine conditions.
- For the numerical examination of how aquatic ecosystems are responding to climate change, we applied the numerical simulation model that we had previously developed to evaluate the effect that topographical changes have had on the amounts of seawater exchanged at bay mouths, and found that the degree of impact of topographical changes on seawater exchanges fluctuates depending on the location and the time of year.
- For the development of methods to improve the functions of seagrass meadow ecosystems, we evaluated their value as a food for fauna inhabiting those meadows in order to evaluate their function as feeding grounds, and developed a simplified model that can explain the maintenance and restoration mechanism of seagrass meadows.
- For data assimilation study to an actual coastal estuary using real one-year observation data, we conducted the first study to apply the ensemble Kalman filter. It was possible to maintain the ensemble spread by perturbing atmospheric forcing, lateral boundary conditions, and river discharge forcing. This method achieves robust annual data assimilation and reflects seasonal fluctuations.
- For the research and development on new techniques that can be used to prevent and remove various types of oil spills caused by natural disasters and other events, we performed an experiment in a large model water tank to test the performance of our next-generation oil recovery system that is being developed, and quantitatively showed that its capability is equivalent or superior to that of the current system in terms of oil recovery efficiency. In addition, we filed a patent application related to this new system. As for the development of our web-application-type simulator for predicting the movement of oil spills at sea, we were able to develop a scalable calculation engine for accelerating the simulation, and also improved its front-end function by adding a new function that enables simulation data to be shared among multiple users. As for our research on the technique to improve the fluidity of high-viscosity oils that remain in sunk vessels so that they can be extracted more easily, we examined a model that was designed to explain the result of a previously conducted beaker experiment, and performed tests to verify the efficacy of the model when it is applied to the hydraulic transmission line system of a vessel, etc. Based on these research findings, we filed a patent application on the concept of our heavy oil recovery method and system.

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, while in other countries their ports are expected to experience far greater amounts of sedimentation and siltation than in Japan, which indicates that the currently available techniques are inadequate for addressing this global issue of sedimentation and siltation which are damaging navigation channels and harbor basins. Meanwhile, many precious natural beaches were lost during the period of rapid economic growth, and this negative trend is yet to be reversed. Although the many benefits that beaches yield for protection, environmental conservation, and human use are clearly recognized, and they are being restored on certain coastlines by taking measures to suppress coastal erosion, global warming is also expected to exacerbate coastal erosion in the future. Also, when remote islands and overseas are taken into account, it is important to maintain not only beaches but also coral-reef coasts.

PARI is currently focusing on identifying means for effectively preserving both natural coastal topography, such as beaches, mangrove shorelines, and coral-reef coasts, and artificial coastal features, including navigation channels and harbor basins that are crucial for logistics, despite the ongoing trend of climate change. Furthermore, PARI is working to predict key changes in coastal erosion as well as sedimentation and siltation affecting navigation channels and harbor basins, and to suggest measures to effectively address these issues while assuming that the trend of global warming might persist. In addition, 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

For research and development on the formation and preservation of coastal topography, we are focusing on the following.

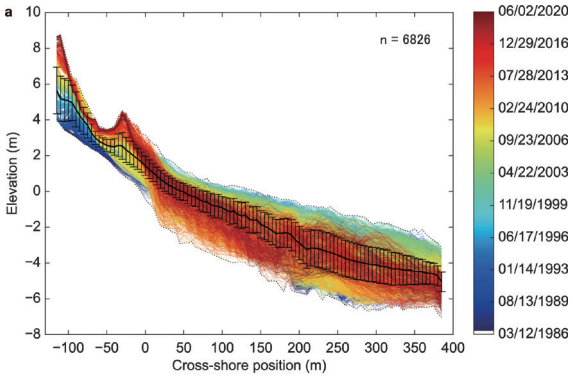
- For the development of a model to predict global coastal morphological changes induced by climate change, we are working on generalizing the parameters of our previously developed model to make the model applicable to other beaches and to predict the future coastal changes. We are also developing a deep-learning model for predicting beach profile changes and verifying its applicability.

- For the breakthrough of coastal topographical changes mechanism and the development of our prediction model, we are continuing with our on-site observations at the Hazaki Oceanographical Research Station while working out how to apply our prediction model to the field of navigation channels, harbor basins, and coastal beaches.

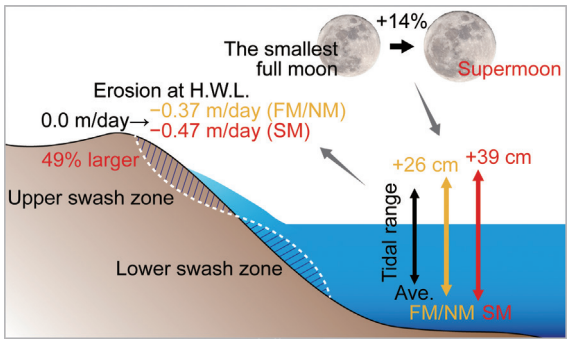
- For the development of a sediment transport control method to minimizee harbor siltation, we are improving our previously developed sand-mud-mixture bottom sediment model while analyzing related in-situ data so that the model can be properly applied to actual coastal zones.

Activities in FY 2020

- We statistically analyzed beach morphological changes previously obtained on Hasaki beach to evaluate the climate change impacts. We will use the statistical information as a basis for generalizing our prediction model with comparing model parameters and beach physical indices. In particular, we focused on tidal fluctuation (especially those caused by a supermoon), which is one of the water-level changes. It was elucidated that the effects of the tidal fluctuations on the responses of beach morphological changes in the swash zones. The beach processes were previously unknown and these findings were also published in an international academic journal and some domestic news. While the work on generalizing model parameters is still in progress, we are simultaneously developing a model representing beach profile changes utilizing deep learning. Thus, we are steadily building the methods to perform future beach prediction from wide-ranging perspectives.



Beach profile changes observed over the past 34 years



Supermoon's effects on beach morphological changes

- As for the clarification of coastal topographic change mechanism and the development of a coastal topographic change prediction model, we continuously conducted on-site observation of wind, waves, currents and topographic changes at the Hazaki Oceanographical Research Station. In addition, we improved our prediction model for topographic changes near pile structures that might occur in the surf zone where the wave and current would change in a complex manner due to breaking waves.

- For our study to elucidate the mechanism of sediment transport around estuaries and sedimentation in navigation channels and harbor basins, we improved our previously developed sand-mud-mixture bottom sediment model and analyzed related in-situ data so that the model can be applied to actual coastal zones (e.g., in Patimban, Indonesia). In addition, we analyzed existing in-situ data in a domestic estuarine port, e.g. Niigata Port (West Port district), to develop a numerical model that can properly simulate the sedimentation mechanism that occurs in the field.

Fundamental Research in FY 2020

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 estimation method for near-fault strong ground motions
4	Development of a new method for predicting liquefaction-induced ground subsidence and flow
5	Evaluation of the deformation and fracture characteristics of coastal soil structures in relation to waves and flows, and development of reinforcement technology
6	Development of the estimation method for local scour around coastal structures due to tsunami
7	Elucidation of oceanographic phenomena based on central processing and analysis of observation data
8	Identification of issues and improvement of wave estimation methods applicable to Japan's coastal areas
9	Evaluation of longterm durability of concrete, steel and various materials based on exposure test
10	Development of the performance evaluation method in protective coating for marine structures
11	Evaluation of applicability of sustainable materials in the marine environment
12	Study on application of inspection and diagnosis systems for improvement of performance evaluation of marine structures
13	Study on process leading to rupture of pier structure for high definition of performance regulation
14	Basic research to develop coreless ground survey methods and establish digital geotechnical engineering
15	Development of analytical methods for the topographic dynamics of carbonate islands
16	Elucidation of the horizontal resistance characteristics of pile foundations for offshore wind power plants under various fluctuating loads
17	Evaluation of the mechanical properties and durability of infrastructure materials in the deep sea
18	Validation of the newly developed global dynamic model for the projection of atmospheric CO_2 uptake rate and inundation control in shallow coastal ecosystems
19	Cross-sectional observation and analysis of atmospheric and oceanographic issues at bay mouths
20	Numerical study on responses of aquatic ecosystem to an environmental change
21	Development of the methods for increasing ecosystem functions in eelgrass meadow
22	Observation of coastal phenomena at HORS and development of numerical simulation of topography change for port and surrounding beaches
23	Developing future projection model of coastal change in the context of climate change
24	Development of sediment transport control method to minimize harbor siltation

Cases of Fundamental Research

Development of a new method for predicting liquefaction-induced ground subsidence and flow

In the cases of the 2018 Hokkaido Eastern Iburi earthquake and the Sulawesi Indonesia earthquake, the disasters apparently involved ground subsidence and flow caused by major liquefaction events in the regions' fine-particle soils that had high silt and clay content. Lead researchers of these disasters have been delivering pioneering results on a global scale in recent years, in the form of practical liquefaction prediction and flow prediction methods that take into account the irregular characteristics of seismic load effects and their durations. Meanwhile, a subsidence and flow prediction method that can be applied to liquefaction of various soils that have highly diverse degrees of granularity and plasticity is yet to be established. Therefore, it is necessary to explore novel prediction techniques to better understand and deal with the subsidence and flow mechanism of liquefied soils with wide-ranging levels of granularity and plasticity.

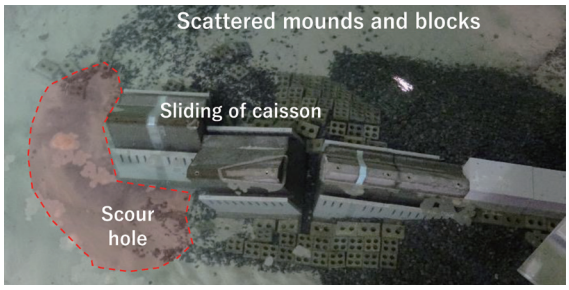
For our FY2020 iteration of this study, the goal of which is to elucidate how subsidence and flow occur in liquefied soils with various levels of granularity and plasticity, we evaluated and analyzed the liquefaction and subsidence characteristics of soils with widely disparate levels of granularity and plasticity under various types of seismic loads such as continuous duration, irregularity, and continuous effects of seismic motions.

Sedimentation of silt and clay content caused by liquefaction-induced sand boiling
(Top) Sulawesi earthquake (bottom) 2018 Hokkaido Eastern Iburi earthquake

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

Concerning methods of designing breakwaters that are tsunami-resistant, several notable design formulas, including the Tanimoto' tsunami pressure formula and the hydrostatic pressure formula during tsunami overflowing were published in the *Guidelines on the Tsunami-Resistant Design of Breakwaters* in FY2013. However, there are many instances of disasters resulting from scouring caused by tsunami overflowing, as happened at the north breakwater in Hachinohe Port which was devastated by the Great East Japan Earthquake disaster. As little research has been conducted so far on the phenomenon of scouring caused by tsunami overflowing, it is crucial to facilitate studies to accurately estimate the amounts of scouring during tsunami attacks. For this purpose, our study entails hydraulic model experiments to observe scouring caused by tsunami overflowing a breakwater (cross-sectional 2D) as well as scouring that occurs around the head of a breakwater (planar 2D). The design of this experiment involves varying the diameters of the sand particles, etc. and observing the armoring effects that are produced by gravel mounds; we are working to develop a scour estimation method that has high general applicability. In addition, we are exploring other techniques for estimating scouring based on particle methods.

For our FY2020 activities, we studied the armoring effects of gravel mounds and reviewed the performance of scour-prevention mats to minimize scouring caused by tsunami overflowing. We also continued with our study that was started in FY2019 to examine the tsunami-resistance measures that are being implemented on the heads of the breakwaters at the mouth of Urad Bay for their ability to mitigate local scouring.



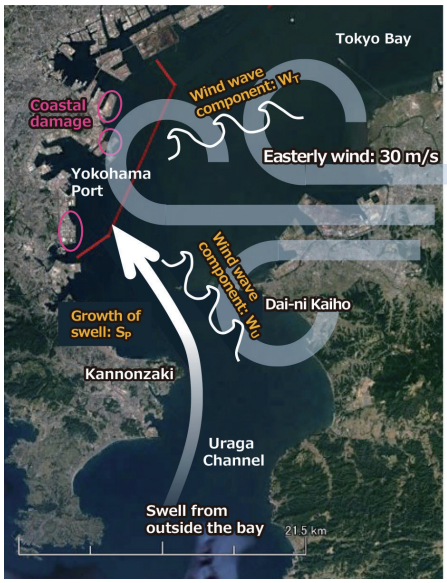
Movable bed experiment at breakwater head

Scour suppression by installation of bag-style armor blocks

Identification of issues and improvement of wave estimation methods applicable to Japan's coastal areas

This study is intended to improve our existing wave model in terms of its ability to simulate or predict the temporal and spatial variation characteristics of sea breeze, the process of fetch-limited wave development, the sheltering effect of coastlines, and their interaction with seabed topography, which are all specific to coastal areas, and to use it to perform high-resolution wave simulations for the medium to long term concerning Japan's coastal areas.

For our FY2020 activities, we analyzed the wave fields that occurred in Tokyo Bay during Typhoon Faxai in 2019, formulated a plausible hypothesis for a mechanical process that explained the wave conditions that arose in the open sea near Yokohama Port (i.e., formation of bidirectional wind waves and arrival of swells), especially as to why Yokohama Port suffered most of the damage caused by the typhoon, and confirmed that the reproduction precision of the wave model would vary depending on the sea wind load products. In addition, we monitored swell activities entering Tokyo Bay to understand their propagation process, and conducted long-term hindcasting on the Sea of Japan.



Conceptual image of oceanographic phenomena around Yokohama Port caused by Typhoon Faxai in 2019

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

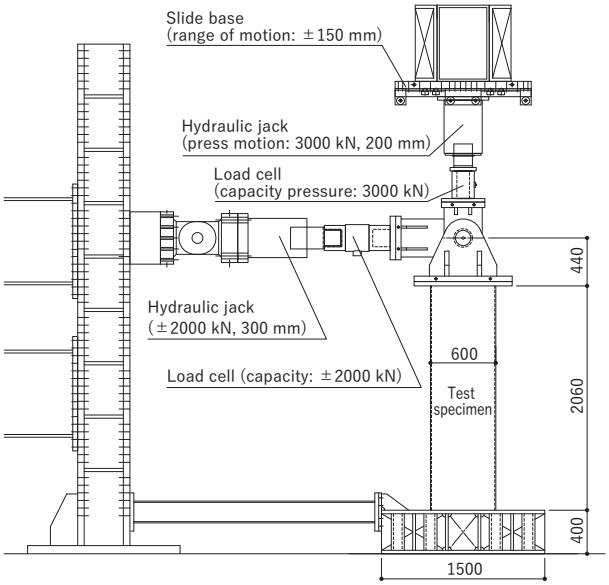
Generally, two types of corrosion-prevention treatment are applied to steel marine structures simultaneously, namely cathodic protection and protective coating, to ensure their long-term durability. Regarding protective coating techniques, their deterioration characteristics (usable lifespan, etc.) are being elucidated through exposure tests, etc. However, while it is essential to review the anticipated performance of each protective coating technique in the design phase, there is no established method to evaluate its current corrosion-prevention capability or predict its future state for the maintenance and management phase. To address this, we have been continuously conducting exposure tests at the pier of our Hazaki Oceanographical Research Station and other locations to track the temporal changes in the condition of the corrosion-preventing techniques applied to their steel piles to evaluate the durability of the protective coating materials in the marine environment. In addition, we reviewed the results of surveys conducted on various port structures, etc. that had been jointly used for extended periods (over 20 years), analyzed some of the samples taken, and evaluated the durability-enhancing ability of each of the corrosion-prevention techniques that were applied. Furthermore, we organized the results of exposure tests conducted on petrolatum coating techniques to elucidate the related deterioration mechanism and establish a method of evaluating the performance of petrolatum-based coating materials. In addition, we studied the results of previous surveys conducted on actual structures (i.e., pier superstructures at Yokohama Port) and used the data to evaluate the performance of the concrete surface coating materials that were applied to those structures.

Exposure test on petrolatum coating method

Study on process leading to rupture of pier structure for high definition of performance regulation

As it is difficult to define detailed performance requirements for any given port facility in a necessary and sufficient manner in relation to the actual performance requirements for use, the current practice of facility design in the field is not yet sufficient to allow the structural components of each pier being built to perform to their maximum potential. To accurately assess the actual usability and repairability of a pier, it is necessary to observe it after its components have failed so that the rupturing process that affected the entire pier structure can be understood in detail, including its behavior following plasticization. To address all these points, we are closely observing the rupturing process of entire pier structures in detail, accurately evaluating the resistance behavior of the pier piles and joint sections following plasticization, and exploring methods of controlling the rupturing process affecting the entire pier structures.

For our FY2020 activities, we numerically analyzed the result of the model experiments conducted in the previous year and attempted to elucidate the rupturing behavior. In addition, we conducted new model experiments to observe the process through which the joint sections of pier superstructures and steel piles would become damaged.



Conceptual illustration of our model experiment for observing the behavior of pile heads following plasticization

Numerical study on responses of aquatic ecosystem to an environmental change

Understanding how aquatic ecosystems respond to changes in their environment is useful for clarifying their current phenomena as well as for formulating future environmental measures. To achieve this objective, it is essential to gather in-situ observation data, but the knowledge that can be obtained from numerical simulations is also useful for a quantitative approach.

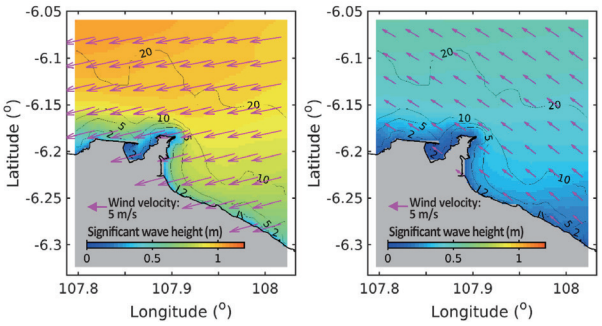
Accordingly, we conducted a study using our previously developed numerical model by applying it to a bay adjacent to a city to quantitatively simulate the environmental changes that had occurred there and how the ecosystem had responded to those changes. For our FY2020 activities, we managed to examine models that reflected cutting-edge science including the non-hydrostatic model, detritus cycles, fish models, etc., and prepared necessary models and arranged basic data to be input to the models, etc.

Development of sediment transport control method to minimize harbor siltation

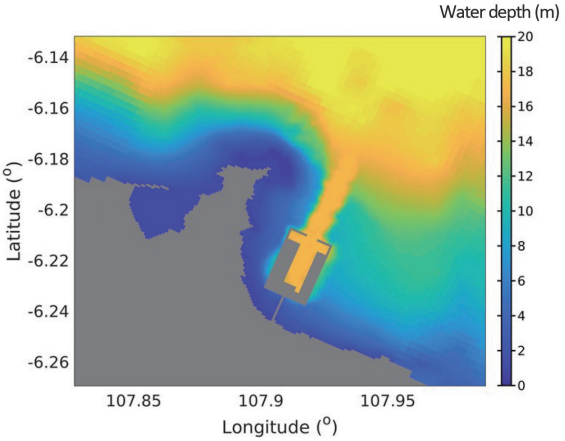
In a number of ports in Japan and overseas, countermeasures against sedimentation of navigation channels and harbor basins due to sediment discharge from rivers and sediment movement by forcing factors (e.g., tides and waves) are required. As dredging of such navigation channels to keep their necessary depths involve issues of maintenance dredging costs as well as the need to secure sites for disposing of dredged sediments, it is necessary to develop methods for reducing the volume of dredged sediments and maintaining management of such port operations in an efficient manner. While it is important to properly predict the amounts of sedimentation in the channels and basins for planning the future efficient maintenance strategy and designing appropriate sediment control countermeasures, the complex mechanism of sediment transport processes in-situ still provide us with various issues that must be resolved for the application of numerical simulations.

Our present study involves using in-situ bathymetric data to improve the accuracy of our numerical model for prediction of siltation of navigation channels and harbor basins, and the development of a numerical prediction system suitable for simulation of siltation in arbitrary shapes of ports and harbors anywhere in South East Asia and other countries.

As for our FY2020 activities, we analyzed in-situ data and improved our previously developed sand-mud-mixture sediment model so that it can be applied to coastal areas (e.g., Patimban, Indonesia). We also discussed the sediment dynamics including the fluid mud transport in Niigata Port (West Port district) through analysis of the in-situ data on the sedimentary processes.



Simulation reproducing wave fields off the Patimban coast



Topographical data representation of the sea zone by Patimban Port after its construction

Exploratory Research in FY 2020

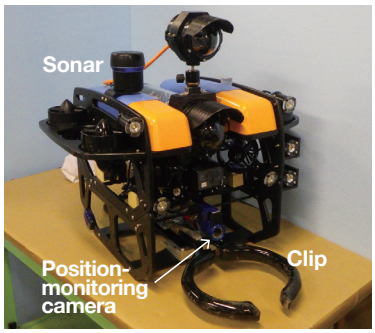
In FY 2020, exploratory research projects based on ingenious and/or advanced ideas that could potentially lead to new research fields for PARI in the future were carried out.

Examination of methods for measuring marine structures with underwater drones

In this study, we conducted examinations and experiments on the use of underwater drones mainly to measure the remaining amounts of electrolytic protection on marine structures and the improvement of underwater drone operability in murky waters, etc. with a view to enhancing the drones' usability in actual on-site operations. For these objectives, we mainly gathered information on techniques for measuring the remaining amounts of electrolytic protection that could be used with underwater drones, and reviewed specific measurement methods that drones can perform. We also researched information on simplified sonar devices that could be mounted on underwater drones and examined how effective they would be in improving the drones' operability. Furthermore, we took our underwater drone mounted with a simplified sonar to our laboratory water tank and sea areas outside to observe its operability and verify its on-site measurement capability, and thus were able to determine the effectiveness of using underwater drones for measuring marine structures, and also identified key issues that need to be resolved.

In this demonstration test, we successfully used the underwater drone to visually inspect anodes and measure anode currents, and verified our theory that underwater drones could be used instead of the conventional method using human divers. Furthermore, we were able to verify the possibility that ROVs and other robots could be used to survey marine structures entirely unmanned in the future.

However, submarine surveys near the seabed which are murky or where the device's thruster could cause sediment turbulence might be unable to visually inspect anodes easily. Hence, we considered that the efficiency of any given survey largely depends on the skills of the underwater drone operator; this issue requires further study.



Underwater drone used in the study

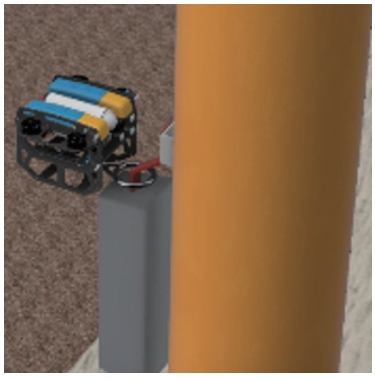
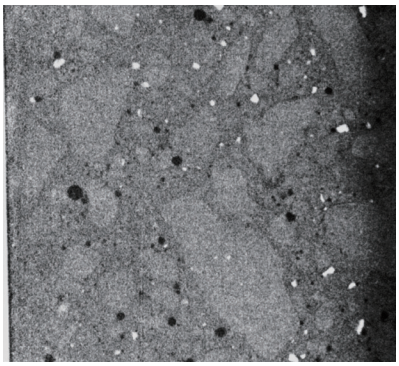
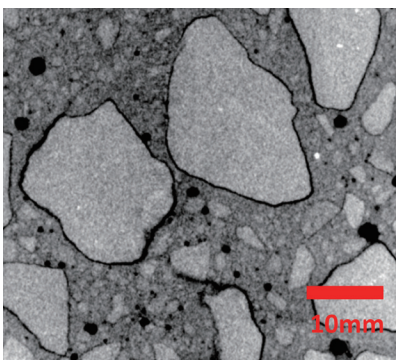


Image of underwater drone measuring anode current

Examination of the seawater-induced deterioration mechanism in concrete materials that are cured under high-temperature conditions in an early stage

Delayed ettringite formation (DEF), which causes cement paste to expand undesirably, is a deterioration phenomenon that is not yet well understood. If the rate of use of incinerator ash for cement and precast cement increases, DEF-induced deterioration of marine structures is expected to increase also in Japan. However, there is very little scientific understanding of the DEF-induced expansion behavior of cement, etc. in the marine environment where DEF is facilitated. Therefore, our ultimate goal is to monitor and comprehend such behavior in an environment with high exposure to seawater, so that DEF can be controlled from the material design phase. The objective of this study is to observe the DEF-induced expansion behavior facilitated by seawater and understand the mechanism. To this end, we prepared mortar test specimens and cement paste powder and submerged them in tap water (or distilled water) and seawater, which revealed that the expansion rate of the mortar specimens immersed in the seawater tended to be lower than those placed in the tap water. However, this tendency was not universal among all specimens tested, which might be explained by the effects of different W/C mixture rates and other ions contained in the seawater besides Na+ and Cl-. We also measured the expansion rate of the cement paste powder specimens and found that those placed in the seawater tended to expand less than those in the tap water. Therefore, the potential expansion induced by DEF may be lower if the object is immersed in seawater than in fresh water.

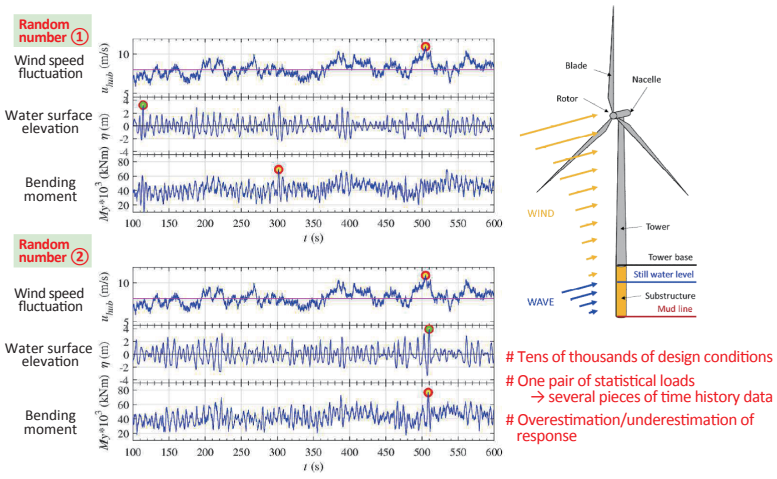

Intact concrete



Concrete affected by DEF-induced expansion

Consideration of uncertainty in external force characteristics for response evaluation of offshore wind turbine

In the design of offshore wind turbines, at first, we typically estimate each time series data of wind speed and water surface elevation by applying random number seeds to energy spectra, and then we perform time history response analysis by using them. In addition, we need to perform analysis on tens of thousands of cases or more to various external loads. However, only a few time series response analysis is performed for each pair of wind and wave loads due to the large number of cases of analysis, and statistical stability of data is not ensured. As such method does not properly factor in the uncertain characteristics of the external loads at the time history level, the response values could be underestimated or overestimated depending on how random seeds are applied. In this study, we attempted to develop a new method that could simply evaluate the response characteristics of offshore wind turbines while considering the uncertain properties of the loads involved. As a result, it is found that the application of combination of a point estimation method and a probability density function approximation method, defined as a simplified response evaluation method here, to characteristic value of wave loads enables us to evaluate the dynamic response taking into account the uncertainty of external loads without an immense amount of time history response analyses. It also was implied that our method could be used not only to reduce the load conditions for design but also to evaluate the response based on the probabilistic approach which is not used in current design.

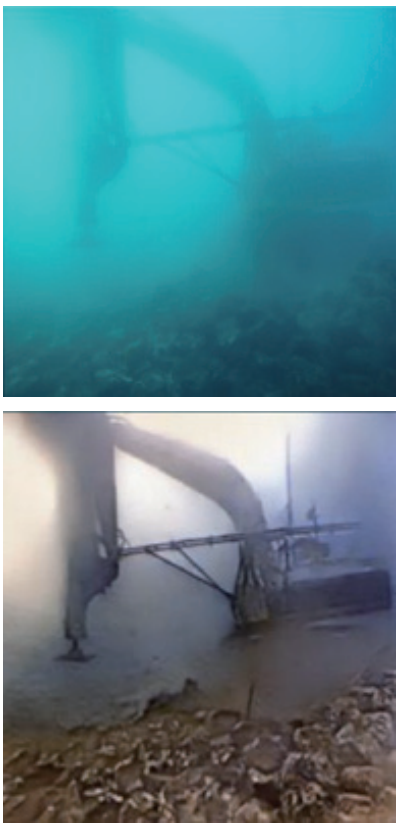


Relation between time history load and response data

AI-based improvement of underwater operation images

Low water transparency and high murkiness hinder the optical recognition of external objects. If optical submarine images are of poor quality due to such factors, the conventional approach to improving them is to use expensive optical devices, a dedicated system and hardware, but these are costly and not optimal for general application. In addition, while acoustic measurement using sonar, etc. is common with such optical image acquisition and processing, it typically yields large estimation errors, and must be executed by an experienced and skilled operator, among other issues.

In this study, we chose to apply AI (deep learning), which is enabling major progress in various scientific fields, to improve the quality of optical images acquired in water. After using a highly intricate submarine image model to create data sets, we observed them and determined that the quantitative indices of deterioration such as PSNR and SSIM were more widely distributed with this approach compared to the existing method. We were subsequently able to create artificial data representing more widely diverse deterioration characteristics using the approach. In addition, we succeeded in performing high-precision calculations by reformulation through Monte Carlo integration. We then applied the artificial data to develop and optimize an AI program and achieved superior results both quantitatively and qualitatively compared to the conventional method, whereby submarine images of significantly deteriorated quality could be restored, with their overall blue tone mostly removed. We also conducted a tank experiment that involved adding various amounts of milk to create shades of murkiness and taking color-chart images so that image restoration could be evaluated. Such tests proved that our developed AI was also effective for restoring actual image data and could be applied to a variety of tasks involving submarine image acquisition. These findings suggest that our AI-based technique could be used to survey the surrounding environment in any underwater task, inspect port facilities, monitor coral reefs, measure submarine robot positions, explore natural resources under the sea, etc. Overall, this method is expected to improve the efficiency of many tasks that must be performed underwater while helping reduce the workload of divers, etc. performing such tasks.



Images before (top) and after (bottom) application of the proposed method

Published Research Papers

Number of Peer-reviewed papers in FY 2020

Number of papers in Japanese	Number of papers in non-Japanese languages	Total	Rate of papers in non-Japanese language
66	71	137	51.8%

* The above numbers contain proceedings that only reviewed the abstract.

Papers Published in PARI Reports in FY 2020

No.	Title	Author(s)	Language	Month/Year
59-1-1	Field observation and statistical analyses of the fugacity of carbon dioxide in shallow coastal waters	Kazufumi TADA, Tatsuki TOKORO, Kenta WATANABE, Hirotada MOKI, Tomohiro KUWAE	Japanese	June 2020
59-1-2	Fundamental study on harbor waves sheltered by impermeable submerged breakwater	Katsuya HIRAYAMA, Yuuki HAMANO, Junya NAGANUMA	Japanese	June 2020
59-2-1	Investigation of applicability of coral based aggregate on marine concrete structures	Takahiro NISHIDA, Toru YAMAJI, Kazuhide YONAMINE, Osamu TANIGUCHI (Penta-Ocean Construction), Ryoichi TANAKA (Toa Corporation), Hiroshi TAKENAKA (Toyo Construction), Osamu KIYOMIYA (Waseda University)	Japanese	September 2020
59-2-2	Centrifuge model tests for investigation of instability of seawall ground due to ocean waves	Hidenori TAKAHASHI	Japanese	September 2020
59-2-3	Interface shear properties between steel-slag-mixed dredged soils and different materials	Satoshi MATSUMURA, Takaaki MIZUTANI, Yoshiyuki MORIKAWA, Yuzo AKASHI (Nippon Steel), Hideki HONDA (JFE Steel), Masahiro SHIMIZU (Nippon Steel Nisshin Co.)	Japanese	September 2020
59-2-4	Advanced method for identification of windsea and swell on the multi-modal directional wave spectrum	Takashi FUJIKI, Koji KAWAGUCHI	Japanese	September 2020
59-3-1	Processes of internal erosion, cavity formation and collapse under various soil and hydraulic conditions with their countermeasures using geotechnical filter	Kenta KUDAI, Shinji SASSA, Soonbo YANG, Kouhei TAKADA, Kojiro SUZUKI	Japanese	December 2020
59-3-2	Development and application of integrated platform for predicting and evaluating coastal benthic ecology-geoenvironmental dynamics	Soonbo YANG, Shinji SASSA, Kenta KUDAI, Kouhei TAKADA	Japanese	December 2020

Papers Published in PARI Technical Notes in FY 2020

No.	Title	Author(s)	Language	Month/Year
No.1372	Evaluation of mooring methods for a ship in remote island ports based on allowable wave heights	Haruo YONEYAMA	Japanese	June 2020
No.1373	Environmental DNA metabarcoding and diversity analysis for the fish community in coastal areas	Shinya HOSOKAWA, Kyosuke MOMOTA, Shota OKURA, Takashi KOMURO	Japanese	June 2020
No.1374	Load tests of piles that support jacket structures at Tokyo International Cruise Terminal	Takaaki MIZUTANI	Japanese	September 2020
No.1375	Suggestion of design method for upgrading sheet pile quay wall	Shunta NAKAMURA, Takaaki MIZUTANI, Satoshi MATSUMURA, Shintaro KAGIMOTO	Japanese	September 2020
No.1376	Sand-mud mixture transport model for prediction of morphological change in estuaries	Taichi KOSAKO, Yasuyuki NAKAGAWA	Japanese	September 2020
No.1378	Analytical study on the effect of strengthening of caisson components by solidification of filling materials in caisson	Yuichiro KAWABATA, Yutaka TANAKA, Ema KATO, Yosuke OHYA, Yoshiyuki MORIKAWA	Japanese	December 2020
No.1379	Meteorological, storm surge and wave characteristics of Typhoon Faxai, 2019 and major inundation in Yokohama Port	Hiroyasu KAWAI, Kojiro SUZUKI, Katsuya HIRAYAMA, Koji KAWAGUCHI, Kota YAMAMOTO, Kazuhiko HONDA, Daiki SATOMURA, Naoki TSURUTA, Takashi FUJIKI, Yu CHIDA, Takumu IWAMOTO, Shota ASAHI, Shingo KAWAGUCHI, Hiroki KUBOTA	Japanese	December 2020
No.1380	A feasibility study of an underwater drone for safe and effective investigation of port structures	Shuji NOGAMI, Ema KATO	Japanese	December 2020
No.1381	Annual Report on Nationwide Ocean Wave Information Network for Ports and Harbours (NOWPHAS 2019)	Koji KAWAGUCHI, Kanichirou YOSHIDA, Takashi FUJIKI, Hitoshi TAMURA	Japanese	March 2021
No.1382	In situ accuracy verification and calibration of wind speed and direction meter on a ship: Study using a ferry on a regular service route at the mouth of Tokyo Bay	Shinya HOSOKAWA, Shota OKURA	Japanese	March 2021
No.1383	Surrounding scouring of surf zone structure and changing uniformity of coast in longshore direction	Satoshi NAKAMURA	Japanese	March 2021
No.1384	Evaluation of performance and applicability of hydro-plane type tsunami breakwater Appendix: Technical and design manual (draft)	Takahiro SUGANO, Tomotsuka TAKAYAMA, Tetsuya HIRAISHI, Ryoukei AZUMA, Nozomi YONEYAMA, Hitoshi GOTO, Hiroyuki IKARI, Akira TATSUMI, Yosuke NAGASAKA, Yu CHIDA, Katsuhide NISHIZONO, Takamitsu FUKAZAWA, Koji TONOMO, Akito SONE, Toshiyuki HIRAI, Kozo KAMIDE, Tadao ITO, Hideaki HANDA, Haruhiko MATSUOKA, Takeshi KONISHI, Ryosuke TANAKA, Mitsunobu YOSHIDA, Takanobu YAMAMOTO	Japanese	March 2021

Annual Report, Technical Journals, and HP

The PARI Technical Journal

"The Annual Report 2020" (Japanese version) and "The PARI Annual Report 2020" (English version), which concisely summarized our activities in FY 2019, were prepared as a record of our achievements and distributed to the related institutions and posted on PARI HP.

Regarding "The PARI Technical Journal", we selected special articles of each research theme for every issue to introduce utilization situations of research results and PARI's experiment and on-site observation facilities. Approximately 2,200 copies of "The PARI Technical Journal" are distributing to approximately 1,600 places.

On HP, we provided various information on events and news including our institute summarized information, results, facilities, symposiums on a real time basis; we got approximately 120,000 accesses in FY 2020.

Implementation of lectures for the General Public

Port and Airport Technology Lecture

In cooperation with the National Institute for Land and Infrastructure Management (NILIM), a lecture on port and airport technology was held remotely on January 20, 2021, with an audience of 157 lines, for the purpose of publicizing and disseminating the results of surveys, research and technological development conducted by the institute.

Special lecture by Dr. Yabuki from Osaka University

Port and Airport Technology Special Lecture in Region

In cooperation with the National Institute for Land and Infrastructure Management (NILIM) and Regional Development Bureaus and other institutes, the seminars were held in small number of venues or remotely in five regions across Japan, with a total of about 400 participants, for the purpose of the seminars was to provide a wide range of information on the research activities and results of the institute and to gather information on research needs in each region.

Open to the Public

Open to the Public

The FY 2020 event has been cancelled due to prevent spreading of the COVID-19, and difficulty of ensuring a safe environment for participants. Due to lose opportunity to learn about the institute by the cancellation of opening to the public access to the facility, we have established a new Virtual Public Access page on our HP.

Other Outreach Activities

Cooperation with Super Science High school (SSH) Projects

For students of Yokosuka High School in Kanagawa Prefecture, which is designated as an SSH school by the Ministry of Education, Culture, Sports, Science and Technology, we provided guidance on the preparation of research projects and conducted tours of the institute's facilities, in order to encourage students' interest in the institute.


Students listening to a researcher's lecture

Book publication

To commemorate the 10th anniversary of the Great East Japan Earthquake on March 11, 2021, a book titled, "*Kizuna* (Bonds); to protect Lives from Tsunami" was published by the International Promotion Committee for Tsunami/Coastal Disaster Resilience Technology, for which PARI serves as secretariat.

"*Kizuna* (Bonds); to protect Lives from Tsunami"

Awards for Papers and Others in FY 2020

	Name	Award	Institution	Date	Remarks
1	Daiki TAKANO Senior Researcher, Soil Mechanics and Geo-Environment Group Geotechnical Engineering Department	Soils and Foundations 2019 Editorial Board Member Award	Japanese Geotechnical Society	July 29, 2020	
2	Toru YAMAJI Director, Structural Engineering Department (Head, Materials Group)	ConMat'20 Best Paper Award	Scientific Committee of ConMat'20	August 10, 2020	Evaluation of durability of concrete used for wave dissipating block based on field survey
3	Shinji SASSA Head, Soil Dynamics Group Geotechnical Engineering Department	Infrastructure Technology Development Award	Japan Institute of Country-ology and Engineering Coastal Development Institute of Technology	September 16, 2020	Method of reducing wave forces that pass through caisson joints to prevent collapse and suction (net buffer construction method)
4	Hidenori TAKAHASH Head, Soil Stabilization Group Geotechnical Engineering Department Yoshiyuki MORIKAWA Director, Geotechnical Engineering Department Hiroaki KASHIMA Senior Researcher, Coastal and Ocean Development Group, Coastal and Ocean Development Department	Distinguished Paper Award (Telford Premium)	Institution of Civil Engineers, U.K.	October 5, 2020	Centrifuge modelling of breaking waves and seashore ground
5	Yuri SUGIYAMA Researcher, Soil Mechanics and Geo-Environment Group Geotechnical Engineering Department	Distinguished Paper Award (Telford Premium)	Institution of Civil Engineers, U.K.	October 5, 2020	Extension of unsaturated soil mechanics and its applications
6	Kazuhide YONAMINE Researcher, Materials Group Structural Engineering Department	Annual Academic Lecture Session Excellent Paper Award	Japan Society of Civil Engineers	October 15, 2020	Changes in workability due to transportation and pumping of concrete with high-level replacement of copper slag fine aggregate
7	Koji KAWAGUCHI Head, Marine Information Group, Ocean Hydrodynamics Department Takashi FUJIKI Senior Researcher, Marine Information Group Ocean Hydrodynamics Department	Coastal Engineering Paper Award	Japan Society of Civil Engineers Coastal Engineering Committee	October 28, 2020	Improvement of stability and reliability of directional spectra observed with Doppler-type directional wave meter (Lead author: Dr. Noriaki HASHIMOTO, Professor, Kyushu University)
8	Kenta KUDAI Researcher, Soil Dynamics Group Geotechnical Engineering Department	Coastal Engineering Paper Encouragement Award	Japan Society of Civil Engineers	October 28, 2020	Prediction of collapse of underground cavity from ground surface displacement and its countermeasures against internal erosion
9	Akihiko KONDO Senior Researcher, Earthquake and Structural Dynamics Group, Earthquake Disaster Prevention Engineering Department	Excellence Award	Ministry of Land, Infrastructure Technology Research Society	November 12, 2020	Development of engineering methods for anti-seismic reinforcement and restoration of pile-supported piers with the use of damper materials

Active participation in International Conferences, Workshops, and etc.

Following the establishment of November 5, Japan's Tsunami Disaster Prevention Day, as “World Tsunami Awareness Day” at the United Nations General Assembly in December 2015, the Goryo HAMAGUCHI International Prize (Minister of Land, Infrastructure, Transport and Tourism Prize) was established in 2016 for those who have made outstanding achievements in the field of coastal disaster prevention technology, including tsunami disaster prevention, and the award was presented on November 4, 2020 to two persons and one organization: Dr. Fumihiko IMAMURA, Director of the International Research Institute of Disaster Science, Tohoku University, and Professor of Tsunami Engineering; Professor Costas Synolakis, University of Southern California (Greece and USA); and the Aceh Tsunami Museum (Aceh Province, Republic of Indonesia).

A prize awarding ceremony and commemorative lecture of the Goryo Hamaguchi Award (November 4, 2020, Tokyo)

At the PIANC (World Association for Waterborne Transport Infrastructure),PARI played an important role in promoting strategic international activities, such as setting up MarCom WG225 (Seismic Design of Port Structures) as its chairman and aiming for the 2022 revision of the "*Guidelines for Seismic Design of Port Structures,*" and participating as a key member in MarCom WG208 (Automation of Container Terminals) and compiling the "*Planning Methodology for Automated Container Terminals* (published in March 2021).”

In addition, PARI gave a keynote speech at the International Workshop of the International Society of Geotechnical Engineering (ISSMGE) as the chairperson of the technical committee, and participated in the International Symposium on Automation and Robotics in Construction (ISARC2020) as the secretariat, and engaged in active technical exchanges with overseas research institutions.

Wide Range of Exchanges with Domestic and Overseas Research Institutes

In order to further improve the quality and efficiency of our research, we have been actively promoting collaboration with domestic and overseas research institutions, and as of FY2020, we have concluded a total of 40 research cooperation agreements: 13 in Japan and 27 overseas. In FY2020, we concluded a cooperative agreement with Singapore University for the digital twin of container terminals newly.

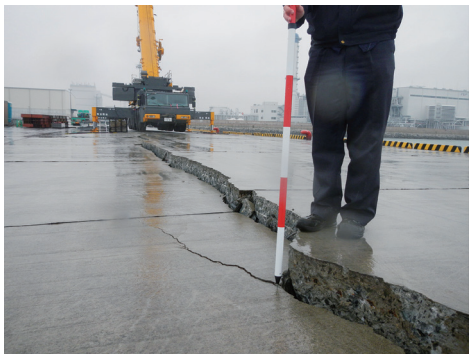
Conclusion of Education and Research Cooperation Agreements

Based on the "Cooperative Graduate School System," in which the institute and national, public, and private universities conclude an agreement and researchers from the institute become professors at graduate schools and supervise graduate students in research books, etc., the institute has concluded cooperative agreements with 12 universities including Tokyo Institute of Technology, Nagoya University, and Nagaoka University of Technology.

In FY2020, we dispatched 14 lecturers. In addition to the cooperative graduate school system, a total of six lecturers were dispatched to the Nagoya Institute of Technology, etc.

Promotion of Administrative Support

The Fukushima earthquake that occurred on February 13, 2021 caused damage to the port of Soma, and the institute dispatched four members to the site as a joint investigation team with the National Institute for Land and Infrastructure Management (NILIM).



Damage investigation at Soma Port

Dispatching of members to Various Technical Committees, etc.

A total of 125 researchers were dispatched to serve as members of various technical committees held by the national and local governments to solve technical problems related to the implementation of public works such as ports, coasts, and airports.

In addition, if we include the technical committees established by various institutions for port, coastal and airport development and airport maintenance, we have dispatched a total of 410 members, who have responded energetically to solve technical problems faced by the government and other organizations.

Support for Operations related to Technical Standards for Ports and Harbors

With regard to technical standards for port facilities, we have cooperated by participating as a member of committees established by the Port and Harbor Bureaus of the Ministry of Land, Infrastructure, Transport and Tourism. We also cooperated in the dissemination of technical standards at workshops held by the National Institute for Land and Infrastructure Management, academic societies, and related organizations. As for airport facilities, we cooperated with various study committees for the smooth dissemination and operation of technical standards for airport civil engineering facilities.

Support for the Evaluation of New Technologies

At the request of the Ministry of Land, Infrastructure, Transport and Tourism (including regional development bureaus, etc.), we dispatched researchers to the "Evaluation Council for New Technologies" established by each organization to evaluate the applicability of technologies registered in the "New Technology Application System for Public Works, etc. (commonly known as NETIS)" to the field in order to promote the use of useful new technologies, and provided technical support.

October 2021

—Creating Technologies that Contribute to the World—

National Institute of Maritime, Port and Aviation Technology

Port and Airport Research Institute

3-1-1 Nagase, Yokosuka, Kanagawa 239-0826, JAPAN TEL +81-46-844-5040 FAX +81-46-844-5072 URL https://www.pari.go.jp