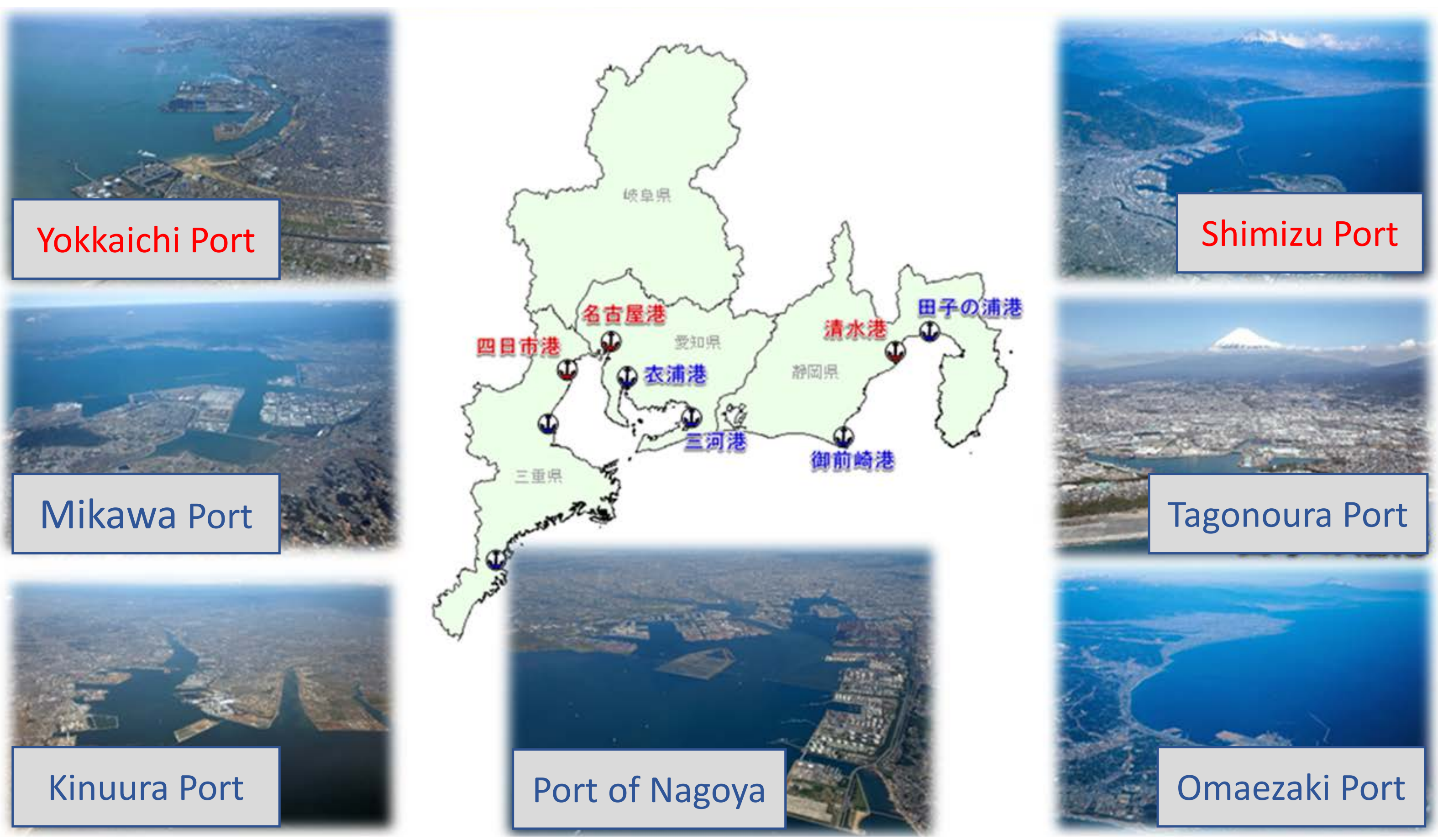
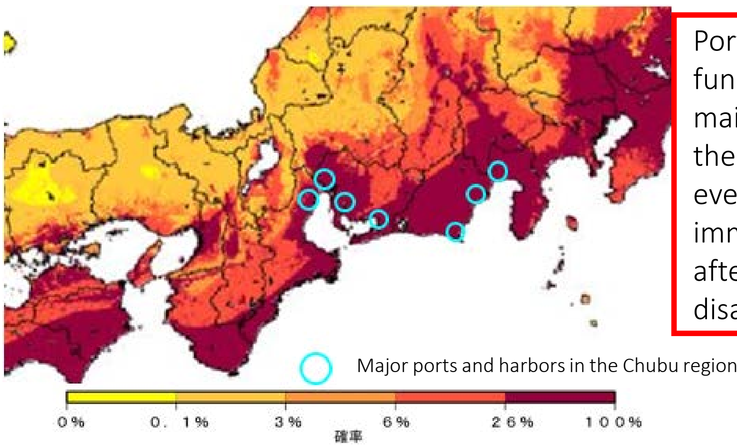
Port and Harbor Facility Damage Diagnosis System

(Jointly developed by the Chubu Regional Bureau, NEWJEC, and the Coastal Development Institute of Technology)



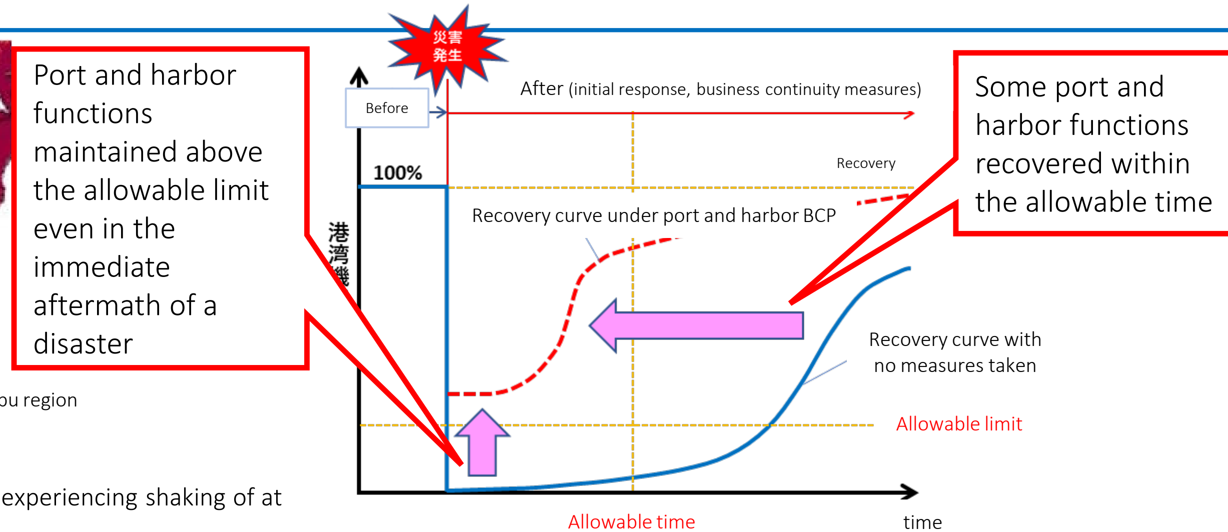
Background of system development

- The probability of a massive (M8–M9) Nankai Trough earthquake occurring in the next 30 years is 70%–80%
- The major ports and harbors of the Chubu region are highly likely to experience shaking of at least seismic intensity 6 in the next 30 years
- During disasters, ports and harbors serve as centers for receiving emergency supplies and reconstruction activities
- Immediately after earthquakes occur, it is extremely important to know if moorings are fit or unfit to remain in service



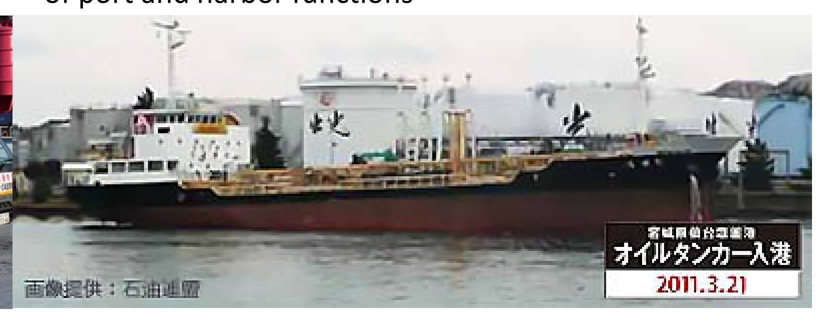
Probabilistic ground motion projection map: Probability of experiencing shaking of at least seismic intensity 6 Lower in the next 30 years

Source: *Zenkoku jishindo yosoku chizu* (Nationwide ground motion projection map), Headquarters for Earthquake Research Promotion, 2017



Conceptual diagram of swift recovery (port and harbor BCP) of port and harbor functions

Receiving emergency supplies and fuel after the Great East Japan Earthquake



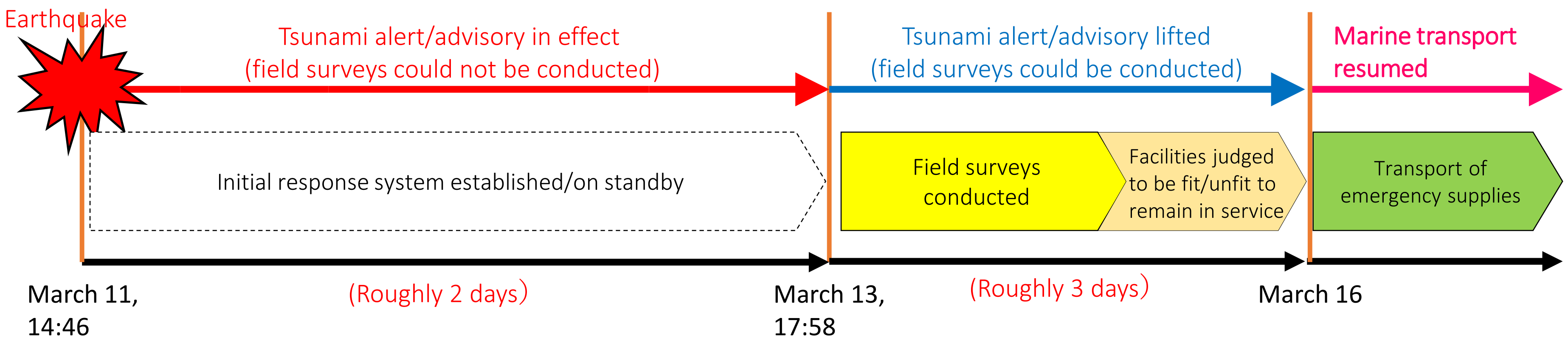
Source: Earthquake Memorial Museum, Tohoku Regional Bureau

3 challenges when checking damage to facilities during disasters

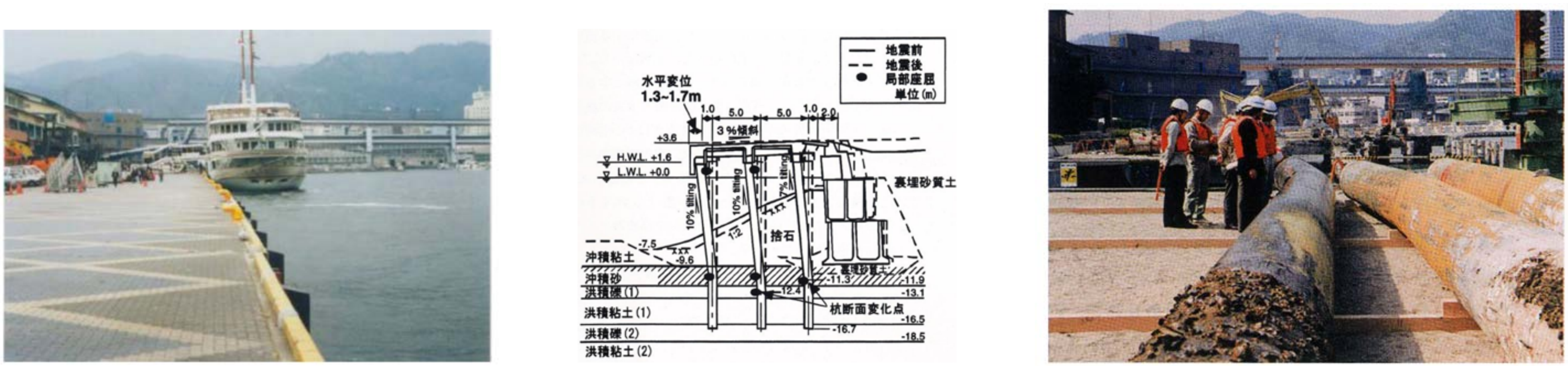
Challenge 1: The inability to ascertain damage because field surveys cannot be conducted while tsunami alerts are in effect

Challenge 2: The difficulty of visually ascertaining damage to the underground portions of mooring wharves & sheet pile-type moorings

Challenge 3: The immense amount of time and human effort required to survey damage to port and harbor facilities

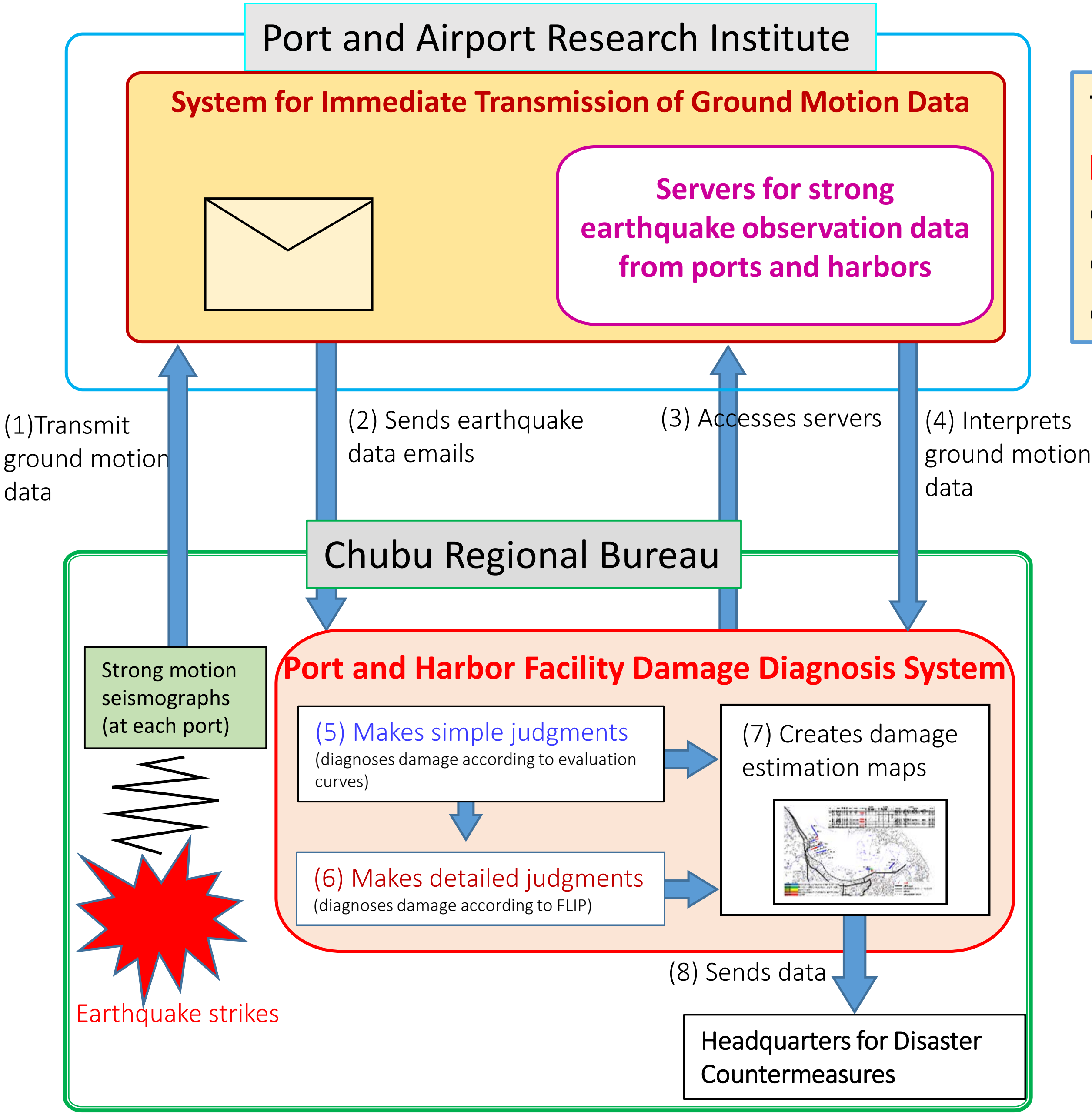


Timeline from the Great East Japan Earthquake to the resumption of marine transport



Example of damage to a mooring wharf after the 1995 Hanshin-Awaji Earthquake
(The wharf appeared to be sound, but the steel sheet piles had buckled)

Overview of the Port & Harbor Facility Damage Diagnosis System



The system automatically processes data when an earthquake strikes, and continues until the damage is estimated

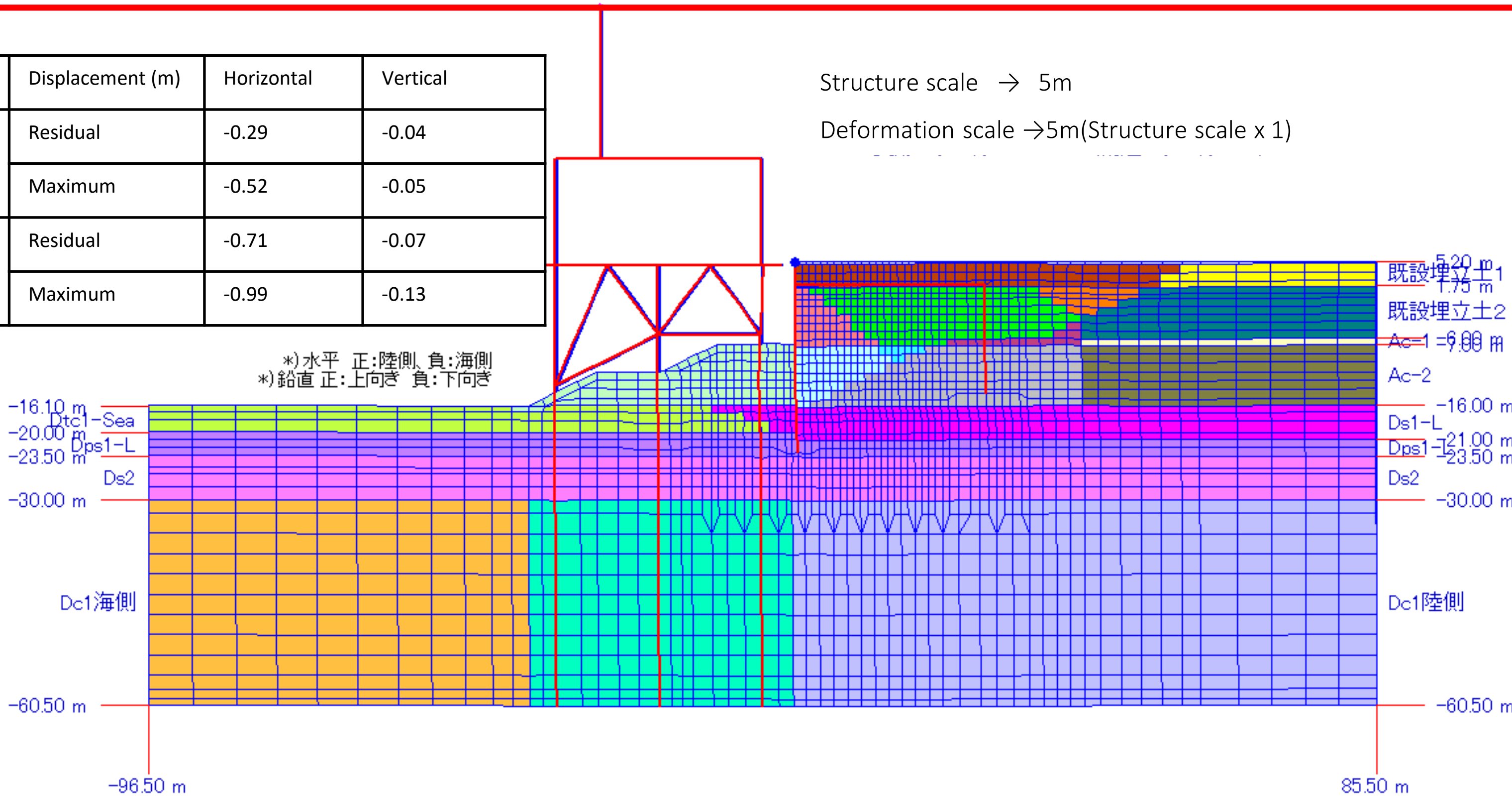
First in Japan!

FLIP-based detailed judgment method

- FLIP provides highly precise damage diagnoses based on comparisons of deformation to port and harbor facility designs, and is used in the detailed judgments of the Port and Harbor Facility Damage Diagnosis System
- FLIP analysis requires a lot of time for calculation; therefore, creative solutions are needed to shorten the diagnosis time

*With input of seismic waves of 300 seconds or longer, analysis requires at least 35 hours to complete

Location	Displacement (m)	Horizontal	Vertical
Quay crown	Residual	-0.29	-0.04
	Maximum	-0.52	-0.05
Embankment crown	Residual	-0.71	-0.07
	Maximum	-0.99	-0.13



Example of FLIP-based earthquake response analysis on a mooring wharf

Simple diagnosis method based on PSI values of speed

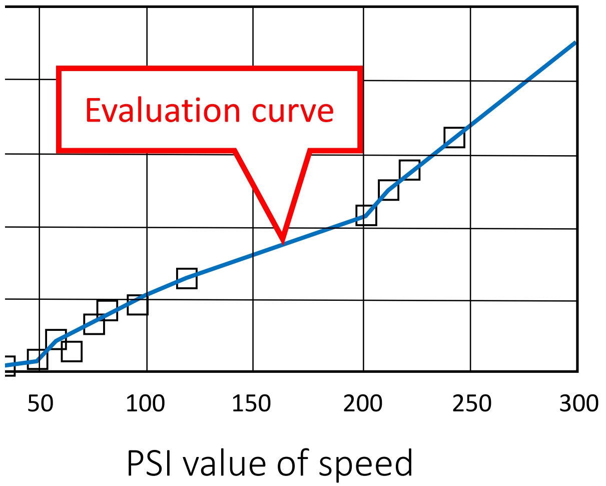
- Conduct FLIP analysis of ground motion of all intensity levels for each mooring
- Create an evaluation curve representing the relationship between PSI value of speed and facility damage evaluation index
- Use the PSI value of speed immediately after the earthquake strikes to develop a method for immediately estimating facility damage
- Eliminate elements beyond expectation, respond to ground motion of all intensity levels as well as consecutively occurring ground motion

*Analysis completed in a matter of minutes, even with input of seismic waves of 300 seconds or longer

【Ground motion waveforms based on FLIP analysis】

Using ground motion prepared by the National Institute for Land and Infrastructure Management

- ◇50-year ground motion
- ◇75-year ground motion (Level 1 ground motion)
- ◇100-year ground motion
- ◇150-year ground motion
- ◇200-year ground motion
- ◇500-year ground motion
- ◇Level 2 ground motion, M-6.5 with hypocenter directly below a populated area
- ◇Level 2 ground motion, active fault-type
- ◇Level 2 ground motion, trench-type, etc.



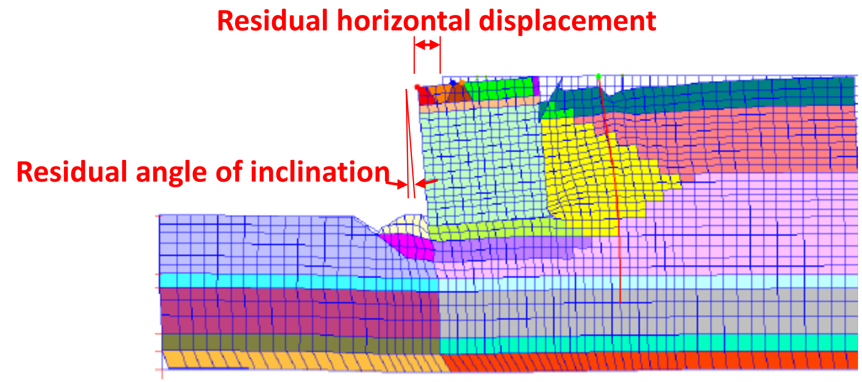
Example of representing the relationship between PSI value of speed and facility damage evaluation index (residual horizontal displacement in this case)

Types of simple-diagnosis facility damage evaluation indices

【Gravity-type】

◇Residual horizontal displacement

◇Residual angle of inclination



【Sheet pile-type】

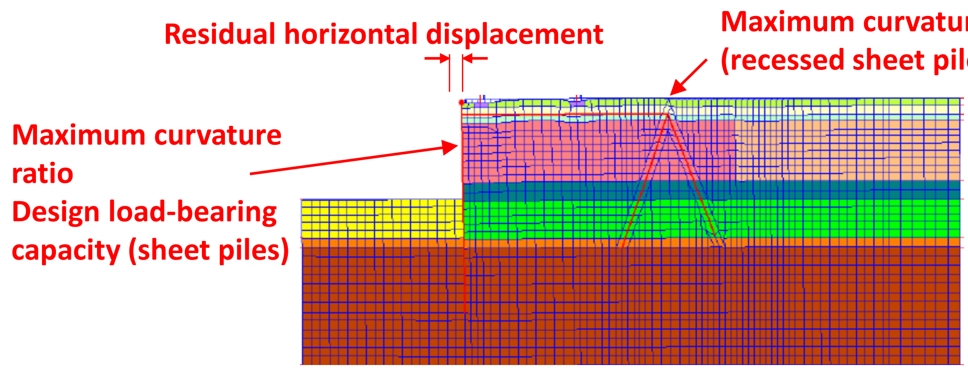
◇Residual horizontal displacement

◇Maximum curvature ratio

(Sheet piles/recessed sheet piles)

◇Design load-bearing capacity ratio

(Sheet piles: Under berthing force/traction)



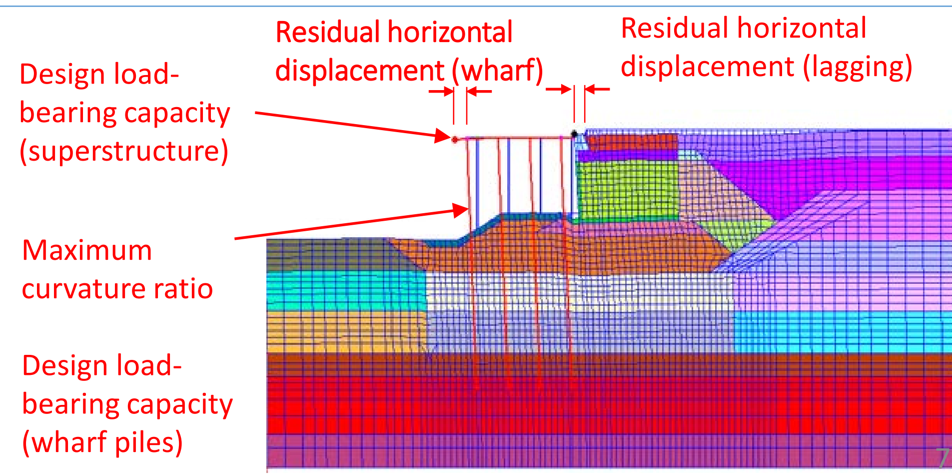
【Wharf-type】

◇Residual horizontal displacement

◇Maximum curvature ratio

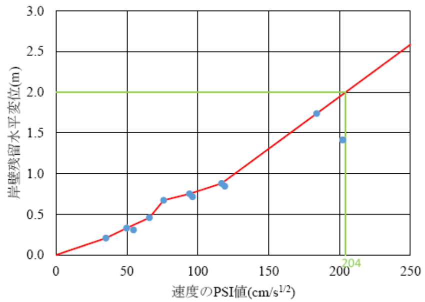
◇Design load-bearing capacity ratio

◇Design load-bearing capacity ratio

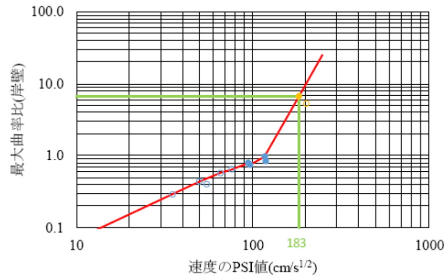


Facility damage evaluation index evaluation curve (Ex: mooring wharf)

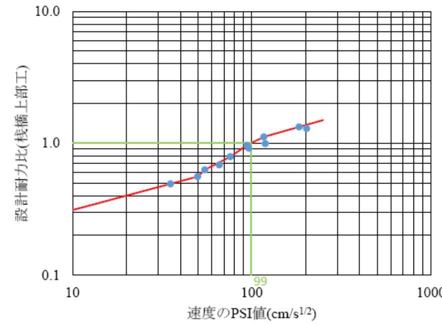
○ Create evaluation curves for multiple facility damage evaluation indices based on the structure type of the moorings



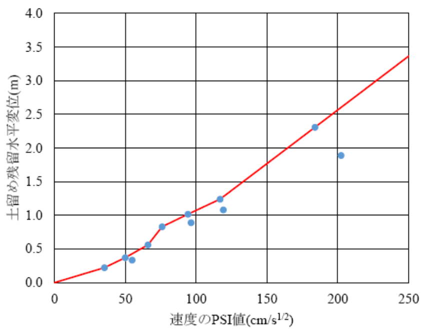
Residual horizontal displacement (wharf)



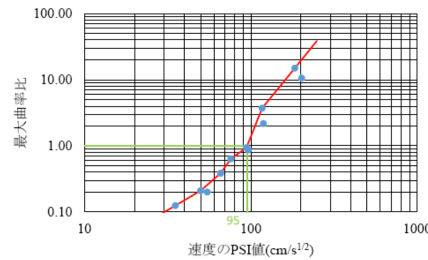
Maximum curvature ratio (wharf piles)



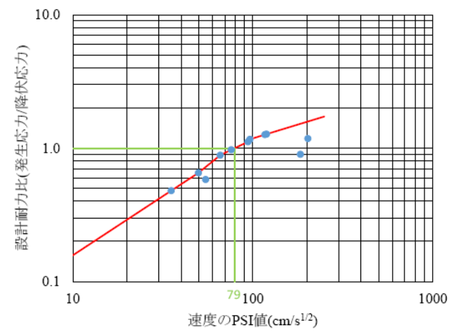
Design load-bearing capacity (wharf piles)



Residual horizontal displacement (lagging)

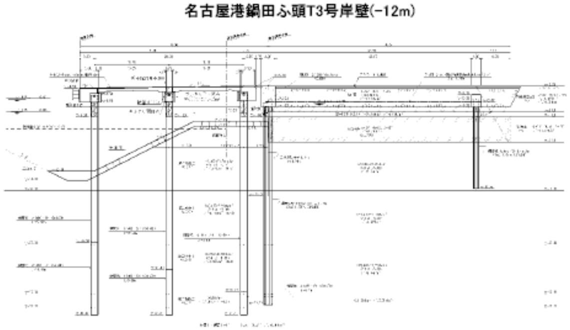


Maximum curvature ratio (lagging sheet piles)



Design load-bearing capacity (superstructure)

名古屋港鍋田ふ頭T3号岸壁(−12m)

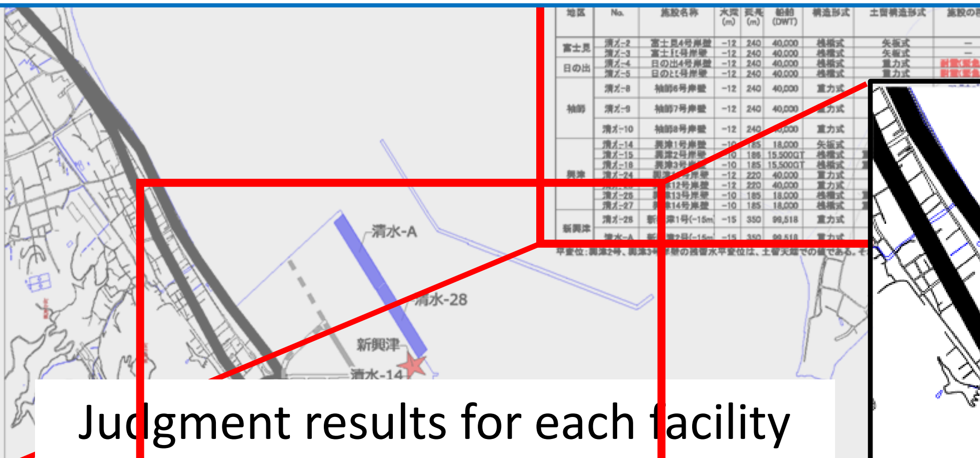


Examples of evaluation curves for facility damage evaluation indices for a wharf-type quay

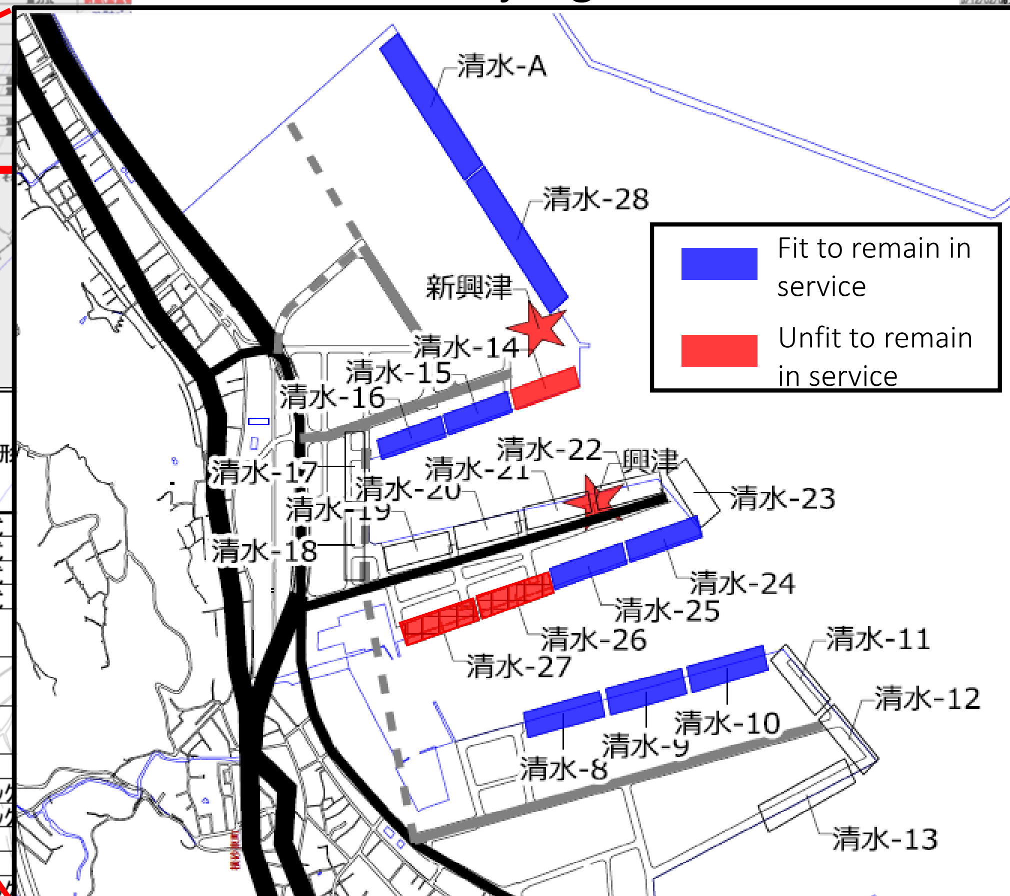
Judge based on various indices whether moorings are fit or unfit to remain in service

Output of diagnostic results (damage estimation maps)

○ Visualizing diagnostic results in the form of damage estimation maps to prepare for submittal to Headquarters for Disaster Countermeasures



Color-coded judgment results



Judgment results for each facility

地区	No.	施設名称	計画水深(m)	施設延長(m)	対象船舶(DWT)	構造形式	土留構造形式									
富士見	清ｽ-2	富士見4号岸壁	-12	240	40,000	桟橋式	矢板式									
	清ｽ-3	富士見5号岸壁	-12	240	40,000	桟橋式	矢板式									
日の出	清ｽ-4	日の出4号岸壁	-12	240	40,000	桟橋式	重力式									
	清ｽ-5	日の出5号岸壁	-12	240	40,000	桟橋式	重力式									
袖師	清ｽ-8	袖師6号岸壁	-12	240	40,000	重力式	—									
	清ｽ-9	袖師7号岸壁	-12	240	40,000	重力式	—									
	清ｽ-10	袖師8号岸壁	-12	240	40,000	重力式	—									
興津	清ｽ-14	興津1号岸壁	-10	185	18,000	矢板式	—									
	清ｽ-15	興津2号岸壁	-10	186	15,500GT	桟橋式	重力式(ﾌﾞﾛｯｸ									
	清ｽ-16	興津3号岸壁	-10	185	15,500GT	桟橋式	重力式(ﾌﾞﾛｯｸ									
	清ｽ-24	興津11号岸壁	-12	220	40,000	重力式	—									
	清ｽ-25	興津12号岸壁	-12	220	40,000	重力式	—									
	清ｽ-26	興津13号岸壁	-10	185	18,000	桟橋式	重力式(ﾌﾞﾛ									
	清ｽ-27	興津14号岸壁	-10	185	18,000	桟橋式	重力式(ﾌﾞﾛｯｸ積み)	—	0.54	○	△	▲	—	—	—	—
新興津	清ｽ-28	新興津1号(-15m	-15	350	99,518	重力式	—	耐震(幹線貨物)コンテナバース	0.48	—	—	◎	0.68 0.65	—	—	◎ ◎
	清水-A	新興津2号(-15m	-15	350	99,518	重力式	—	耐震(幹線貨物)コンテナバース	0.62	—	—	◎	0.83 0.82	—	—	◎ ◎

Example of the system in action (Osaka Earthquake, June 18, 2018)

■ Process from the earthquake striking to the system engaging to the output of results

June 18

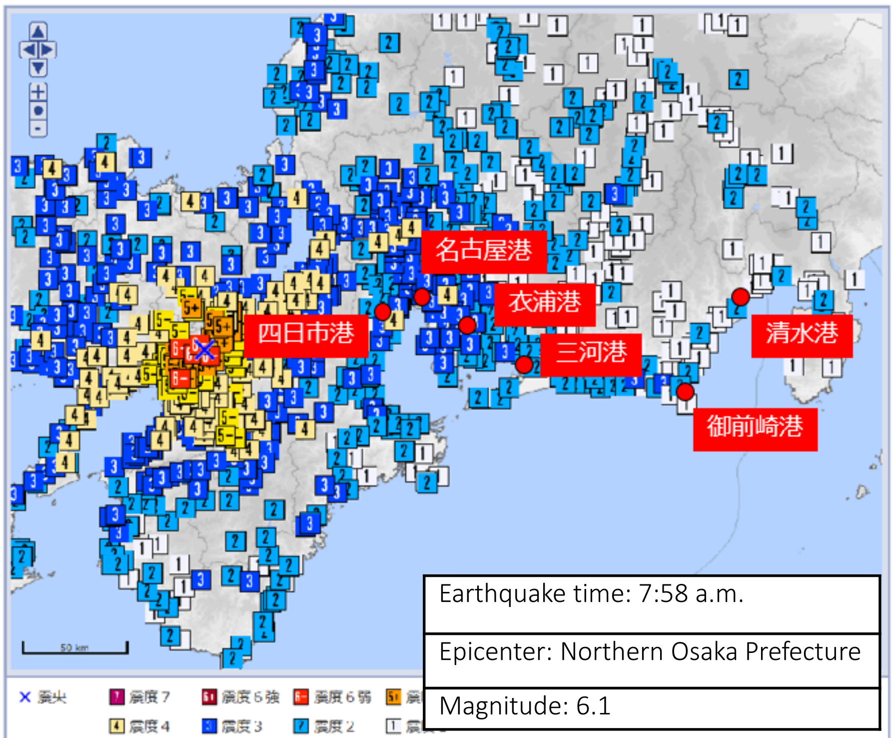
07:58 Earthquake strikes

08:04 Emails containing ground motion data sent out through the network for strong earthquake observation at ports and harbors (Port and Airport Research Institute)

08:09 08:09 System operation begins
(13 minutes after the earthquake struck)

08:43 Mapping of simple judgment results completed for all ports
(45 minutes after the earthquake struck)

16:27 Mapping of detailed judgment results completed for all ports
(8 hours, 29 minutes after the earthquake struck)



※気象庁HPより引用

Ports and harbors for which ground motion was observed

- Yokkaichi Port
- Port of Nagoya
- Kinuura Port
- Mikawa Port
- Omaezaki Port*
- Shimizu Port*

*No judgment as to fitness for remaining in service because the PSI value was 2.0 or lower

Facilities judged by the system as fit or unfit to remain in service

- Yokkaichi Port: 8
- Port of Nagoya: 20
- Kinuura Port: 6
- Mikawa Port: 3

Totals: 37 facilities at 4 ports

Time from earthquake to completion of simple judgments: 45 min.
Completion of detailed judgments: 509 min.

Types of simple-diagnosis facility damage evaluation indices

Challenge 1: The inability to ascertain damage because field surveys cannot be conducted while tsunami alerts are in effect

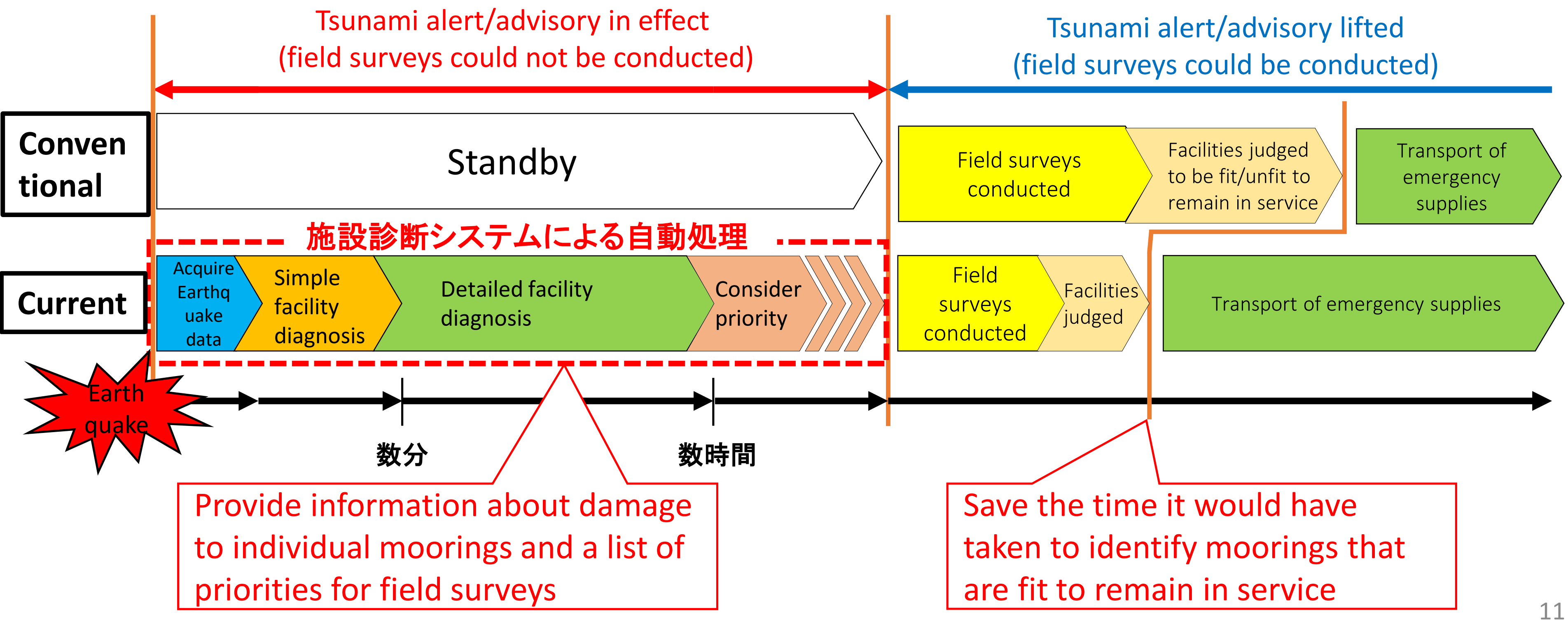
⇨Estimate damage to moorings during the time when field surveys cannot be conducted

Challenge 2: The difficulty of visually ascertaining damage to the underground portions of mooring wharves and sheet pile-type moorings

⇨Estimate the situation underground and ascertain damage based on FLIP analysis results

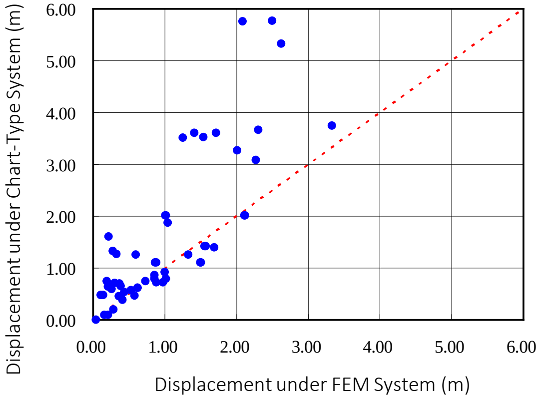
Challenge 3: The immense amount of time and human effort required to survey damage to port and harbor facilities

⇨Provide a list of priorities to streamline field surveys, shorten schedules, and reduce workloads



Comparison with similar technology (Chart-Type Seismic Diagnosis System for coastal structures)

Tool	Port and Harbor Facility Damage Diagnosis System	Chart-Type Seismic Diagnosis System
Reason for development	Judging whether moorings are fit to remain in service immediately after earthquakes strike	Screening coastal structures at high risk due to earthquakes
Scope of diagnosis	Moorings registered in the system (specific facilities)	Coastal structures with various structural specifications and ground conditions (facilities not specified)
FLIP model	Detailed model that reflects structural specifications and ground conditions of individual facilities	Simplified model based on standard structure types and ground conditions
Labor required	Automatic processing from seismic waveform input to judgment of fitness to remain in service	Manual input of facility, ground, and earthquake data into an Excel spreadsheet
Output	•Residual horizontal displacement •Results of steel material comparison (wharf-type, sheet pile-type) •Results of superstructure comparison (wharf-type) •Fitness to remain in service (including judgments of fitness to remain in provisional service)	•Residual vertical displacement (except mooring wharves) •Residual horizontal displacement (except sloped/gravity-type breakwaters) •Soundness of steel materials (only sheet pile-type/wharf-type) •Hinterland subsidence (except sloped/gravity-type breakwaters)
Precision of diagnoses	•Simple judgment: Nearly identical to FLIP analysis •Detailed judgment: Identical to FLIP analysis	More conservative evaluations then FLIP analysis
Other	•Creates maps of judgment results for each port and harbor •Capable of judging whether cranes are fit to remain in service	•Capable of evaluating the risk of toppling for gravity-type embankments and gravity-type breakwaters

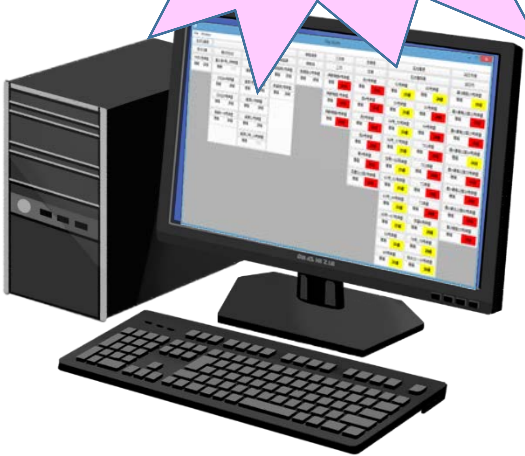


Comparison of estimated displacement under FLIP and Chart-Type systems

Conclusion (characteristics and advantages of the FLIP system)

- The system combines and actualizes the most advanced port and harbor technology available now
- Unprecedented creativity and novelty
- Development of a method of estimating damage evaluation indices using evaluation curves eliminates elements beyond expectation and enables fully automated, rapid, high-precision judgments of whether facilities are fit to remain in service
- A parametric study made it possible to apply the system to facilities other than port and harbor facilities (e.g. river levees)

First in Japan!!



The Port and Harbor Facility Damage Diagnosis System monitors seismic activity 24 hours a day, 365 days a year—it is always ready for a major earthquake.

The Port and Harbor Facility Damage Diagnosis System on standby in the Nagoya Research and Engineering Office for Port and Airport