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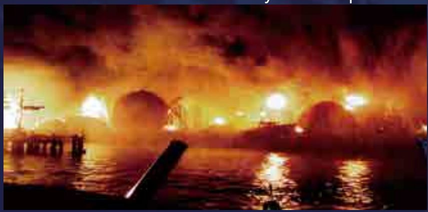
Feature Articles

Initiatives for Enhancing Seismic Resistance of and Damage-prevention Technologies for Foundation Structures

Photo: Tokyo Fire Department



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Measures for Earthquake Resistance Enhancement of Industrial Parks in Bay-Front Areas

by Masanori Hamada
Chairman, Asian Disaster Reduction Center

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During past earthquakes, industrial parks have been repeatedly damaged by the strong seismic motion amplified by the soft reclaimed ground, the liquefaction of the sandy soil, the overflow of tank oil induced by the long-period seismic motion, and huge tsunamis. Heavy damages to industrial parks by future earthquakes and tsunamis will cause serious impacts on the safety and the security of the societies as well as the worldwide economy. Therefore, the enhancement of earthquake and tsunami resistance of industrial parks is the most urgent subject in earthquake- and tsunami-prone countries like Japan.

Photo: Tokyo Fire Department

Photo 1 Explosion and fire of 17 spherical LPG tanks (2011 East Japan earthquake)

Photo 2 Fire of crude and naphtha tanks by long-period seismic motion (2003 Tokachi-oki earthquake)

Photo 3 Settlement and inclination of oil product tank by soil liquefaction (1995 Kobe earthquake)

The Japanese government initiated a national project for the reinforcement of industrial facilities around the Tokyo, Ise and Osaka Bays since 2014, by spending about 15 billion yen per year for the financial support to oil refinery industries. This report previews the damage to industrial facilities caused by the past earthquakes, and introduces the outline of the national project for the reinforcement.

Damage to Industrial Facilities during Past Earthquakes and Tsunamis

The damage to industrial facilities caused by past earthquakes and tsunamis are summarized as follows;

- **Breakages of Oil Tanks by the Dynamic Inertia Forces Caused by Seismic Motion**

Photo 1 shows the explosion and the fires of 17 spherical LPG tanks in an oil refinery plant in the Tokyo Bay during the 2011 East Japan earthquake. The cause of the damage was identified as an extensively strong seismic inertia force amplified by soft reclaimed ground.

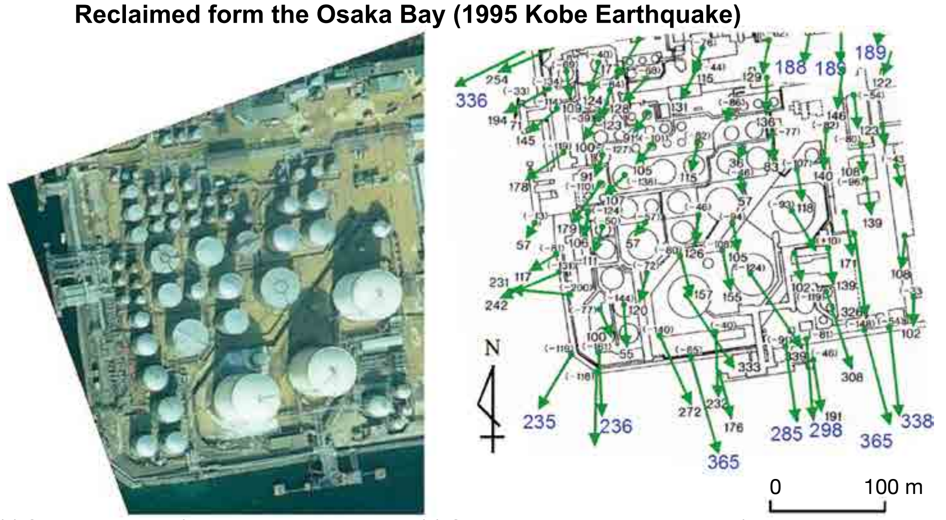
- **Overflows of Oil from Tanks and Subsequent Fires**

As shown in Photo 2, during the 2003 Tokachi-Oki earthquake, a crude oil tank and a naphtha tank were fired and burnt down due to the sloshing vibration of the content oil induced by the long-period seismic motion.

- **Settlement and Inclination of Oil Tanks Caused by Soil Liquefaction of the Foundation Ground**

Photo 3 shows the inclination of an oil product tank due to the decrease of the bearing capacity of the foundation ground by the soil liquefaction during the 1995 Kobe earthquake.

Fig. 1 Soil Liquefaction and Ground Displacement of a Man-made Island Reclaimed form the Osaka Bay (1995 Kobe Earthquake)



(a) Soil liquefaction (The yellow colored ground surface shows the thick deposit by the boiling of liquefied sand)

(b) Ground surface displacements (The vectors show the horizontal displacements, and the numerals in the parentheses are the vertical displacements, unit: cm)

Photo 4 Floating out of oil tanks into the sea by the tsunami (2011 East Japan earthquake)

• Ruptures of Pipelines of Oil and Gas, and Foundation Piles by Liquefaction-induced Large Ground Displacement

Fig. 1(a) is an aerial photo taken over a tank yard in Kobe, two days after the Kobe earthquake. Boiled sand accumulated all over the yard, indicating that its entire area had liquefied (yellow colored part in the figure). A large amount of gas leaked by the rupture of the LPG pipeline. Fig. 1(b) shows horizontal and vertical ground displacements on the ground surface of the tank yard, indicating that the seawall displaced 3.6 m seaward at maximum, and the whole tank yard, with about 400 × 400 m area, also moved 2-3 m seaward.

• Lift-up and Flow of Oil Tanks

The inundated tsunami lifted up oil tanks and floated them into the sea as shown in Photo 4, and ignited the large sea surface fire at the time of the 2011 East Japan earthquake.

Assessment of Damage to Industrial Parks in the Tokyo Bay

Around the Tokyo Bay, there are huge man-maid islands reclaimed from the bay. Most of these islands and their quay walls have not enough resistance against soil liquefaction, because those had been constructed before the 1964 Niigata earthquake, which firstly let us recognize the phenomena of soil liquefaction and its caused damage from the viewpoint of engineering. Fig. 2 shows one example of the assessment of soil liquefaction, and seawall and ground movement in the horizontal direction of a man-made island in the Tokyo Bay by the Northern Tokyo Bay earthquake, which has been predicted as one of impending earthquakes in near future. The thickness of the liquefied soil layer and the maximum seawall movement were estimated as about 10 m and 7 m, respectively. On the reclaimed land around the Tokyo Bay, more than 5 thousand tanks have been constructed for the storage of oil, oil products, high pressure gas and poison materials. A large number of them is located on the ground which has high potential of soil liquefaction, and horizontal and vertical ground displacements.

Furthermore, there are more than 600 floating roof tanks for the storage of crude and heavy oil around the Tokyo Bay. A large amount of oil is assessed to overflow from these tanks due to the long-period seismic motion induced by the Nankai Trough earthquake along the Pacific coast of the western Japan.

Fig. 3 shows one example of the numerical simulations on the diffusion on the sea surface of the oil of a volume of about 22,000 kl, resulting from the breakage of oil tanks due to soil liquefaction and overflow of oil due to long-period seismic motion. The spilled oil from the east coast of the Tokyo Bay will reach to the west coast within three days under the condition that the wind speed is 5.0 m/s in summer season. Under such condition, the maritime function of the main sea routes of the bay may be paralyzed and the economic activity in the metropolitan area of Tokyo will be seriously affected by the stop of sea transportation.

Measures for Earthquake Resistance Enhancement of Industrial Facilities

The reinforcement of the seawalls is required to prevent the damage to the industrial facilities nearby the seawalls. As shown in Fig. 4, three kinds of countermeasures were applied to protect the existing seawalls. The first method is a construction of new steel sheet pile walls behind the existing seawalls. The second method is the soil improvement against the liquefaction. In the third method, steel piles are driven in two rows with a proper interval behind the seawall. In this method, the pile group is expected to prevent the flow of the liquefied soil. The effectiveness of each method has been examined by experiments under centrifuge conditions.

Fig. 5 shows an example of measures of oil tanks against soil liquefaction and tsunamis. The steel sheet piles around the tank restrain the outflow of the liq-

Fig. 2 Assessment of Soil Liquefaction and Its Induced Ground Displacement (Northern Tokyo Bay Earthquake)

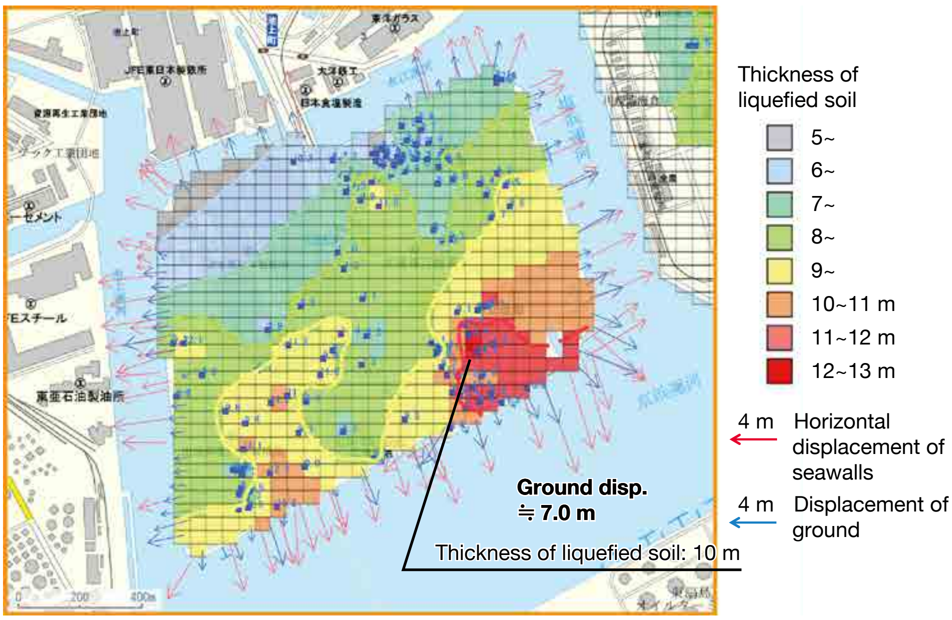
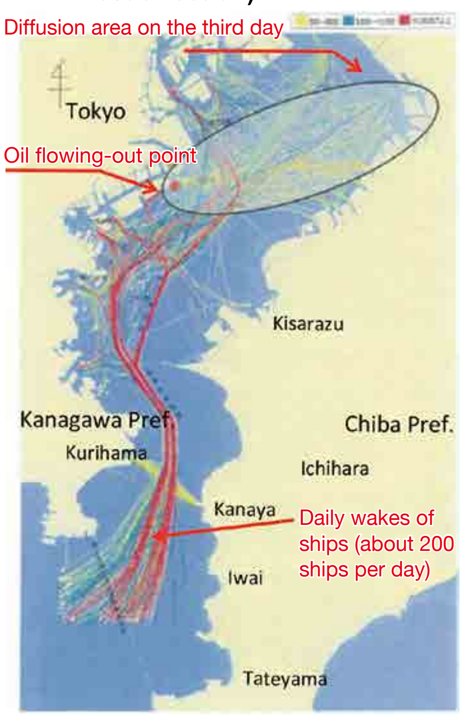


Fig. 3 Diffusion of Crude Oil in Tokyo Bay (summer season, the wind speed of 5.0 m/s in southern-west direction)



uefied soil beneath the tanks, resulting in prevention of the settlement and the inclination of the tanks. The steel pipe piles above the ground prevent the collision of the floating objects with the tank during tsunamis.

Recommendation for Earthquake and Tsunami Resistance of Industrial Parks

In 2013, the Ministry of Economy, Trade and Industry (METI) of the Japanese government initiated the policy for the enhancement of earthquake and tsunami resistance of industrial parks. Twenty four petroleum plants were selected from the areas which have high probability to be hit by large earthquakes and tsunamis in very near future. (Refer to Fig. 6)

The author recommended the following advices to concerned organizations including the Japanese government for more active promotion of earthquake- and tsunami-resistance enhancement of industrial parks.

The first recommendation is that, in addition to reinforcement of each industrial plant, the earthquake- and tsunami-resistance enhancement in larger areas such as whole areas of man-made islands including sea areas should be strongly promoted, because the disaster at one plant may extend to the neighboring plants and affect the wider areas. To achieve this, strong leadership by the central and the local governments is strongly required to lead the group of the industrial companies. For the enhancement of disaster resilience of the larger areas, more public investment is also required for private properties of the industries, particularly for small industries, most of which has not enough financial foundation.

The risk information sharing is required among governments, industries and local communities. This is essential in order to promote the total enhancement of earthquake and tsunami resistance of wider industrial areas including neighboring local communities. The assessment of the impact of the loss of the function of industrial parks on the country as well as on worldwide economy is also required for establishment of effective national policies and strategies. ■

Fig. 4 Reinforcement of Seawalls against Soil Liquefaction and Its-Induced Ground Displacement

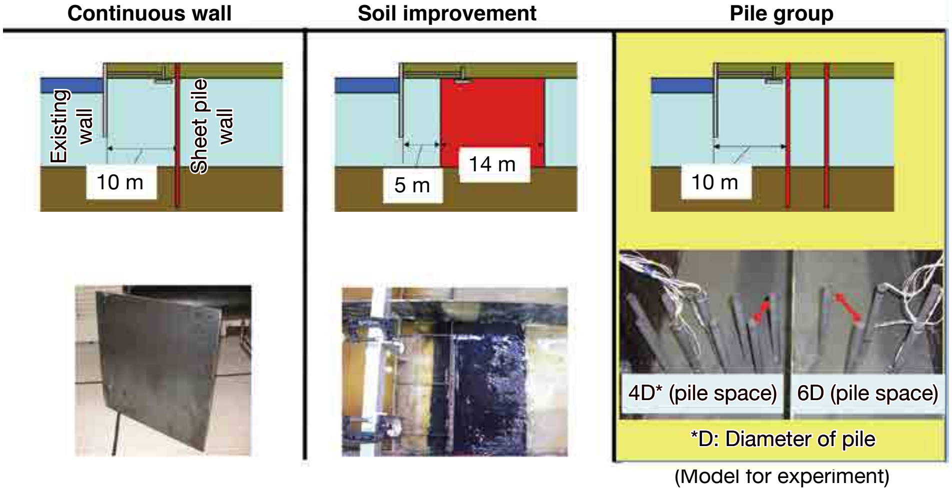


Fig. 5 Measures of Oil Tanks against Soil Liquefaction and Tsunamis

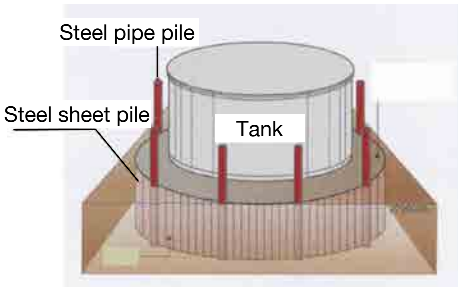
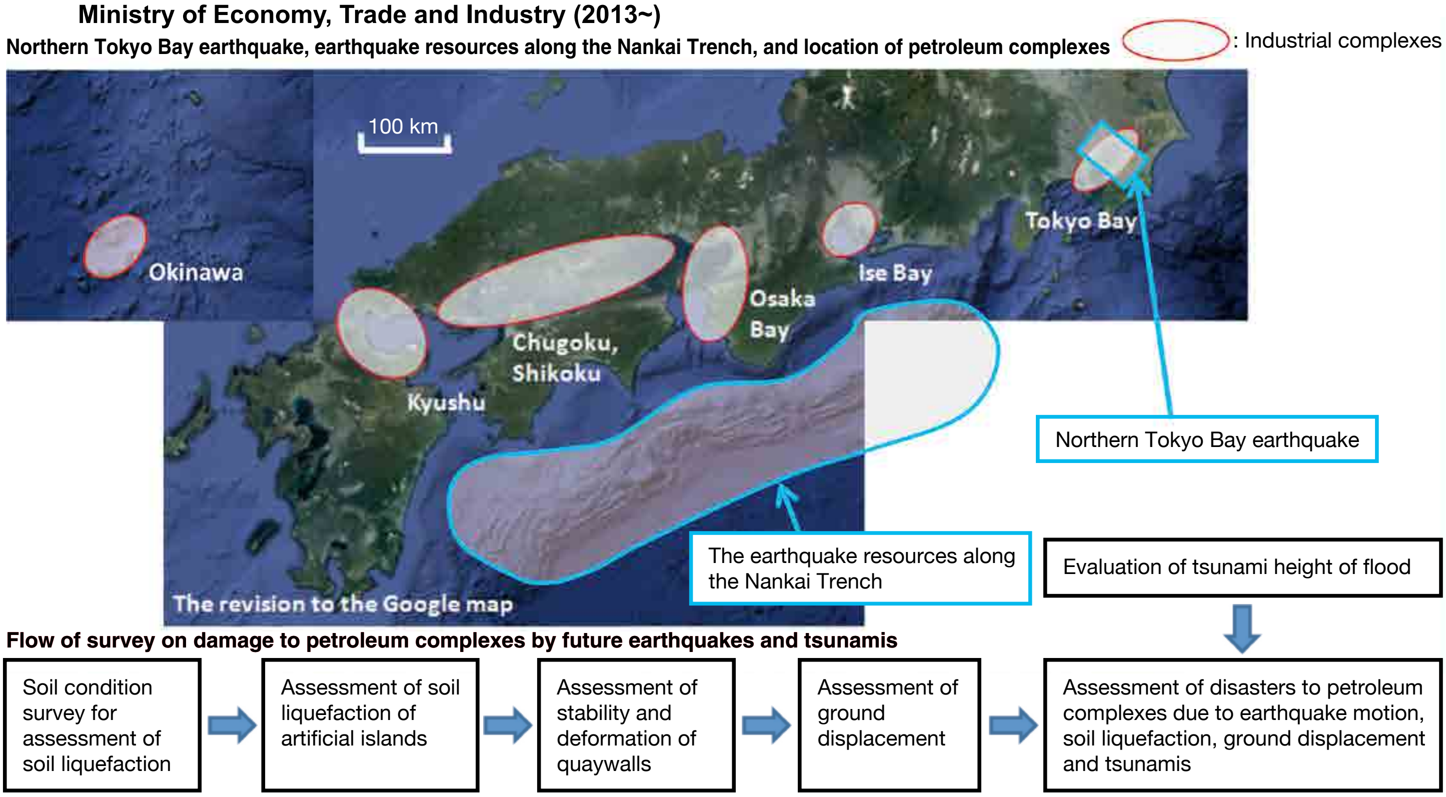


Fig. 6 Survey and Practice of Earthquake and Tsunami Resistance Enhancement of Industrial Complexes—Policy by Ministry of Economy, Trade and Industry (2013~)



• 24 petroleum industries, 16 billion yen/year (public fund)

Prevention of Liquefaction-induced Damage to Existing Bridges

—Development of Seismic Resistance Evaluation Method and Seismic Countermeasure Technologies for Bridge Foundations—

by Toshiaki Nanazawa and Michio Ohsumi
Public Works Research Institute

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Toward Highly Resilient Highway Networks

Among the existing bridges located on liquefiable ground, there is risk to be damaged seriously due to great earthquakes. In order to make the highway network resilient, it is important to extract these bridges by the use of a rational verification method and to structure a method to effectively promote seismic countermeasures. To attain this goal, at the Center for Advanced Engineering Structural Assessment and Research (CAESAR) of the Public Works Research Institute, a research project has been underway since 2014 that aims to develop a seismic resistance verification method and seismic-resistant technologies for bridge foundations in liquefiable ground.

This article describes the status of this research project.

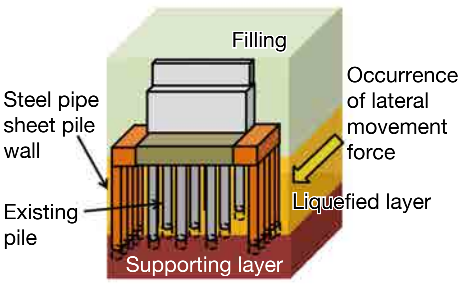
Outline of Research

• Analysis of Examples of Damage due to Past Great Earthquakes

An analysis was made of 38 examples of damage to bridges installed in ground where liquefaction occurred in past great earthquakes. Through this analysis, the form of damages affecting the seismic resistance of bridges was classified into three types[1]. Of these three forms of damage, the current research has targeted damage to bridge abutments for which comparatively many examples of damage that might cause trouble in the transportation function are found and for which examples of existing research are few. Experiments and analytical examinations are being promoted on the damage to these bridge abutments. Photo 1 shows an example of such damage to a bridge abutment.

Photo 1 Damage to bridge abutment located in the ground where liquefaction occurred[2]

Fig. 1 Example of Reinforcing Structure for Abutment Foundation (Steel Pipe Sheet Pile Wall: Side-integrated Type)



• Proposal of Reinforcing Methods and Structures for Foundations

A proposal was made through joint research with the Japanese Association for Steel Pipe Piles (JASPP). Specifically, a reinforcing method and a structure for foundations employing steel pipe piles and steel pipe sheet piles were proposed through examinations made from the following three aspects:

- Effectiveness for seismic behavior and mechanism of the damage of foundations
- Avoidance of traffic hindrance during reinforcement work
- Applicability of construction machinery in narrow execution yards such as clear headway under girders

Fig. 1 shows an example of reinforcing structures thus proposed for bridge abutments.

• Verification of Seismic Behavior of Foundations and Seismic Countermeasure Technologies through Shaking Table Tests

In order to verify liquefaction-induced ground flow, the seismic behavior of old foundations and the effectiveness of proposed reinforcing structures, shaking table tests were conducted on abutments on liquefiable ground using the large scale shaking table in the Public Works Research Institute. Photo 2 shows the specimens on the shaking table.

In the following, the test results of two cases are introduced—Case 1 in which an existing abutment built without design for liquefaction is modeled; and Case 5 in which the footing of it was extended to the side and steel pipe sheet pile was integrated there. (Refer to Table 1 and Fig. 2) The reduced scale of the model bridge abutment is 1/10. The abutment model was designed by assuming an abutment height of 8 m and a liquefiable layer thickness of 10 m in prototype scale. In the test, an artificial seismic wave was to be input to the bridge axial direction, and the design earthquake ground motion (I-I-3) for dynamic analysis specified in the current *Specifications for Highway Bridges* of the Japan Road Association[4] was applied.

Photo 2 Specimens on the shaking table

Photo 3 shows the ground deformation conditions after excitation in Case 1. It is understood from the photo that almost no deformation occurred in the rear of the abutment but large deformation occurred in front of the abutment. Fig. 3 shows the secular change of excess pore water pressure in the rear of the abutment and at the slope toe (red circles in Fig. 2). In both cases, while the excess pore water pressure ratio reached approximately 1.0 at the slope toe and ground liquefaction occurred, liquefaction did not occur in the ground on the rear side of the abutment.

Fig. 4 shows the distribution of the bending strains of the piles at section 1-1 in Fig. 2 at the time when the bending strain of the piles and the displacement of the abutments reach their maximum level. In both cases, the bending strain surpassed the yielding strain by a great margin at the pile head and in the pile intermediate section of the existing piles. On the other hand, in Case 5, because the bending strain of the reinforcing pipe remained nearly within elastic range and the shear strength of the rein-

Table 1 Test Cases for Seismic Countermeasures for Abutments

Case	Standard applied	Detail of foundation	Countermeasure structure	Configuration of backfill
Case 1	Former standards*	Prefabricated RC pile: φ450 mm 8×3 rows	No countermeasure	River dike
Case 5	Former standards*	Prefabricated RC pile: φ450mm 8 ×3 rows	Steel pipe sheet pile wall: Side-integrated type φ600×8 piles (one side: 4 piles)	River dike

* *Design of Pile Foundations—Guidelines to Design of Substructures of Highway Bridges* (Mar. 1964, Japan Road Association)

Photo 3 Ground deformation after excitation (Case 1)

Fig. 2 Outline of Abutment Model

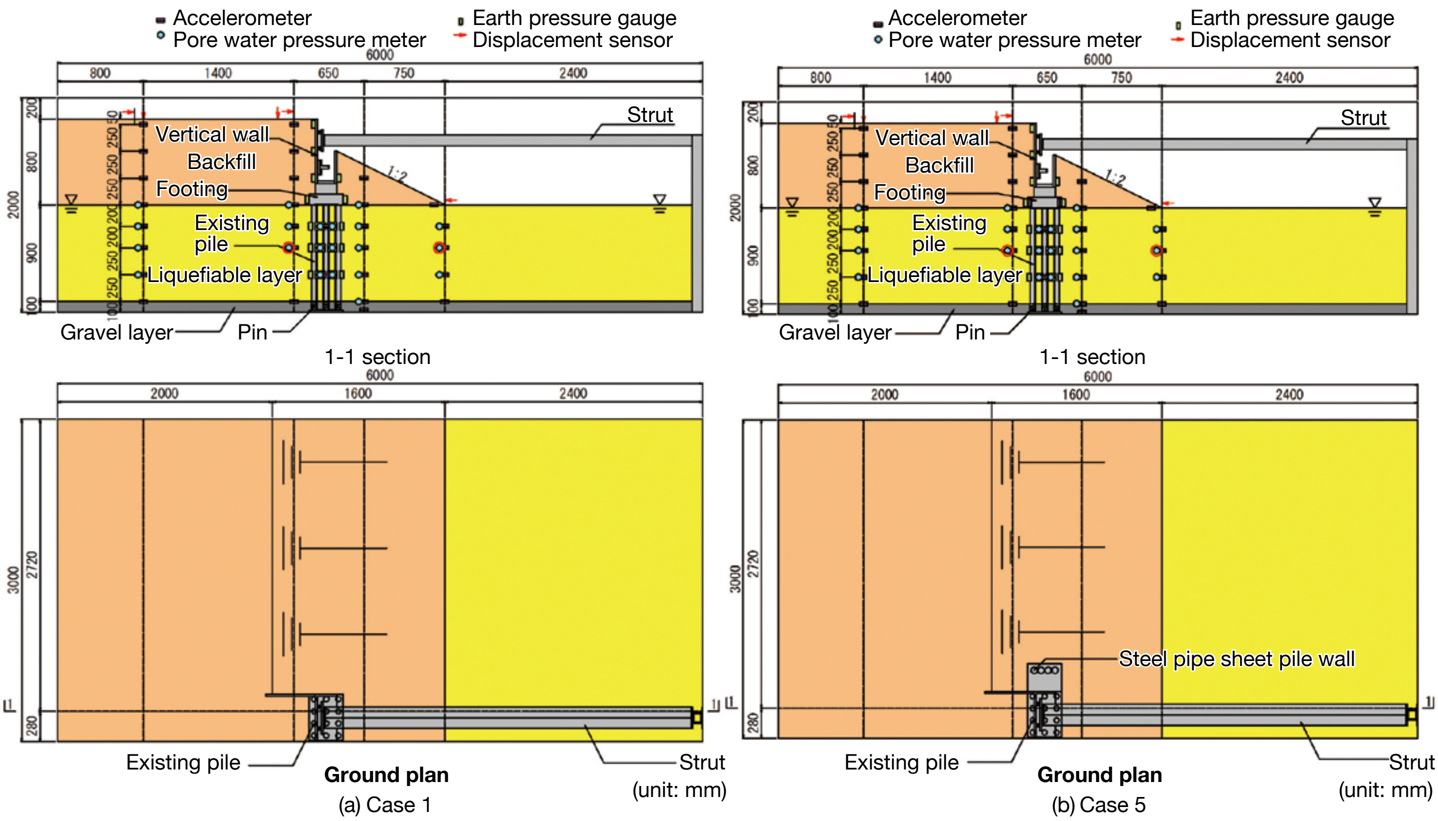


Fig. 3 Secular Change of Excess Pore Water Pressure

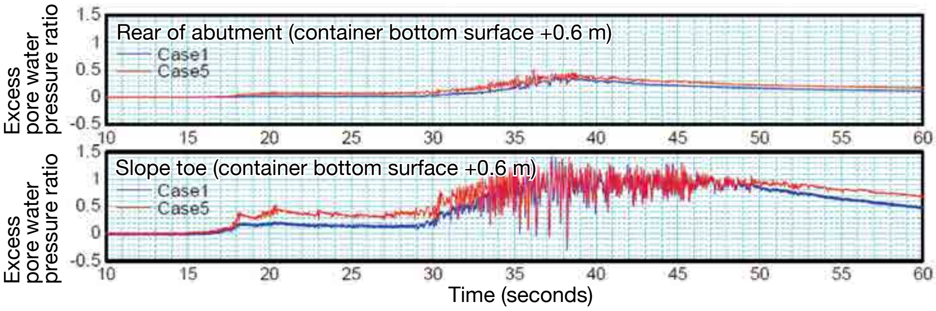


Fig. 4 Distribution of Bending Strains of Pile at the Time of Maximum Response

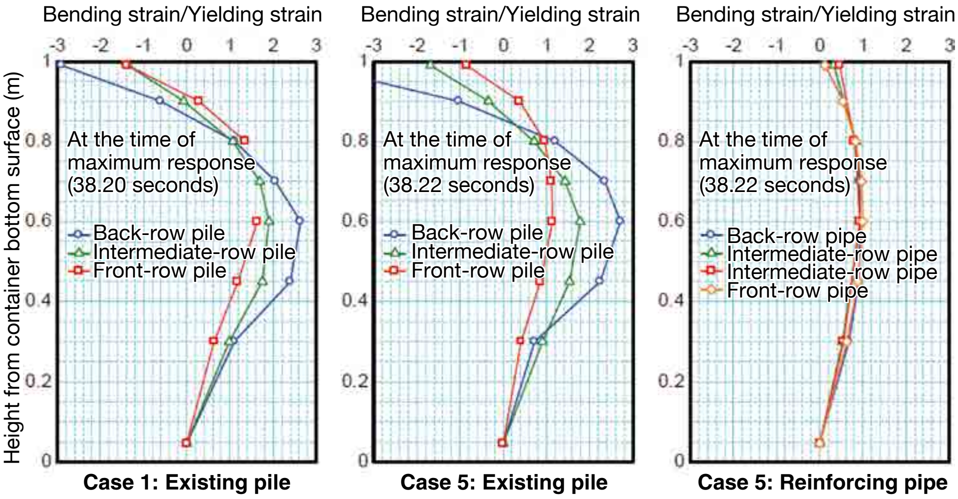
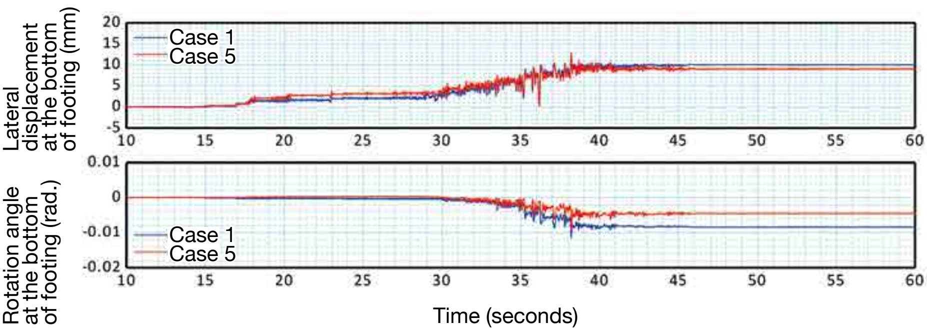


Fig. 5 Secular Change of Lateral Displacement and Rotation Angle at the Bottom of Footing



forcing pipe was sufficiently large, it can be assessed that seismic resistance is secured for the entire foundation structure.

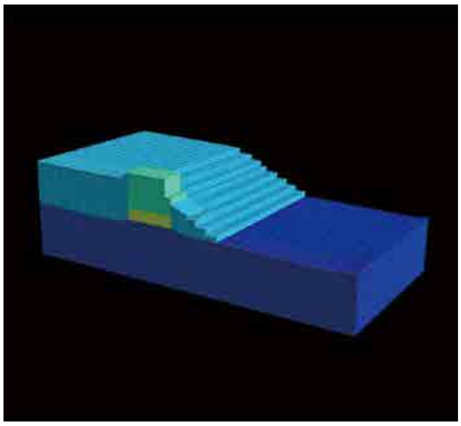
Fig. 5 shows the secular change of lateral displacement and rotation angle at the bottom of the footing. In both cases, while nearly no difference of displacements of abutments was seen, if plasticization of the existing piles progresses, it is forecasted that differences of displacement may occur.

In the future, in order to clarify the behavior of a foundation after its plasticization, it is planned to conduct a large-scale verification test using a model with a reduced scale of 1/4.5.

• Structuring of Advanced Analytical Approaches

A joint research project pertaining to the analytical technology is being promoted between CAESAR and the Tokyo Institute of Technology. Its aim is to develop an analytical technology for foundations in liquefied ground that can reproduce damage examples and shaking table tests[1]. For that purpose, examinations are being promoted by means of dynamic analysis using a three-dimensional finite model in which the ground and the abutment are treated as solid elements and the piles are treated as beam elements (Fig. 6).

Fig. 6 Dynamic Analysis Using Three-dimensional Finite Element Model in Case 3 (Tokyo Institute of Technology)[1]



Dispersal into Society

CAESAR is striving to apply and disperse the attainments obtained in the current research to society by capitalizing on various means—the reflection of these attainments on the design standards of bridges and the technical support of seismic reinforcing measures by means of public announcements of design guidelines employing these attainments.

Acknowledgment

The current research has been supported by Council for Science, Technology and Innovation (CSTI), Cross-ministerial Strategic Innovation Promotion Program (SIP), "Enhancement of societal resiliency against natural disasters" (Funding agency: JST). We offer our thanks to those of the Council for Science, Technology and Innovation who has supported our current research project. ■

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Estimation of Bearing Capacity of Steel Pipe Piles
—Measures for Improving Estimation Accuracy Employing Dynamic Loading Tests—

by Takaaki Mizutani
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Toward the Highly Accurate Estimation of Pile Bearing Capacity

Application of performance-based design in the technical standards follows an international trend. In light of this, performance-based design and reliability-based design approaches have been introduced in the *Technical Standards and Commentaries for Port and Harbor Facilities in Japan*[1] since its revision starting in 2007. Application of the reliability-based design approach allows for efficient structural design and an examination of advanced seismic resistance. However, an article concerning the pile bearing capacity (axial resistance) used in the Standards still remains within the framework of the safety factor method, and currently falls behind the entire system of the Standards. In order to establish a system that targets pile bearing capacity and takes reliability into account, it is necessary to collect data and prepare statistics pertaining to a number of piles.

For that purpose, it is necessary to implement loading tests for a number of piles in order to obtain the related data. However, the pile loading test is large in scale and greatly effects the construction cost and term, and thus the number of loading tests to be implemented is restricted. Meanwhile, dynamic loading tests are increasingly being adopted as a simple means of testing. In the construction of port and harbor facilities in Japan, there are many cases in which steel pipe piles are installed using hydraulic hammers, and this pile hammering method is well compatible with dynamic loading tests because the pile hammering device can be applied as the dynamic loading test device.

As a measure to improve the accuracy of estimates of pile bearing capacity using dynamic loading tests, loading tests were conducted using a number of piles to examine a method that evaluates the variation in pile bearing capacity and applies the evaluation results in the management of pile construction work, an example of which is introduced in the following.

Outline of Dynamic Loading Tests

The dynamic loading tests subjected to the current examination were conducted at the construction site for a coastal highway bridge located in Mizushima Port in Okayama Prefecture. Fig. 1 shows the location of the testing site, and Fig. 2 shows the longitudinal profile of soil confirmed in prior ground surveys. Plans call for the construction of a bridge near the mouth of the Takahashi River where it flows into Mizushima Port and of 19 bridge piers spanning the river width, which is about 1,400 m. As can be seen in Fig. 2, the soil stratum is approximately uniform in the bridge axial direction, and it was planned to adopt gravel layer Dg2 as the stratum to support the piles.

The dynamic loading tests were conducted at the planned construction position for the respective piers (indicated as P1~P19 in Fig. 2) and by changing the end shape of the piles (open-ended piles or cross-shape ended piles in which a cruciform rib plate was weld-joined to the inside of the ends of the open-ended piles) and the curing days (the time just after pile installation to 28 days) as well. The diameter of the test piles used was 1,000 mm and, while the pile embedded length (the length from ground surface to the pile end) slightly differs depending on the pier position, it ranged from 18 m to 24 m.

The test method followed the standard method specified by the Japanese

Fig. 1 Location of Testing Site

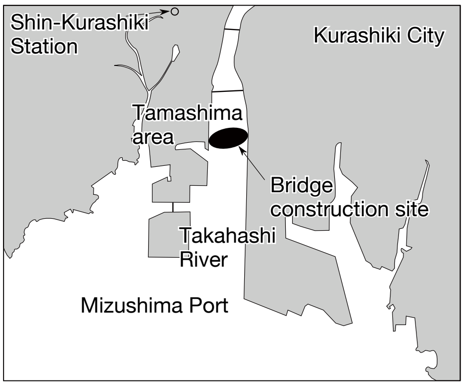
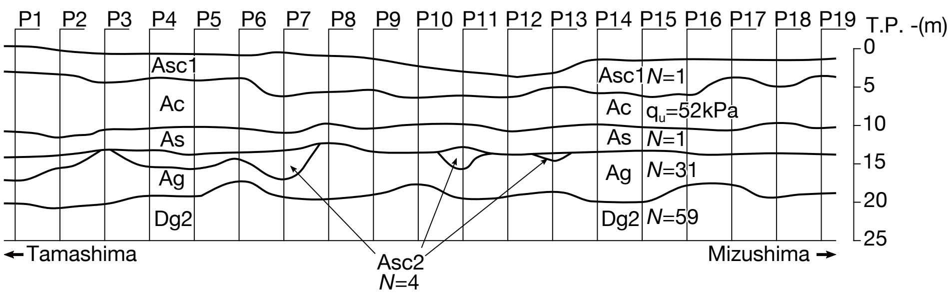


Fig. 2 Longitudinal Profile of Soil



Geotechnical Society[2], and the waveform matching analysis using CAPWAP was conducted for the data obtained using PDA to calculate the pile bearing capacity. Photo 1 shows the condition for dynamic loading testing, and Photo 2 the condition where sensors are pasted on the test pile (section encircled using while line). As regards the testing conditions, please refer to the existing literature[3].

Evaluation of Variations in Pile Bearing Capacity

Results of all 53 dynamic loading tests thus conducted were organized and then subjected to statistical treatment from various aspects[4]. In the following, examples of the evaluation of variations in pile point resistance are introduced.

Fig. 3 shows the distribution of pile point resistance obtained from the respective pier positions. When examining the figure, despite the piles being embedded in the same supporting stratum, it can be understood that the values for pile point resistance show a certain level of variation. Meanwhile, when noticing the data in which the number of curing days and the pile end shapes coincide with each other at an identical pier position (Fig. 3), the variations in pile point resistance look to be slight. Then, the statistical data thus obtained were classified by testing condition and compiled, the result of which is shown Table 1. As seen in the table, it is understood that the coefficient of variation (C.V.) is nearly 20% or lower when examining all piers, and nearly 10% or lower when focusing on specific piers.

Based on these results, specific concepts were shown that pertain to the characteristic values of the pile bearing capacity obtained from the loading tests, the method for determining the safety factors to be adopted when applying these characteristic values, and the practical application of that method. More specifically, it has been reported that the partial safety factor (resistance factor) for reliability-based design method can be increased (the redundancy in terms of safety can be decreased) by conducting the loading tests at the original pier position, compared to cases where the design was conducted by estimating the pile bearing capacity using common estimation formulas. To that end, it is being examined to reflect these specific results in the next revision of the *Technical Standards for Port and Harbor Facilities*.

Application of Dynamic Loading Test Results in Management of Piling Works

When steel pipe piles are driven by means of hammering in the construction of port and harbor facilities in Japan, there are many cases in which the pile driving work is managed employing Hiley's pile driving equation. While the aim of the equation is to estimate not only the pile penetration resistance from the penetration amount and rebound amount of the driven piles but also the pile bearing capacity, its estimation accuracy is very low. To remedy the situation, it is proposed that Hiley's equation be corrected based on the pile bearing capacity obtained from the dynamic loading tests and that the corrected equation then be applied in managing the piling work[5].

Photo 1 Condition of dynamic loading testing

Photo 2 Condition in which sensors are pasted on test pile

Fig. 3 Pile Point Resistance Obtained from Dynamic Loading Tests

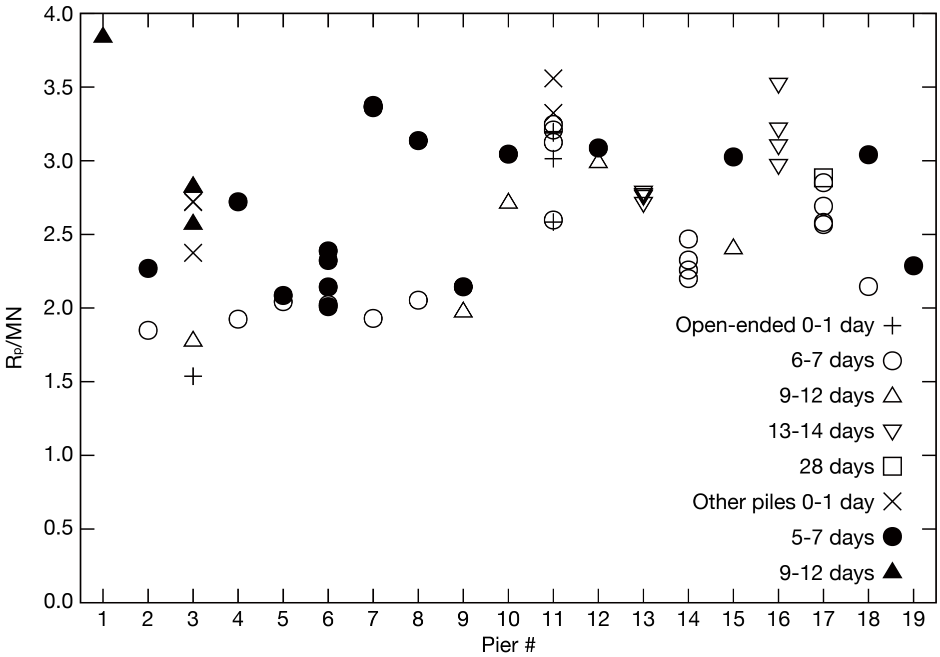


Table 1 Statistical Amount of Pile Point Resistance

Pier #	Pile type	Curing days	Sample size	Mean (kN)	C.V. (%)	Standard error
All	All cases	All cases	53	2650	19.2	69.9
All	Open-ended	All cases	33	2570	18.4	82.2
All	Cross-shaped	All cases	20	2790	19.6	122
11	Open-ended	6	4	3040	9.93	151
14	Open-ended	7	4	2310	5.02	58.0
17	Open-ended	6	4	2670	4.91	65.5
13	Open-ended	14	4	2760	1.18	16.4
16	Open-ended	14	4	3200	7.34	118
6	Cross-shaped	6	4	2220	7.75	86.0
7	Cross-shaped	6	4	3370	0.190	3.20

Fig. 4 shows the relation between the pile bearing capacity Rt obtained from the dynamic loading tests and the pile bearing capacity Rth calculated using Hiley's equation. As can be seen from the figure, both the loading test results and Hiley's equation calculation results have a nearly proportional relation. In the figure, while regression lines are shown that conform to the kind of hammers applied and the shapes of the pile ends adopted, the coefficient of variation (Rt/Rth) exactly exceeds 20%, thereby resulting in a great variation in the data. Accordingly, it is considered difficult to apply a corrected coefficient for Hiley's equation in all the bridge piers.

On the other hand, when we look at tests conducted at specified pier positions, many data comparatively come together at these specified pier positions as seen in Fig. 4, and accordingly it is considered feasible that a corrected coefficient for Hiley's equation can be applied to the piles of specified piers. That is, in cases when one loading test is conducted at a respective pile position, it is possible to conduct piling work management with high accuracy by making use of the data obtained from the loading tests.

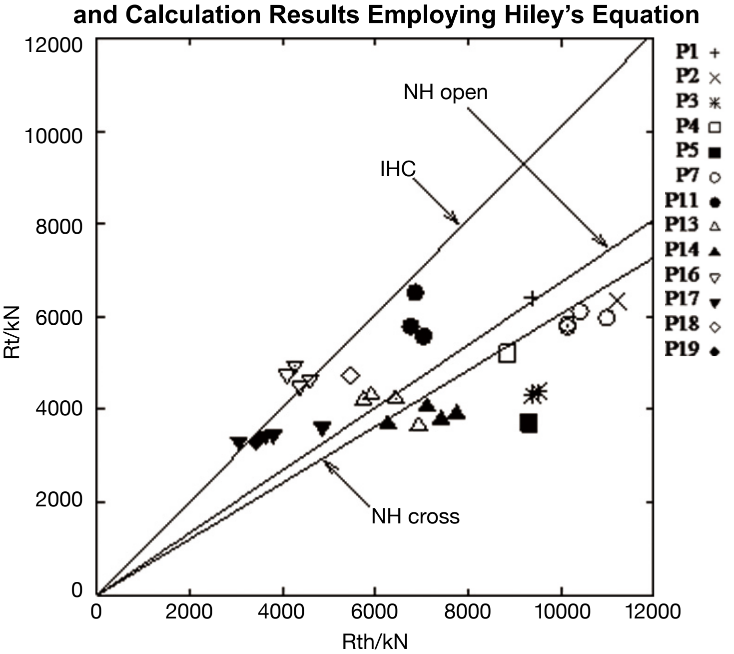
Photo 3 The Kurashiki Minato Bridge under construction at the testing site was completed and opened to traffic in March 2017 (foreground)

Development of Simpler Pile Testing Methods

In this article, diverse examinations are introduced on improving the accuracy of estimated pile bearing capacities and to manage piling work by making use of loading tests, which are being promoted toward the revision of *Technical Standards for Port and Harbor Facilities in Japan*. In order to enhance the reliability of the examination, it is effective to collect a large number of data pertaining to pile loading tests. Meanwhile, even if the accuracy of pile bearing capacity estimates can be enhanced, we can never forget that there is no method to confirm the pile bearing capacity with high accuracy other than to conduct a pile loading test at the original piling position.

Anyway, the development of a simple pile testing method like dynamic loading tests will offer a greater contribution to the structural design and construction of piles, and expectations are high for increasing adoption of dynamic loading tests and other simple pile testing methods.

Fig. 4 Comparison between Dynamic Loading Test Results and Calculation Results Employing Hiley's Equation



Meanwhile, at the site where the dynamic loading test introduced above was carried out, construction of a coastal highway bridge has made steady progress. Then, the completed bridge was named the Kurashiki Minato Bridge and opened to traffic in March 2017 (Photo 3). ■

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Evaluation of Ultimate Strength of Steel Pipe Piles in Liquefied Soil

—Ultimate Strength of Pipe Piles Used for High-rise Buildings in Liquefied Soil during Great Earthquakes—

by Yoshihiro Kimura
Professor, Tohoku University

Yoshihiro Kimura: After finishing the doctor's course at the Tokyo Institute of Technology in 1995, he served as professor at the Nagasaki University and the Tohoku University. He assumed his current position as Professor, Tohoku University (New Industry Creation Hatchery Center) in 2012. Among his recent awarding are Paper Awards of JSSC (Japanese Society of Steel Construction) 2009, 2014, Best Paper Award and Keynote Paper Award of GEOMATE 2012, 2016 and The Prize of AIJ (Architectural Institute of Japan) 2017.

Clarification of Pile's Dynamic Buckling Phenomenon

In the Great East Japan Earthquake of 2011, soil liquefaction occurred in a wide area including the Tokyo Bay coastal area more than 500 km from the focus of the earthquake[1]. Due to the soil liquefaction caused by the earthquake, many buildings suffered inclination damage. Meanwhile, in the upper stories of high-rise buildings, horizontal displacement measuring several meters occurred in the earthquake. And, the overturning moment of these high-rise buildings caused by the inertia force amounted to a value several times that of medium- and low-rise buildings, which means that reversed axial forces not assumed in the design stage occurred in the foundation piles used for these high-rise buildings.

In the coastal areas of big cities, many high-rise buildings are constructed on reclaimed land and soft ground near rivers. In cases when these buildings are subjected to a great and long-period earthquake such as the one mentioned above, the building and the liquefied soil cause resonance, and as a result, large reversed axial force works on the foundation piles (refer to Fig. 1). And, when the piles installed on a liquefied layer that has lost horizontal stiffness of the soil are subjected to a high axial compression force, flexural buckling of the piles is likely to occur.

In the current research, the flexural buckling phenomenon of steel pipe piles beneath high-rise buildings constructed on soil liquefied due to an earthquake is clarified by means of centrifugal loading experiments, and at the same time, the ultimate strength of these piles is evaluated by the use of buckling curves employing the modified equivalent slenderness ratio.

Centrifugal Loading Experiments for a Superstructure, Steel Pipe Pile-Liquefied Soil Model

The specimens are composed of a superstructure, steel pipe piles and soil as shown in Fig. 2. The dimensions of the specimens and the measurement positions are shown in the figure. The pile length in the model measures 265 mm (10.6 m in full-scale size). The specimen parameters cover the initial axial force of the piles, the plate spring length of the superstructure, the input seismic waves, and their maximum values (Table 1). The soil of the specimens was prepared by an air dropping method in which dry Toyoura silica sand is air-sprayed and accumulated. In order to saturate the soil, the "Metolose" solution (nonionic water-soluble cellulose) is adopted in which its viscosity is adjusted to 40 times that of water.

Fig. 1 Concept for Flexural Buckling of Steel Pile in Liquefied Soil

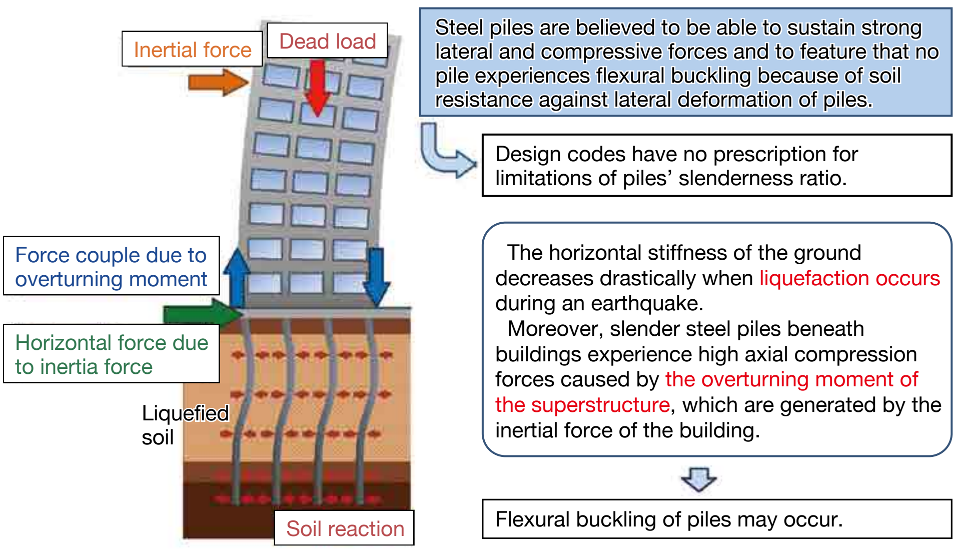
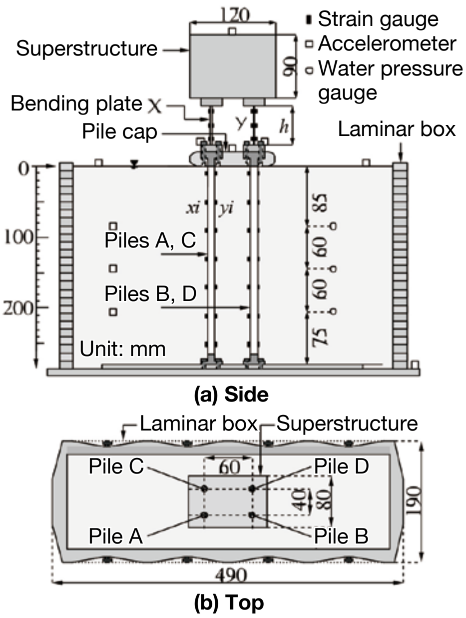


Fig. 2 Specimen and Instrumentation



Two waves are adopted as the input seismic waves: the coastal seismic wave as the simulated wave and the wave observed at Urayasu in the Great East Japan Earthquake of 2011. The centrifugal loading experiment was conducted at a 40g site using a centrifugal loading apparatus at the Disaster Prevention Research Institute of the Kyoto University. (Refer to Photo 1)

Fig. 3 shows examples of the centrifugal loading experiment results—(a) in the figure, response of the acceleration of the superstructure; (b): response of the excess pore water pressure ratio; (c): response of the axial force working on the piles; and (d) response of the bending strain of the piles.

In Fig. 3-(b), it can be understood from the water pressure gauges installed in three locations to the depth direction that soil liquefaction occurred through the entire layer in the neighborhood of the 16th second. In Fig. 3-(c), the maximum axial force working on the piles reached 1,582 kN in the neighborhood of the 22nd second (reversed axial force of 307 kN due to the response of the superstructure). In Fig. 3-(d), as regards the bending strain of the pile heads, the maximum bending increment strain reached its maximum level in the neighborhood of the 21st second, then the bending strain showed an upward trend in one direction to reach the maximum level in the neighborhood of the 26th second, which caused the collapse of the piles.

Photo 2 shows the condition of the final deformation of the pile specimens. Regardless of the length of the superstructure plate spring and the differences in the relative density of the soil, the steel pipe piles underwent large bending deformation underground, and the cross section of the piles caused yielding.

It was shown from the above experiment results that the steel pipe piles beneath the building are likely to cause collapse due to soil liquefaction occurring during a great earthquake[2].

Table 1 Specimen Parameters

Specimen	Initial axial force, N_0 (kN) (N_0/N_y)	Plate length h (mm)	Relative density Dr (%)	Input wave	Maximum input wave (m/s^2)
Case1-1	1275 (0.33)	35	30	Coastal wave	4.5
Case1-2			60		
Case1-3		55	30		3.0
Case1-4		70			
Case1-5			60		
Case1-6	856 (0.33)	35	30		4.5
Case1-7	1275 (0.49)				3.0
Case1-8				Urayasu wave	6.0
Case1-9		45		Coastal wave	3.0
Case1-10		35	45		

Evaluation of Ultimate Strength of Steel Pipe Piles

In order to evaluate the ultimate strength of steel pipe piles during dynamic buckling, firstly a formula for elastic flexural buckling loads applied to steel pipe piles in liquefied soil that are subjected to compression axial force is led using a variational principle based on the energy method, and secondly the modified equivalent slenderness ratio to which this elastic flexural buckling load formula is applied is adopted as a parameter to evaluate the ultimate strength[3].

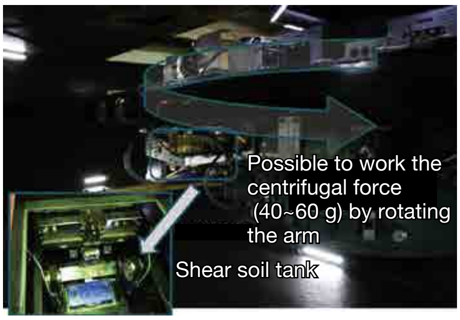


Photo 1 Centrifugal loading apparatus

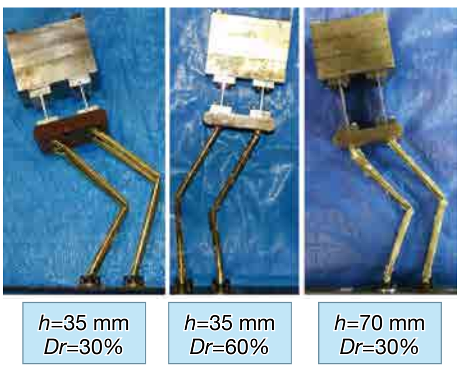
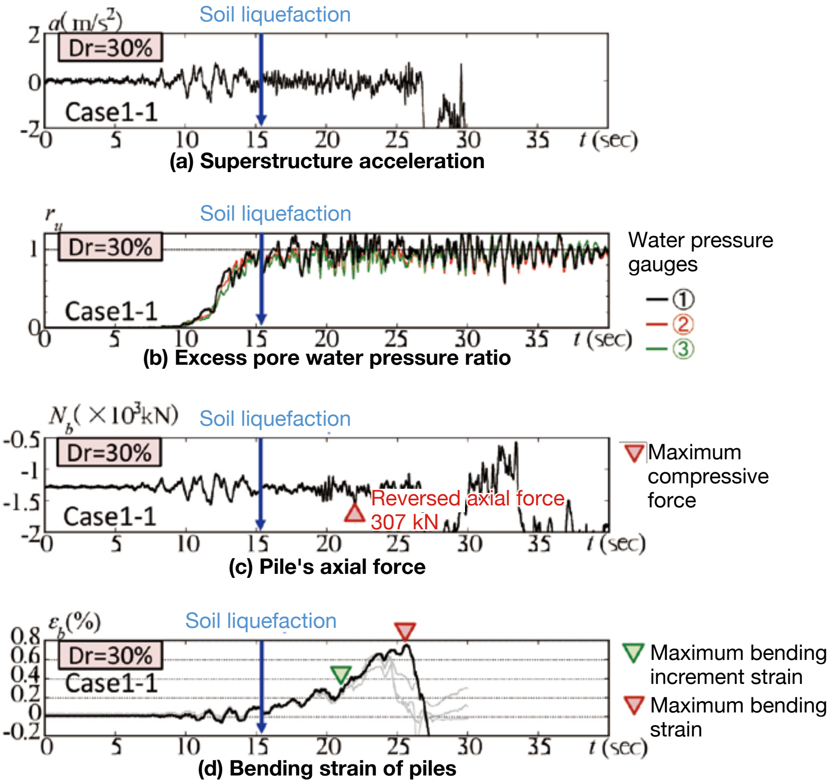


Photo 2 Bending deformation of piles

Fig. 3 Response Time History of Case 1-1



Then, the elasto-plastic flexural buckling strength of the steel pipe piles, obtained by means of the finite element elasto-plastic large deformation analysis and the centrifugal loading experiment mentioned above, are evaluated using the buckling stress curve (Fig. 4) that applies the modified equivalent slenderness ratio[4, 5]. Further, not only the centrifugal loading experiment results[2] are applied but numerical analysis is conducted for the single pipe pile model and the superstructure-pipe pile model[3] in order to evaluate the ultimate strength mentioned above.

As regards the dynamic buckling strength obtained from the experiment and numerical analysis, the buckling stress curve that applies the modified equivalent slenderness ratio can practically be evaluated as the lower limit for such dynamic buckling strength.

Further, in Fig. 5, the ultimate strength of the steel pipe piles in liquefied soil that are subjected to horizontal force and compression force is evaluated[6]. The vertical axis shows the ratio of the maximum compression force to the elasto-plastic buckling strength obtained from the buckling stress curve in Fig. 4, and the horizontal axis, the ratio of the maximum bending moment to the full plastic bending strength.

The respective curves in the figure show the M-N interaction allowable strength curve shown in the currently prevailing design guidelines in Japan and the ultimate strength curve obtained from existing research[6]. The mark + shows the numerical analytical results for a single pipe pile and other plots, the centrifugal loading experiment results; these plots are the major values from the time-history response of the piles to their collapse and are excerpted from the guidelines and experiment results. Of these values, the green plots are the values for axial force and bending moment in the case of the maximum bending increment strain found by the use of the strain gauges pasted to the pile heads, and the red plots are the values for axial force and bending moment in the case of the maximum bending strain at identical positions. (Refer to Fig. 5)

The strength in the case of the maximum bending increment strain (green plot) is held within the M-N interaction allowable strength curve shown in the currently prevailing design guidelines, and the ultimate strength in the case of the maximum bending strain (red plot) is held within the ultimate strength curve in existing research[6]. To these ends, the allowable strength of steel pipe piles and their ultimate strength can be evaluated using these M-N interaction allowable strength curves. ■

Fig. 4 Dynamic Buckling Strength and Buckling Stress Curves

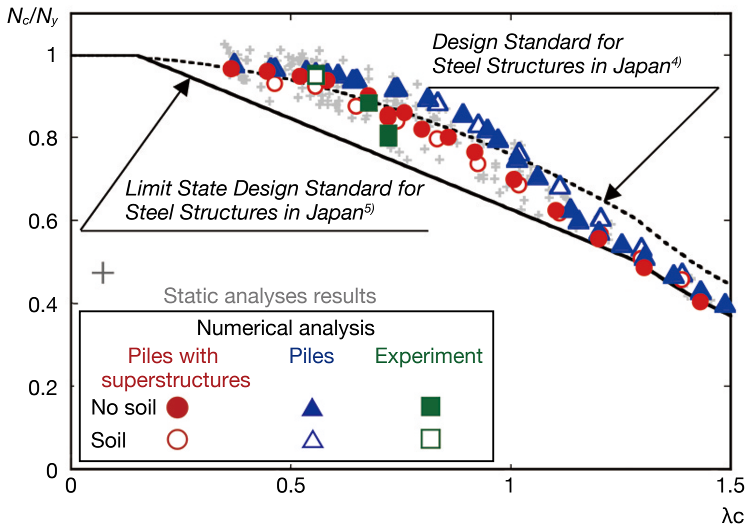
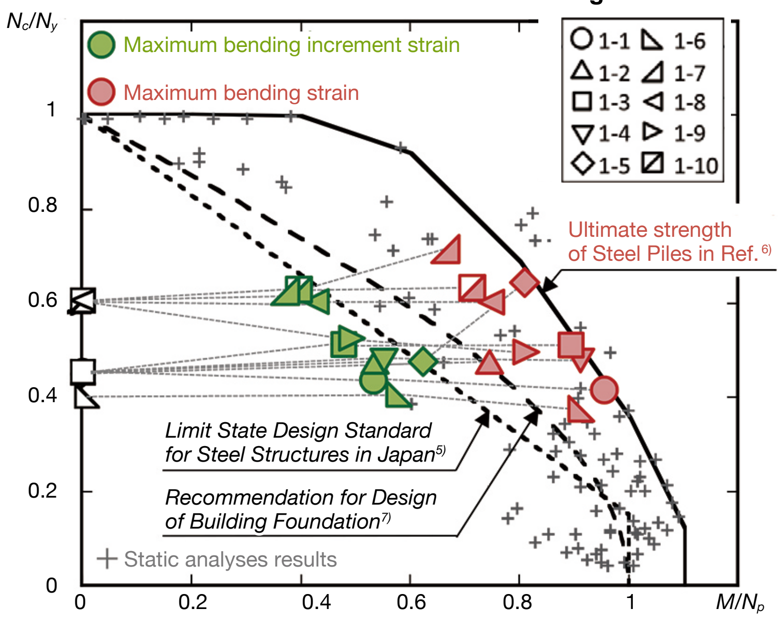


Fig. 5 Estimation of Axial Force and Bending Moment of Piles Using M-N Interaction Curves and Ultimate Strength Curves



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Study of Evaluation Method for Pile Stress during Earthquakes
—Towards Establishment of Secondary Design Method for Steel Pipe Pile Foundations—

by Katsuichirou Hijikata
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Purpose of the Study

In the construction of energy-related facilities and other similar important facilities, demand is growing for steel pipe piles that are high in toughness and offer high strength. In the seismic design of these piles that support such important facilities, it is necessary to confirm the safety of their application against two levels of seismic motions: level 1 seismic motion that has an occurrence probability of once or twice during their service period and level 2 seismic motion that has an extremely rare occurrence probability.

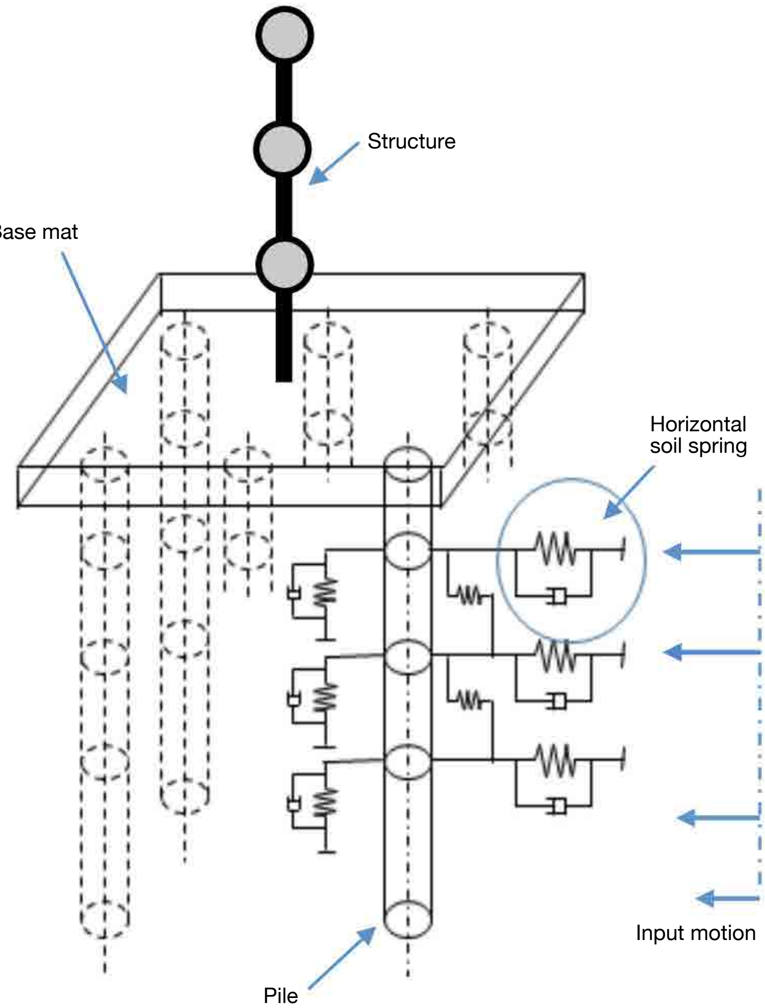
Because examinations of the safety for level 2 seismic motion are made from the standpoint of the ultimate limit of structural strength, it is necessary to appropriately evaluate nonlinearity up to the occurrence of large deformation of the ground and piles. However, at the current stage, it cannot be said that an approach for these examinations has been established. Targeting steel pile piles and other pile foundations having high toughness, the current study aims at establishing a method to evaluate the stress occurring in piles during earthquakes and the seismic response of structures by means of seismic response analysis.

Composition of Analytical Models
• Outline of Seismic Response Analysis Method

Fig. 1 shows an outline of the seismic response analysis method (EENA-Multi-PILE) for pile groups that was developed in the current study. This method adopts an integrated model that evaluates the ground−pile group−structure coupling effect. Herein, the pile group is modeled by every pile using a beam element, to which a horizontal ground spring is added that reflects the reaction force characteristics of the peripheral ground around the piles.

The horizontal ground spring serves as a model that can evaluate ground nonlinearity even with a large deformation of the piles. The seismic motion of the free ground at the pile's respective depth position in the ground is calculated, and the pile response is calculated by applying these calculated motions from outside of the horizontal ground spring.

Fig. 1 Outline of EENA-Multi-PILE (Seismic Response Analysis Method)



In the pile group, reciprocal effects between piles occur via the ground, and it is known that a phenomenon occurs in which the stress of the aft pile in the vibration direction becomes larger than the stress of the anterior pile.

In EENA-Multi-PILE, a method is adopted in which the pile stress, which differs depending on the position of each of the piles, is directly calculated by imparting a ground spring having different characteristics by pile.

• Study of Soil Spring around Piles

In examining the load-deformation relation of horizontal ground springs, which indicates the characteristic property of the peripheral ground around a pile, a Kishida-Nakai method[1)] of the bilinear type was adopted. With this method, the initial rigidity of pile peripheral ground is evaluated using a Francis ground spring to which an appropriate modulus of deformation is given, and the size of the ultimate ground reaction force (Pmax) is evaluated using the so-called "wedge formula."

In the Kishida-Nakai method, the method is not shown that applies the elastic wave exploration (PS logging) results that can precisely evaluate the dynamic characteristic of the ground. Then, we noticed the following description shown in the *Design Standards of Railway Structures and Commentaries—Foundation Structures* and settled the modulus of deformation to be used for the Francis ground spring.

→"The modulus of deformation equivalent to E_{50} (secant rigidity at the position 50% of maximum stress) is the value 0.1 times the modulus of deformation obtained from PS logging."

In the pile group, it is known that a phenomenon occurs in which the pile rigidity/pile is lowered due to reciprocal effects between piles. This phenomenon is a group effect of the piles, and the level of the effect is evaluated using the pile group coefficient of formula (1). In the current study, evaluation formula (2) using the pile group coefficient was proposed based on a recently conducted "three-dimensional nonlinear analysis" and on an "actual site experiment" for pile groups. In the formula (2), N indicates the number of piles, B the diameter of the piles, and S the space between the piles.

$$e=\frac{\text{Pile head rigidity of pile group}}{\text{No. of piles}\times\text{Pile head rigidity of single pile}} \quad \cdots\cdots(1)$$

$$e=1/N^{B/S}+0.2 \ (e\leqq 1.0) \quad \cdots\cdots(2)$$

Fig. 2 shows an example of a comparison of pile group coefficients between the proposed formula (2) and the three-dimensional nonlinear analytical results in the case of pile-to-pile space ratio (S/B) at 2.5. As seen in the figure, the pile group coefficient obtained from formula (2) coincides well with that of the existing analytical research.

Further, it is known that in the pile group, the difference in the value of "ultimate ground reaction force (Pmax)" occurs depending on the plane pile position. Then, targeting pile groups having an equal pile-to-pile spacing and arranged in a square form and based on the three-dimensional nonlinear analytical results for pile groups, we proposed a simple evaluation method for the standardized reaction force η indicated in the definition of formula (3)[2)]. With the proposed evaluation method, the difference between Pmax of the aft pile to the vibration direction and that of the anterior pile can simply be evaluated, and as regards the Pmax distribution, the distribution in the proposed method is to be applied.

Fig. 3 shows an example of the evaluation of η.

$$\eta=\frac{\text{Pmax of respective pile positions of pile group}}{\text{Pmax of single pile}} \quad \cdots\cdots(3)$$

Fig. 2 Evaluation Formula for Pile Group Coefficient (S/B=2.5)

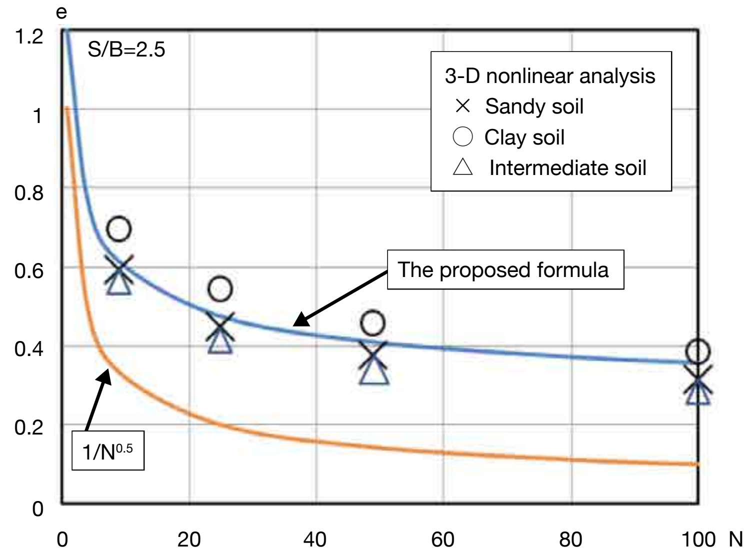
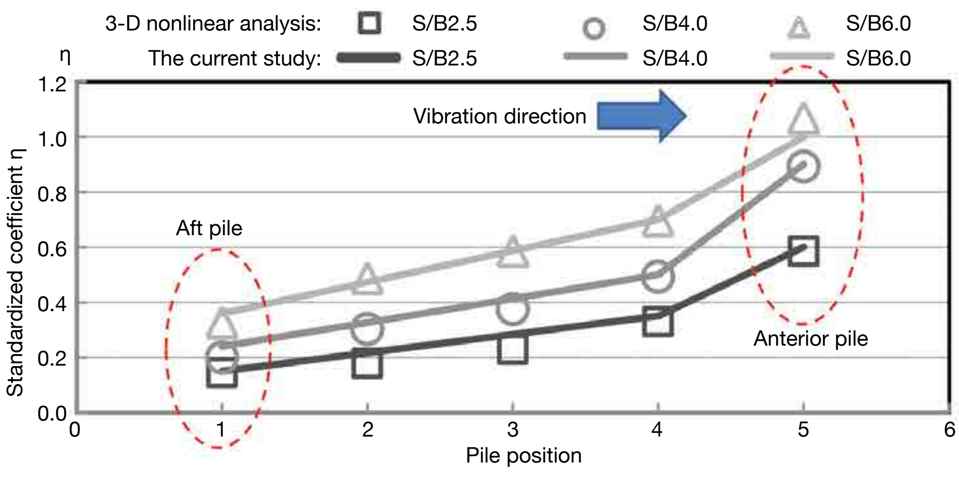


Fig. 3 Comparison of Standardized Coefficient η between Proposed Evaluation Formula and 3-D Analysis



• Proposal of Soil Spring around Piles

From the above, the soil spring around piles is proposed as shown in Fig. 4, and the evaluation is made based on the following:

- The skeleton curve of a single pile is based on the Kishida-Nakai method of the bilinear type. For the skeleton curve in the figure, a revision that considers the group effect of the piles is made using ξ and η.
- The modulus of deformation used for the Francis ground spring is evaluated using ($0.1\times E_{PS}$) based on PS logging.
- The rigidity of the horizontal ground spring of the pile group is decreased using the following formula.
  $\xi=(1/N^{B/S}+0.2)^{4/3}$
- The difference of Pmax depending on the position of each pile is evaluated using the proposed simple evaluation method for η. Meanwhile, as regards the Pmax of identical pile, a different value is adopted depending on the vibration direction: the value in the case of the aft pile (η+) and that in the case of the anterior pile (η–).

Analytical Results Obtained by Means of EENA-Multi-PILE

A seismic response analysis was conducted targeting an important energy-related facility of RC structure with a height of 8 m. The facility is supported using 25 steel pipe piles (600 mm in diameter) arranged in a square form and with a pile-to-pile spacing ratio (S/B) of 3.3. The ground is sandy two-layer ground composed of the surface ground layer with a thickness of 22 m and about Vs 200 m/s and the solid ground that supports the piles. For the input seismic motion, seismic motion was adopted that was obtained by multiplying by 2.5 the main shock at the Ofunato-bochi-S in the 1978.6.12 Miyagiken-Oki Earthquake (observed by Port and Airport Research Institute: Observation of Port/Harbor Area Strong Motion Earthquake).

Fig. 5 shows the maximum shear force and the maximum moment respectively for the center and corner piles. As can be seen from the figure, it was confirmed that the moment differs depending on the pile position.

Appropriate Evaluation of Pile Stress by Means of EENA-Multi-PILE

In the current study, we developed a seismic response analytical method (EENA-Multi-PILE) for foundations composed of pile groups. This method can appropriately evaluate the stress of piles and the response of structures. In the future, we plan to undertake a parametric study of the proposed method and the improvement of the codes necessary for this study. ■

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Fig. 4 Skeleton Curve Considering Group Effects of Piles

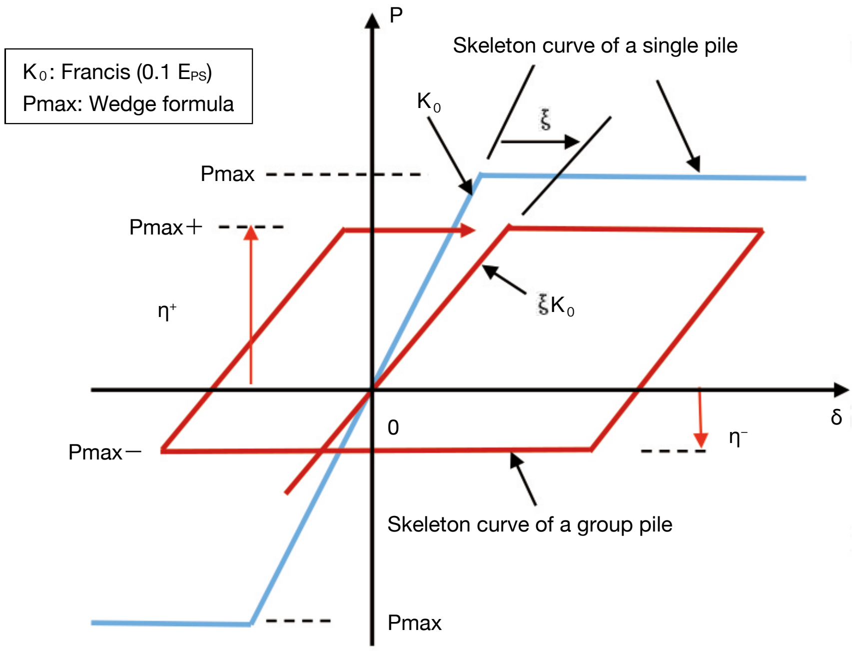
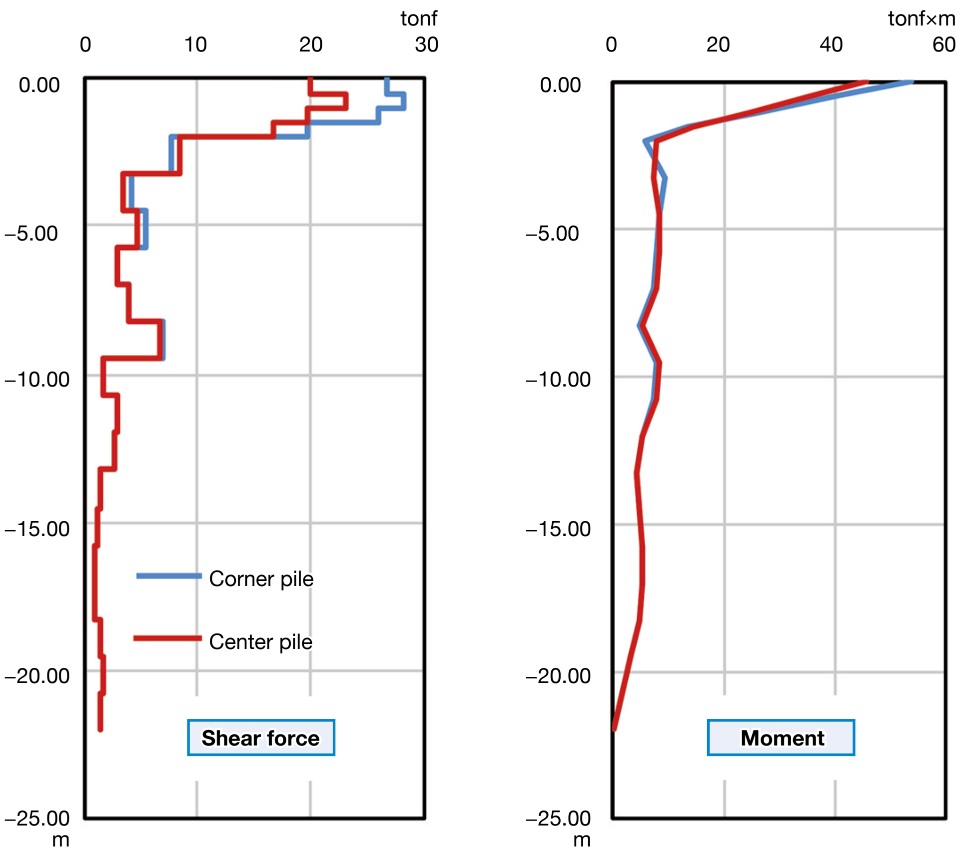


Fig. 5 Stress of Piles Evaluated Using EENA-Multi-PILE



How to Improve Social Infrastructure in Disaster-prone Areas

—Disaster Resilience and Lessons Learned from the 2016 Kumamoto Earthquake—

by Yoshiaki Kawata
Director of Research Center for Societal Safety Science
Kansai University

Yoshiaki Kawata: After finishing the doctor's course at the Graduate School of Engineering, Kyoto University in 1971, he became Professor in 1993 and Director of Disaster Prevention Research Institute in 2005, Kyoto University. He assumed his current position as Director of Research Center for Societal Safety Science, Kansai University in 2012.

Actual State of Infrastructure Damage due to the Recent Kumamoto Earthquake

When disasters occur, the most important measures are the restoration and reconstruction of damaged social infrastructure. As shown in Fig. 1, social infrastructure covers various kinds of "lifelines" (critical infrastructure), communications, logistics, public services and financial services.

In the recent Kumamoto Earthquake that occurred in March 2016, many pressing concerns arose particularly about logistics. Based on reflections of the Great East Japan Earthquake of 2011, the Japanese government extended push-type support and delivered 2.62 million meals to Tosu in Saga Prefecture, which is adjacent to Kumamoto Prefecture. While these relief supplies were supposed to be delivered from Tosu to 855 specified refuge sites in Kumamoto Prefecture by means of home delivery services, traffic congestion occurred in a wider area than anticipated and their delivery did not go smoothly.

The most notable reason for this adverse situation was that the expressways running from north to south and the trunk lines running from east to west in the Saga and Kumamoto areas were damaged so badly that traffic had to be suspended. In particular, highway networks were cut off and bridges gave way due to the large-scale collapse of slopes that occurred on the hillsides of Mt. Aso, a volcano in Kumamoto Prefecture (see Photo 1). This greatly hindered the practical execution of disaster countermeasures and the promotion of restoration work.

Furthermore, in this earthquake, even though traffic on ordinary roads was passable and congestion information was available on a real-time basis through car navigation systems, traffic congestion spread to a wider area and became

Fig. 1 Kinds of Social Infrastructure (once suffered from disasters, social functions come to a standstill.)

The following items are cited as social infrastructure:

- **Lifelines (critical infrastructure)**
Electricity, gas, waterworks, sewage, garbage, fossil fuel, transport (expressway, ordinary road, railway and air route)
- **Communications**
Communication (telephone, Internet), broadcasting, social network service
- **Logistics**
Supply of food, water and daily necessities
- **Public service**
Education, medical treatment, administration, crime prevention
- **Financial service**
Electronic transactions

Photo: Geographical Information Authority of Japan

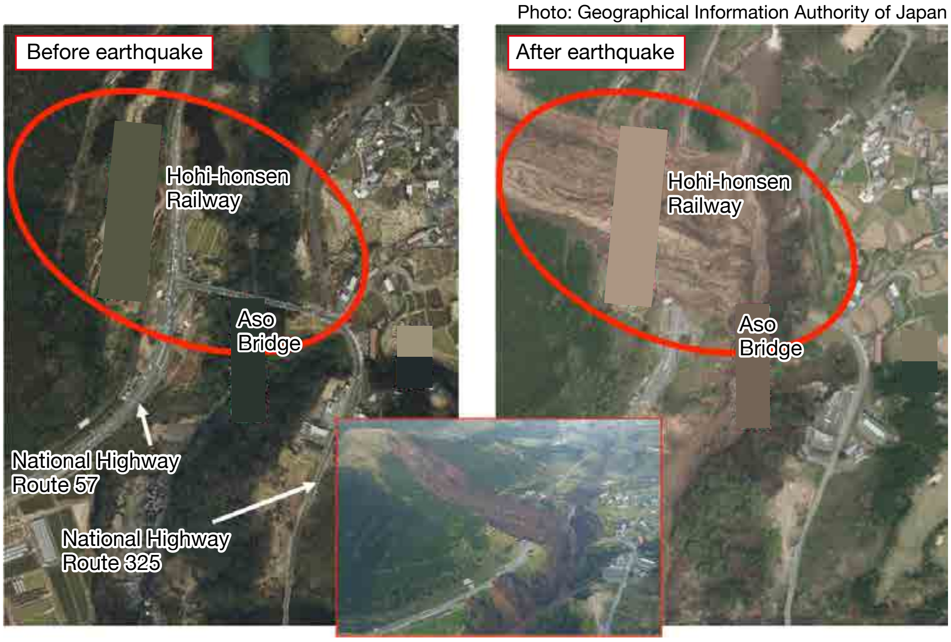


Photo 1 Suspension of traffic services at National Highway Routes 57 and 325 and Hohi-honsen Railway during Kumamoto Earthquake

worse than expected. As a result, many trucks that were loaded with relief supplies could not arrive at their target destinations for a long time.

Mainstreaming of Disaster Resilience and Reduction, and the Assumption of Worst Damage Scenarios

There is a word "disaster resilience." The term was translated by the Japanese government into "Building National Resilience." The translation is not quite appropriate, but the term "disaster resilience" has eight meanings and a wide context involved in social infrastructure improvement in disaster-prone areas. Fig. 2 shows the eight specific elements covered by that term.

Fig. 2 What Is "Disaster Resilience"?

"Disaster resilience" means not only the disaster control that reduces damages but an earlier recovery from disasters. The resilience relates to the following eight specific terms.

Flexibility	Responsiveness
Adaptability	Redundancy
Innovation	Rapidity
Robustness	Resourcefulness

Herein, what is important is how the eight elements are satisfied. When each of the eight elements are individually satisfied with social significance, it is called partial optimization, but when all eight are together satisfied, disaster resilience is totally optimized for the first time. Particularly in assessing benefits in the cost benefit (B/C) analysis of social infrastructure, it is necessary to assess new benefits to social infrastructure from the aspect of these eight elements.

In addition to the above, it is necessary to recognize that Japan has entered a new stage with regard to disasters. As regards storm and flood disasters, the characteristic features of typhoons and rainfall have recently shown notable changes due to global warming. The characteristics of earthquakes are also undergoing some changes.

Although these changes are not attributable to the time-like background, there have arisen many unknown and unclear factors in the earthquake phenomenon itself. Whenever an earthquake occurs, it shows a new fact. For example, in the recent Kumamoto Earthquake, aftershocks registering 1+ on the Japanese seismic intensity scale occurred 4,200 times in the year since the occurrence of the main shock on April 16, 2016, but the cause of these shocks has yet to be clarified. Accordingly, we may experience new earthquake tremors that we have not experienced with past earthquakes, which may bring about new hazards to us.

Given this situation, how should the improvement of social infrastructure in areas frequently struck by disasters be promoted? Specific measures to effectively deal with such tasks is organized in Fig. 3.

First, to capitalize on disaster resilience or assumption that a disaster will occur, measures should be implemented that prevent disasters to social infrastructure from occurring. To attain this goal, the concept of "mainstreaming disaster resilience" should be promoted. This is the greatest lesson learned from the Great East Japan Earthquake of 2011.

On top of this, the concept of mainstreaming disaster resilience is trending toward global diffusion. Both the International Monetary Fund and the World Bank are supporting the economic development of developing countries on the assumption of mainstreaming disaster resilience. The reason why is that, even when economic development is attained with the support of these agencies, certain problems may have already occurred in which economic development investment comes to nothing if a disaster occurs.

To prevent such a problem from occurring, it is widely known that it is necessary to pay due consideration to disaster-reduction investment right from the start of the planning stage. There is an international verity that an early investment of one dollar in disaster reduction yields six dollars in profit.

Then, it is also important to hold a roundtable conference with the participation of those working in the field of social infrastructure improvement and to find out the worst disaster scenarios in face of disasters. That is, it is required to write the scenario that practically images the worst disaster cases. Next, it is necessary to discuss how disaster risks can be avoided, mitigated or passed to, for example, insurance; and, to attain these goals, it is also necessary to quantify the risks.

To these ends, it is necessary to hold a roundtable conference with the participation of all stakeholders in order to share risk information, and then to identify the risks after the implementation of disaster countermeasures in order to guarantee the sustainable development of local communities.

Concepts Required for Improving Social Infrastructure in Areas of Frequent Disasters

The following measures are required to maintain expressway traffic in volcanic areas or in tsunami areas during earthquakes like the recent one in Kumamoto:

- Assumption of the scale of disasters, such as ground damage, that are likely to occur
- Change of transportation routes in cases when a large-scale disaster occurs
- Provision of transition sections in cases when medium- and small-scale disasters occur: for example, additional installation of interchanges, passing separation of the in and out bound lanes, advance installation of temporary roads on the assumption of disaster occurrence

Fig. 3 Prior Consultations Required for Promoting Social Infrastructure Improvement in Disaster-prone Areas

- In the disaster resilience conceived by assuming that disasters will occur, disaster-preventive measures aiming to improve social infrastructure are implemented right from the start of the planning stage (mainstreaming of disaster reduction).
- Not only the worst damage scenario but also all the scenarios of damages that are likely to occur are extracted to prepare specific damage images (scenario writing).
- Examinations are made of how a risk can be avoided, mitigated or passed to, for example, insurance (quantification of risks).
- A roundtable conference is held with the participation of all stakeholders to share risk information and to guarantee the sustainable development of local communities (identification of risks).

• New construction of ordinary roads with multiple traffic routes as a substitute for expressways; simultaneous maintenance and management of both newly-installed roads and ordinary roads with backup functions in a compatible system

In areas that are frequently struck by disasters, implementation of these measures is required in order to maintain highway traffic. (For more details, refer to Fig. 4)

Fig. 5 shows how to improve social infrastructure on the assumption that disasters on a national scale will occur, such as an inland earthquake in the metropolitan Tokyo area and a Nankai Trough mega earthquake that are both forecasted for the near future. Once such a mega-scale disaster occurs, it is widely accepted that the Disaster Relief Act that was enforced 70 years ago will fail. This act denotes a system in which the national or local or municipal governments will distribute all the necessities to people who temporarily reside in places of refuge just after the occurrence of a mega disaster. It is impossible for the current Disaster Relief Act to respond to such a request.

When large-scale disasters occur, self-help and mutual assistance are inevitably required for reconstruction and restoration after a disaster. And, even when the promotion of restoration and reconstruction efforts requires the use of public assistance, the financial and human resources are all too short. Meanwhile, it is regrettable to say that a national disaster will certainly occur. To cope with such a situation, it is absolutely required that a system of self-help, mutual assistance or industry assistance be routinely introduced in the course of social infrastructure improvements. That is, it should be recognized that the time has passed when social infrastructure improvement is undertaken by counting on public assistance.

As mentioned above, disaster resilience is a concept devised on the assumption that disasters will occur. To that end, it is essential to make a prior assessment of disaster risks particularly in areas that are frequently struck by or vulnerable to disasters. Another essential means is to dispel bottlenecks that will hinder the management of social infrastructure facilities during disasters. ■

Fig. 4 Example of Expressway Reinforcement in Areas Vulnerable to Disasters such as Volcanic Area and Tsunami Attacking Area

➡ The scale of ground damages and other disasters that are likely to occur is assumed.

➡ When large-scale disasters occur, the transportation route is changed.

➡ When medium- and small-scale disasters occur, transition section is provided. To illustrate: increase of interchanges, passing separation of the in and out bound lanes, advance installation of temporary roads on the assumption of disaster occurrence

➡ Instead of expressways, ordinary roads with plural routes are newly constructed to substitute for expressways.

➡ These newly-constructed roads and the ordinary roads with back-up functions are maintained and managed in a compatible system.

Fig. 5 How to Improve Social Infrastructure on the Assumption of National Crisis-scale Disasters

1 The spirit of the Disaster Relief Act established 70 years ago has failed, and when disasters occur, it is no longer the times in which all these disasters are restored by the use of public assistance.

2 Even if restoration of great disasters are planned by the use of public assistance, all of financial resources, human resources and information are entirely scarce.

3 However, national crisis-scale disasters will certainly occur in the near future.

4 Given such situations, a mechanism for applying self-help, mutual assistance and industry assistance (enterprise cooperation) systems should be routinely introduced in the improvement of social infrastructure.

5 Disaster resilience denotes a measure devised on the assumption of disaster occurrence.

6 It is indispensable to evaluate disaster risks especially in areas frequently attacked by disasters and vulnerable to disasters.

7 During disaster attacks, it is necessary to dispel the bottlenecks that lead to hindrance in management of social infrastructure facilities.

8 If these bottlenecks are to be dispelled, it is necessary to promote tie-ups and coordination among related administrative organs, but at the current stage it is nearly impossible to promote them and further new financial resources are unavailable.

9 It is therefore inevitable that those who will benefit should, as a basic principle, bear the expense to dispel the bottlenecks.

10 For expressways responsible for logistics in particular, it is inevitable to extend an industry assistance (private enterprise cooperation), but the current toll system is very political. To this end, a new benefit/cost concept is introduced.

11 The above can also be applied to the case of home delivery services in which highways are utilized as a virtual warehouse (because the road of an area equivalent to the size of a truck is occupied by a truck).

12 Further, because the delivery tax for light oil is cheaper than that for gasoline (a policy peculiar to Japan), truck transport becomes profitable in terms of cost.

13 An extremely high dependence (maldistribution) of logistics on highway transport offers a great risk during disasters.

14 It is necessary to change the policy so that the logistics be appropriately shifted to aviation, railway and shipping transport (uniform sharing of transport cost). However, the current application condition does not conform to a move to improve social infrastructure (ship transport particularly by means of coastal shipping is in a slump).

15 Currently, the increased cost required to pursue convenience is covered by an increased transport volume. It is necessary for us to recognize that this situation ultimately brings about an excess over-concentration in Tokyo.

Two Events for the Steel Cooperation Program of the Japan-Thailand EPA

As a link in the Japan-Thailand Economic Partnership Agreement: Steel Cooperation Program, the Japan Iron and Steel Federation (JISF) in collaboration with the Iron and Steel Institute of Thailand (ISIT) held two events at the beginning of 2017 in Japan.

• Program for Linkage between Steel Standards and Technological Regulation/Code

In order to enhance the capability to draft and certify standards in Thailand and to promote the application advantages of high-performance steel products for bridge construction, JISF carried out two programs in five days starting from March 6, 2017: lecture presentations and related site visits to a steel-frame fabrication plant of Tokyo Tekkotsu Kyoryo and to the National Institute for Materials Science.

A total of 16 persons participated in the programs, including people from the Thai Industrial Standards Institute, the Department of Rural Roads and the Department of Highways in Thailand, and steel companies in Thailand as well. The Thai participants highly rated the lectures and site visits regarding the application practices of steel product standards in Japan and "High-performance Steels for Steel Bridges."

Scenes of the Program for Linkage between Steel Standards and Technological Regulation/Code

• Program on Production and Safety Control

During 10 days starting from February 22, 2017, JISF held lecture meetings on diverse aspects of the Japanese manufacturing industry: the concept of *monodzukuri* (product making), equipment control, cost control, cost improvement and solutions for industrial safety and health and other tasks arising on the production floor. In addition to the lectures, a tour of related sites was held. They were attended by a total of 10 engineers from Thai steelmakers.

In the second week, a two-day study tour was made to three manufacturing plants in the Kita-Kyushu area, whereby the participants gained first-hand experience of production floors in the Japanese manufacturing industry. On the final day, a group discussion and report meetings were held to confirm the practical achievements of the various training courses mentioned above.

Fourth Steel Structure Conference in Cambodia

The Japan Iron and Steel Federation held a conference titled "Recent Technologies for Steel Structures 2016" in Phnom-Penh, Cambodia on December 9, 2016. It was jointly held by the Ministry of Public Works and Transport of Cambodia and the Institute of Technology of Cambodia, and was supported by the Embassy of Japan in Cambodia, the JICA Cambodia Office, JETRO PHNOMPENH and the Japanese Business Association of Cambodia.

The opening ceremony of the conference was held with the participation of the Acting Minister of Public Works and Transport and other distinguished guests. Subsequent to the ceremony, five lectures with themes on ports and harbors, bridges and building construction were delivered by experts from both Cambodia and Japan and were attended by about 160 engineers and university students from Cambodia.

Subsequent to the lecture, a small group session was held with the participation of key persons from both nations, where views were exchanged on the prospects for the diffusion of steel-structure applications in Cambodia. And, an introduction was also made regarding the support system for students studying in Japanese universities.

This conference was the fourth in the series, following those held in 2012, 2014 and 2015.

Scenes of the Fourth Steel Structure Conference in Cambodia

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