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DESIGN OF A TSUNAMI COASTAL LEVEE USING TRAPEZOIDAL CSG DAM TECHNOLOGY AND QUALITY CONTROL DURING CSG PRODUCTION (COASTAL OF HAMAMATSU CITY)*

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SUMMARY

In order to mitigate giant tsunami damage predicted to occur on the Hamamatsu City Coastline, a coastal levee higher than Level-1 Tsunami is being constructed about 17.5 km from Lake Hamana to the mouth of the Tenryu River. Here, Level-1 Tsunami is a tidal wave which occurs as the result of an earthquake of magnitude (M) 8 with the return period of roughly 100 year-150 year cycle along Suruga-trough and Nankai-trough. The planned coastal levee is located on a long sandy beach, parallel to a seaside protection forest on the north side. Its location imposed the design requirements for the conservation of valuable fauna and flora, and scenic appearance, and for the restoration of the seriously eroded shoreline. The levee of CSG (Cemented Sand and Gravel) placed at the center

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* *Conception d'une digue côtière de tsunami à l'aide d'une technologie de barrage trapézoïdal de type CSG et contrôle de la qualité au cours de la production du CSG (Côte de la ville de Hamamatsu)*

and surrounded with embankment are applied for raising the ground elevation of the seaside protection forest. The planned coastal levee is required to have tenacity enabling it to withstand overflow of Tsunami, but strength equal to that of a concrete structure is not needed, so a CSG structure, which has been developed by dam engineering, is adopted for the internal portion of the levee. Furthermore, the usage of ICT is also attempted to rationalize and advance quality control of CSG material.

Keywords: Quality control, Sound.

RÉSUMÉ

Afin de limiter les dégâts du tsunami géant censé se produire sur la côte de la ville de Hamamatsu, une digue côtière plus élevée que les tsunamis de niveau 1 va être construite à environ 17.5 km du lac Hamana, à l'embouchure de la rivière Tenryu. Ici, le tsunami de niveau 1 est un raz-de-marée qui survient à la suite d'un séisme de magnitude (M) 8 avec une période de retour d'environ 100-150 ans le long de Suruga et de Nankai. La digue côtière prévue est située sur une longue plage de sable avec une forêt de protection de bord de mer parallèle à ce côté nord. Compte tenu de la conservation des plantes et animaux précieux, du rivage sérieusement érodé et de l'aspect pittoresque du site, fondamentalement, le niveau du sol de la forêt de protection de bord de mer est élevé, le CSG (ciment, sable et gravier) est placé au centre de la section de la digue et les sections extérieures sont construites comme des digues de terre. La digue côtière prévue est tenue d'avoir une ténacité lui permettant de résister aux débordements dus aux tsunamis, mais une force égale à celle d'une structure en béton n'est pas nécessaire; par conséquent, une structure CSG, qui a été développée par l'ingénierie des barrages est adoptée pour la partie interne de la digue. De plus, nous essayons d'utiliser la technologie de l'information pour également rationaliser et faire progresser le contrôle qualité du matériau CSG.

1. INTRODUCTION

Terrace deposits and mudstone quarried at Mt. Akura in Hamamatsu City shown in Fig. 1 are used for CSG (Cemented Sand and Gravel) material, to achieve effective usage of material in the field, it is mixed with locally produced beach sands from excavation work executed to construct the coastal levee. To surely design and construct CSG structure on sandy ground, the results of plate loading tests, standard penetration tests, and Swedish sounding tests performed before the construction have been summarized and analyzed to develop a method of evaluating bearing capacity and the foundation elevation of CSG structure, which can be performed simply at the site. At this coastal levee, a new approach to the quality control of CSG was performed. Applying the new “Quality Control System” at the levee was a first step in improving and rationalizing “CSG material quality control” during placing of CSG. Rationalization in particular is counted on to lighten harsh labor and decrease costs by reducing manual test.

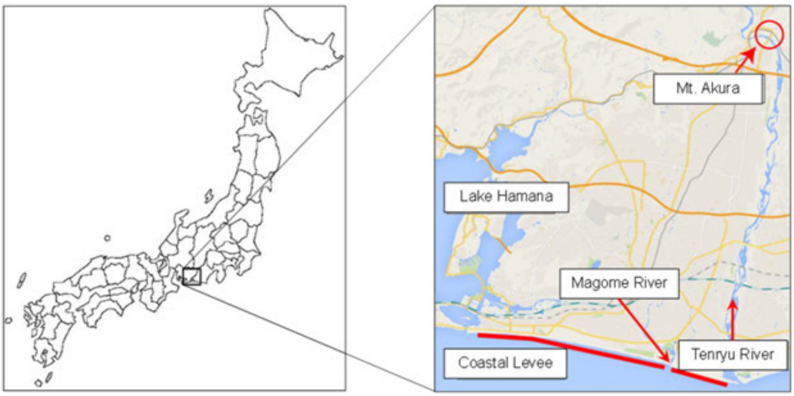


Fig. 1
Locations of the coastal levee and Mt. Akura
Emplacements des digues côtières et du Mont Akura

2. STRUCURE OF COASTAL LEVEE

2.1. BASIC CONDITIONS AND CHARACTERISTICS OF THE COASTAL LEVEE

The following are the basic conditions required for the construction of the Hamamatsu Coastal Levee.

First, the crest height of the coastal levee is basically T.P.+13.0m (Tokyo Bay mean sea level; Tokyo Peil, T.P.), which was determined from the height of Level-2 Tsunami as reference. The crest height is lower than that of Level-2 Tsunami. Here, Level-2 Tsunami is a tidal wave which occurs as the result of a disastrous earthquake of Magnitude (M) 9 with a return period of several thousand years, and which can cause enormous damage when it occurs. However, the levee body has been composed of CSG which is a tenacious structure to resist breaching against the overflow of sea water. CSG is made from cement, water, rocky materials, and has been developed as the new design and construction methods at dam engineering. CSG has the characteristics of the rapid construction and the usage of materials obtained from the vicinity of the field with less restriction [1].

Secondly, the coastal levee is located in a seaside forest reserve, which prevents the intrusion of blowing sand from the shoreline. Therefore, even after the levee is completed, it is necessary to restore the forest reserve to maintain its original protection function.

As the basic structure of the coastal levee, CSG with trapezoidal shape and wide levee base is located in the center, constructing embankments at each end to satisfy the above two basic conditions (see Fig. 2). Finally, the coastal levee has the following special characteristics.

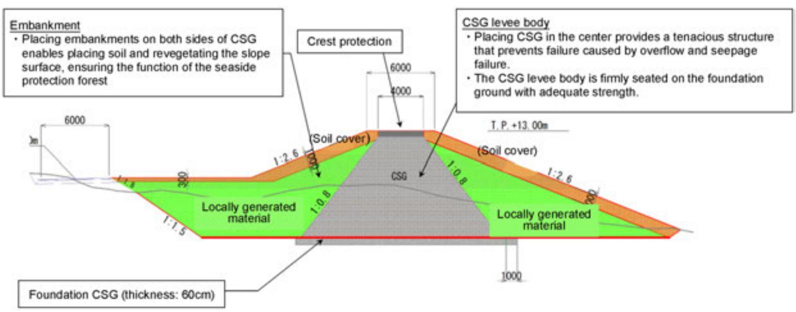


Fig. 2
Typical cross section of the coastal levee
Coupe tranceversale typique de la digue côtière

a) Forming a trapezoidal shape of CSG in the center lowers vertical reaction force of the structure base and reduces fluctuation of the basal reaction force by changeable load caused by earthquakes etc. Additionally, a highly rigid structure can be constructed on sandy ground. Furthermore, the trapezoidal shape basically helps it resist overturning.
b) CSG is, as a mixture of rocky material with cement and water, material with higher strength than foundation grounds and embankments made of earth materials, so a levee body composed of these materials can resist the failure by seepage or overflow.
c) As a result of the above factors, the levee structure with extremely large yield strength against Level-2 Earthquake and Level-2 Tsunami, which will come from Nankai megathrust earthquakes, can be constructed.
d) Once liquefaction or other deformation of the foundation ground is caused by an earthquake, CSG dam body will also naturally be deformed. But the levee body is composed of CSG and embankment, so it will be not destroyed

partially or completely by the succeeding tsunami. Therefore its reconstruction after the disaster will be performed relatively easy.

e) Embanking on both sides of CSG part will enable the soil-covering and revegetating the surface of levee, enabling the maintenance of the original function of the seaside forest reserve.

Based on the above conditions, the basic structure and shape of the coastal leveeareobtained as shown in Fig. 2.

2.2. STRUCTURAL STABILITY ANALYSIS OF THE COASTAL LEVEE

The stability analyses of the basic structure of the coastal levee shown in Fig. 2 considered I) stability of CSG body, II) stability against sliding through the foundation, and III) subsidence caused by foundation liquefaction. In cases where the above conditions were not satisfied because of insufficient strength of the ground, improvement measures for ground were investigated and the stability was confirmed. Specifically, the structure of the coastal levee was studied by the following steps as shown in Fig. 3.

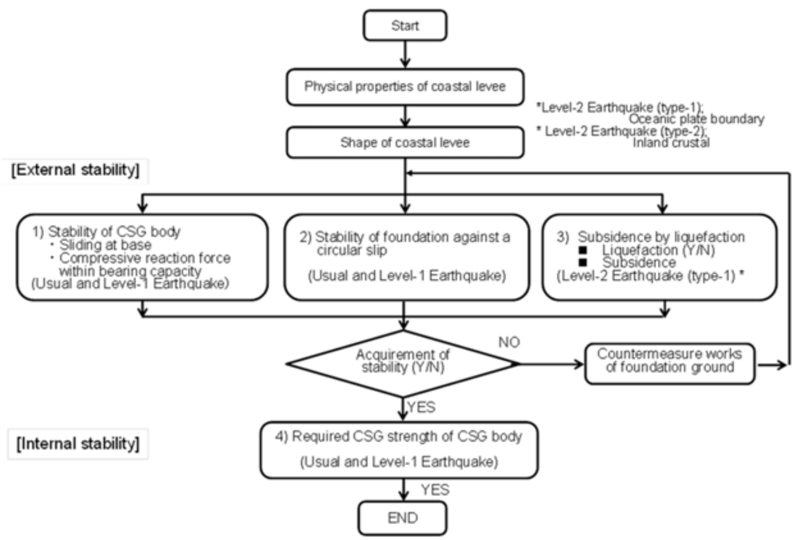


Fig. 3
Structure analysis flow
Flux d'analyse de structure

1) Stability of CSG body (Usual time, Level-1 Earthquake, see Fig. 4.)
2) Stability against circular slip throughout the foundation (Usual time, Level-1 Earthquake, see Fig. 5.)
3) Confirmation of the amount of subsidence caused by liquefaction (Level-2 Earthquake (type-1), see Fig. 6)
4) Required CSG strength of CSGbody (Usual time, Level-1 Earthquake, see Fig. 7)

In cases where the external stability analysis described in 1) to 3) cannotensure the stipulated safety due to insufficient strength of the foundation, ground improvement measures were studied.

Analysis will becontinued until the stabilities in 1) to 3) above are satisfied. Additionally, stabilities 1) and 2) were confirmed under Level-2 Earthquake (type-1) and Level-2 Tsunami.

Where, Level-1 Earthquake: Ground motion by earthquake that occurs rarely
Level-2 Earthquake: Ground motion by maximum credible earthquake (Type-1(L2-1 type); oceanic plate boundary, Type-2(L2-2 type); Inland crustal)
Level-2 Tsunami: Maximum class tsunami that causes serious disaster

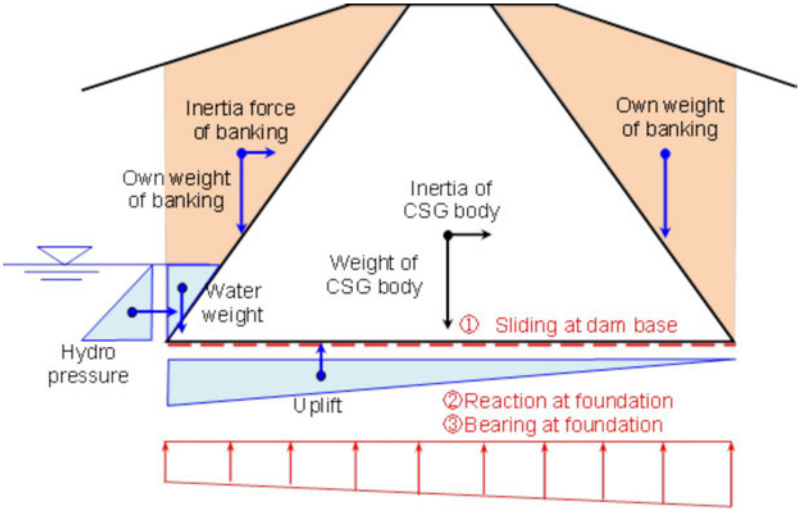


Fig. 4
Load condition at stability analysis of CSG body (external safety)
État de la charge à l'analyse de la stabilité du corps CSG (sécurité extérieure)

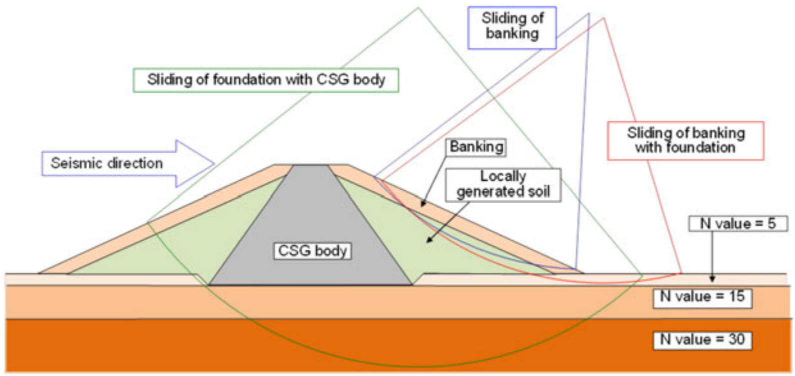
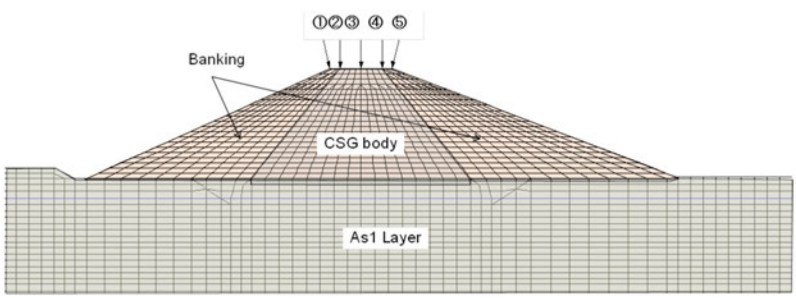


Fig. 5
Stability analysis of CSG body and foundation (external stability)
Analyse de la stabilité du corps CSG et de la fondation (stabilité externe)

Required CSG strength of CSG body was obtained as a study of internal stability. The calculation was performed by FEM for usual time and Level-1 Earthquake as shown in Fig. 7, obtaining required CSG strength of 192 N/mm². Two CSG mixtures of unit cement were applied corresponding to the height of CSG body as shown in Table 1.



#	Location at crest	Settlement (cm)
①	Shoulder of banking (sea side)	10.59
②	Crest of CSG (sea side)	9.04
③	Crest of CSG (central)	9.04
④	Crest of CSG (inland side)	9.04
⑤	Shoulder of banking (inland side)	10.59

Fig. 6
Settlement due to the liquefaction of foundation (external stability)
Règlement en raison de la liquéfaction de la fondation (stabilité externe)

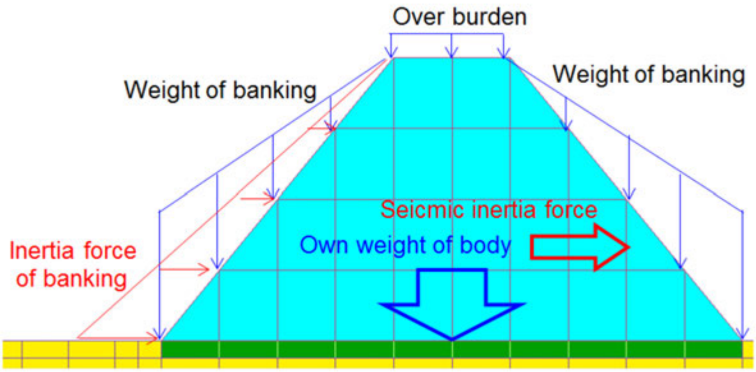


Fig. 7
Calculation of internal stress (Level-1 Earthquake)
Calcul des contraintes internes (Tremblement de terre de niveau 1)

Table 1
Mix proportion of CSG

Unit cement content at lower elevation	60 kg/m^3
Unit cement content at higher elevation	40 kg/m^3

3. CSG MATERIAL AND CSG STRENGTH

3.1. BLEND RATIO OF CSG MATERIAL

As CSG material, terrace deposits and mudstone quarried at Mt. Akura have been used. Each of sediments and mudstone is efficiently mixed with 20% or 40% of beach sands produced during excavation of the levee foundation [1], [2]. The blend ratios of materials from Mt. Akura and beach sands were set based on in-situ conditions and the properties of CSG etc.

1) The difference between the amount of materials obtained at the site (about 2 million m^3) and the amount diverted for use as banking material (about 1.4 million m^3), was approximately 600,000 m^3 and used as CSG material. This corresponds to about 30% of the total quantity of CSG body (about 2 million m^3).
2) Mudstone is rock debris and likely to be coarser than the terrace deposits in grain size, so basically, the blend ratio of in-situ beach sand is larger for mudstone.
3) From the mixing properties of CSG in laboratory test, the upper limit of the blend ratio of in-situ beach sand to mudstone is judged to be about 40%.
4) The quantity produced in the area between Lake Hamanaand Magome River forming sand dunes, is larger than that between Magome River and Tenryu

River. Transporting material across the Magome River is difficult for a heavy environmental load on the region.

Considering the above conditions, basic blend ratios were set as:

- Terrace sediment : In-situ sand = 80 : 20
- Mudstone : In-situ sand = 60 : 40

In a case where mudstone is used at the construction area between Tenryu River and Magome River, the following blend ratio was adopted because of the shortage of in-situ sand.

- Mudstone : In-situ sand = 80 : 20

Fig. 8 shows the grain size distribution of CSG after blending.

3.2. CSG STRENGTH

Standard cylindrical specimens (15 cm in diameter and 30 cm in height) with CSG mixed at a unit water content of 100 to 130 kg/m^3 were prepared, then, compressive strength test of the specimens ware performed to obtain the diamond-shape of CSG. The tests by standard specimen were carried out according to, “Trapezoid CSG Dam Design, Execution, Quality Control Technology Document” [3]. CSG strength in the coastal levee was evaluated by calculating peak strength (compressive strength) similarly to that in concrete.

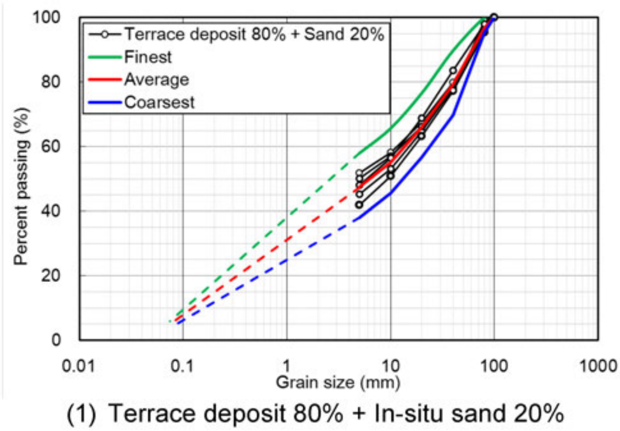
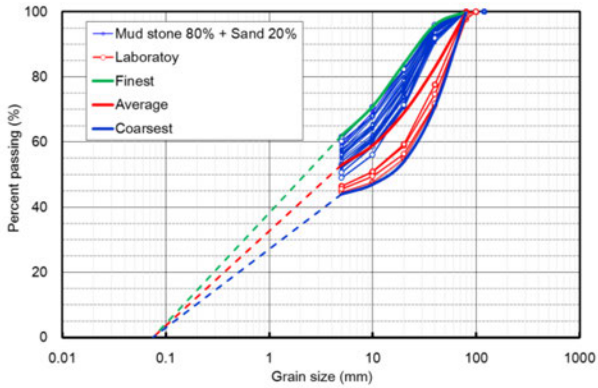
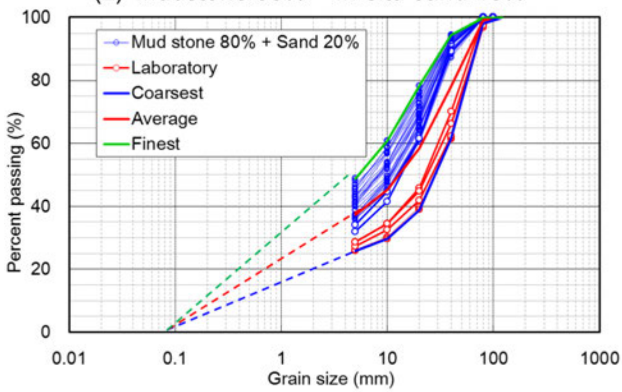


Fig. 8
CSG materials (Grading after blend)
Matériaux CSG (nivellement après mélange)



(2) Mudstone 60% + In-situ sand 40%



(3) Mudstone 80% + In-situ sand 20%

Fig. 8
CSG materials (Grading after blend)
Matériaux CSG (nivellement après mélange)

Table 2 shows the test results of CSG strength using standard specimens for each cement content using each CSG material, and Fig. 9 shows the diamond shape of terrace deposit 80% + In-situ sand 20%.

Table 2
CSG strength by standard cylindrical specimen

RAW MATERIALS USED	UNIT CEMENT CONTENT (KG/M³)			
	80	60	50	40
Terrace deposit 80% + In-situ sand 20%	—	2.34	1.91	1.64
Mudstone 60% + In-situ sand 40%	1.60	1.26	0.93	0.65
Mudstone 80% + In-situ sand 20%	2.94	1.70	—	0.71

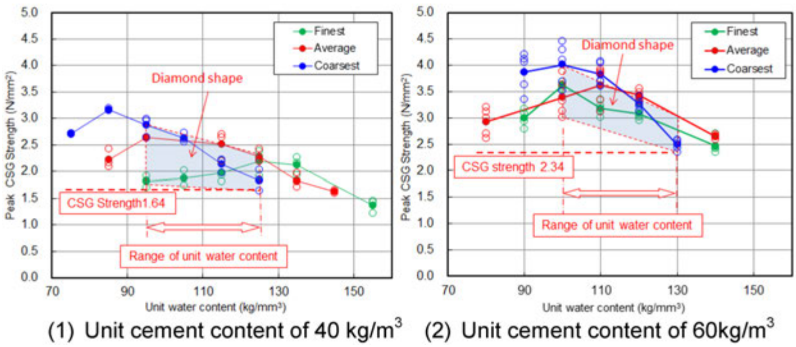


Fig. 9

Diamond shape by standard specimen (terrace deposit 80% + sand 20%)

Losange de spécimen standard (terrasse de dépôt 80 % sable 20 %)

4. FOUNDATION EXCAVATION

4.1. PRELIMINARY SURVEY

In order to directly confirm the bearing capacity of the ground, a plate loading test was carried out during a preliminary inspection and trial execution. A boring survey and Swedish weight sounding test were performed at the same time as the plate loading test, comparing the bearing capacity obtained from the plate loading test with the N-value. Fig.10 shows the positional relationship of the tests and the test procedure is shown below [4].

The allowable bearing capacity at N-value of 15, is 273 kN/m^2 as the median value in the correlation zone, so here, the allowable bearing capacity at N-value of 15 is set at 270kN/m^2 (Usual time) and 405 kN/m^2 (earthquake time). The bearing capacity of 405 kN/m^2 at earthquake timeis 1.5 times as much as that of 270 kN/m^2 at usual time.

1) A standard penetration test (SPT) was executed on the initial ground surface (ground surface of the original topography) at the same time as the boring survey, to measure the N-value at each depth.

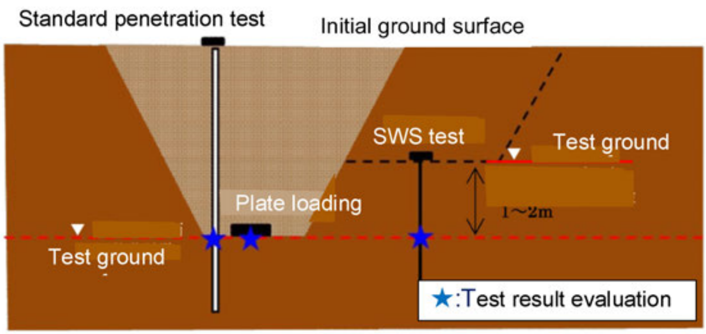


Fig. 10
SPT test, Plate loading test and SWS test
Test SPT, test de chargement de plaque et test SWS

2) The original ground is excavated to perform the plate loading test. The plate loading test is carried out on each ground surface which is lowed every 1 m by stage in order to compare the result with the N-value measured by SPT.
3) The Swedish weight sounding test (SWS test) is done near the same location as the boring and plate loading test. This test is also done in a same manner as the plate loading test.

Regarding the bearing capacity of the foundation ground, the relationship of the allowable bearing capacity obtained by the plate loading test performed in-situ with the N-value at the adjacent boring was arranged as shown in Fig. 11.

4.2. Survey during construction

During construction, the SWS-test was done at 25m long intervals along the axis of the levee, confirming that the required bearing capacity could be obtained. The SWS-test was influenced by looseness near the ground surface, but it clarified by a preliminary survey that test results with the earth covering of 1 to 2m or thicker conform to the values of SPT as shown in Fig. 12. Therefore, as shown in Fig. 10, the SWS-test was done when the excavation had reached 2m above the planned foundation ground, and the excavation was continued till the required bearing capacity near the planned foundation ground elevation was confirmed.

4.3. Ground improvement work

According to SWS-test results during execution, in cases where the elevation with the required bearing capacity (N value of 15 or higher) is partially lower than that of planned foundation ground, the ground improvement work was performed to ensure the stipulated bearing capacity.

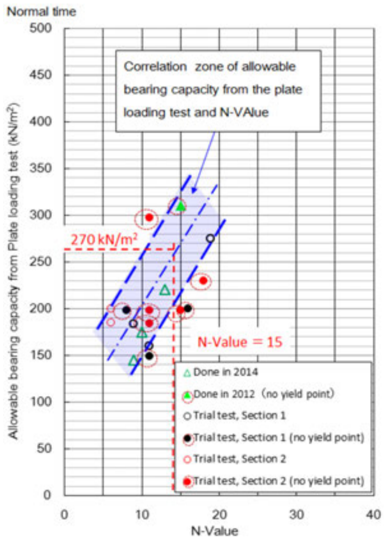


Fig. 11
Relationship of N-value and bearing capacity from plate loading test
Relation valeur N et capacité portante de la plaque de test

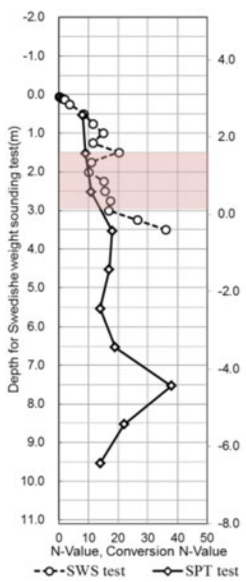


Fig. 12
Relationship of SWS test results and N-values of standard penetration test *Relation des résultats des tests SWS et des valeurs N du test de pénétration standard*

The ground improvement method was basically replacing the foundation with good quality sediment. The replacement was accompanied by the shallow mixing method in cases where the soft layer is thicker than 3 m (see Fig. 13). Additionally, in cases where the groundwater is shallow and it is difficult to achieve adequate compaction under the existence of water springs, even if the soft ground is thinner than 3 m, the shallow mixing method was applied. The layout of the ground improvement equipment is shown in Fig. 14.

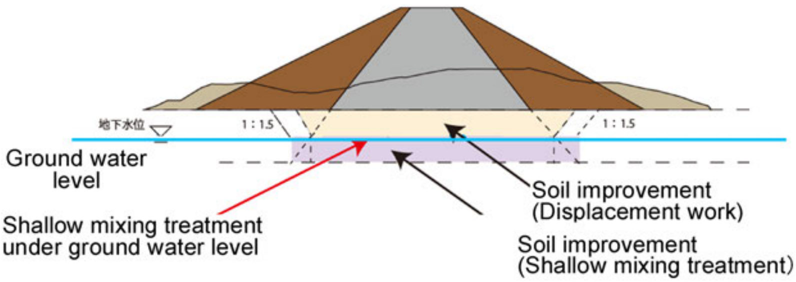


Fig. 13
Soil stabilization method and depth of stabilization
Méthode de stabilisation de sol et profondeur de la stabilisation

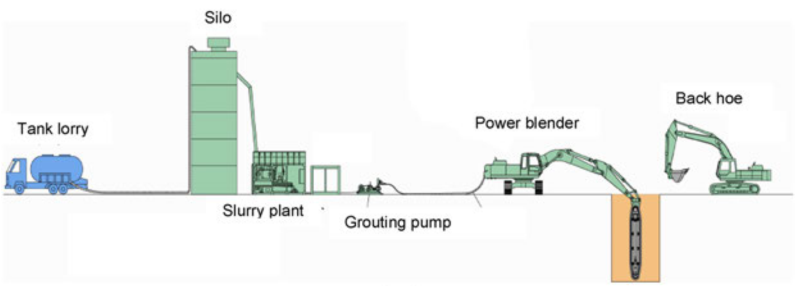


Fig. 14
Equipment of soil stabilization and its arrangement
Équipement de la stabilisation des sols et arrangement

5. QUALITY CONTROL

5.1. Quality control test

Quality control of CSG is performed according to the reference [3].

5.1.1. Quality control of the raw material

The raw materials of terrace deposits from Mt. Akura and in-situ beach sand produced in the vicinity were used inthe sectionof the trial execution work. The terrace deposits were screened to remove largergrain size over 80 mm from the excavated material, then transported to the work field. The quality control of the raw material was performed to confirm its density, water absorption, grain shape of gravel by visual observation and the hardness of the gravel by hammer tapping.

5.1.2. Quality control of CSG material

Quality control of CSG material also confirmed density, water absorption, the distribution of grainsize, surface moisture content at the primary and secondary stock piles. In the trial execution work, a blend of terrace deposits and the in-situ sand was tested to use as CSG material.

5.1.3. Quality control of CSG materials and of CSG

Quality control of CSG materials and of CSG during placing was performed as described below.

1) Controlling CSG material: The grain size and surface moisture content of CSG material were controlled. Measurement intervals were principally performed once an hour.
2) Weight measuring control: The control of CSG material, water, cement was done by automatic measuring control devices on CSG mixer (self-propelled soil improvement machine) during CSG production.
3) Control at the placing field: During placing, the number of roller compaction by the vibrating roller was controlled to obtain the required compaction energy. After roller compaction, the RI (Radio isotope) method and sand replacement method are used to measure the in-situ density, confirming that the quality of CSG is not changed by the placing work.
4) Confirmation using specimens: The strength fluctuation trend of CSG was surveyed based on 7-day compressive strength of the standard cylindrical specimens prepared with CSG produced in the field, confirming that the quality does not change. Simultaneously, large-scale specimens (30 cm in diameter and 60 cm in height) were prepared to confirm the relationship between its density and the in-situ density (sand replacement method).

Table 3 shows items and test frequency of the quality control. Quality control of CSG partially consists of the quality control of CSG materials. The rationalization and improvement of quality control of CSG materials using ICT (Information and communication technology) are described at the following section.

5.2. Quality control of csgmaterials

5.2.1. Quality Control System

The Quality Control System is an automatic quality confirmation system installed on the in-situ production plant in order to rationalize productivity of CSG quality control. Quality control performed manuallycan be rationalized applying ICT [5].

Fig. 15 shows the flow of measurements by the Quality Control System. At the Hamamatsu Coastal Levee, there is the main line of a conveyor belt for transporting mudstone or terrace deposits (CSG material II)to the mixer and a branch line that supplies in-situ beach sand produced in the vicinity (CSG material-I) to the main line. Each line is equipped with a microwave moisture meter to measure moisture content of each CSG material. A separate system that takes the mudstone or terrace deposits (CSG material-II) from the main line at the certain interval is installed, and the moisture content of CSG material-IIwas measured by microwave moisture meters installed on the separate line.

Table 3
Items and frequency of quality control

	ITEMS CONTROLLED	MEASUREMENT METHOD	MEASUREMENT FREQUENCY
Control of raw material	Weathering, hardness	Visual, Hammer diagnosis	Once / day
	Grain shape	Visual	
	Saturated – surface dry density and absorption content	Density and water absorption test	Once / week
	Grading	Dry method	
Control of CSG material	Saturated – surface dry density and absorption content	Density and water absorption test +5mm JIS A1110 -5mm JIS A1109	Once / day
	Grading	Dry method, JIS A 1102	
	Surface water content	Dry method, JIS A 1125	
Control of CSG material and CSG	Grading	(Manual) simple method	Once / hour
	Surface water content	(Manual) simple method (water content)	Once / hour
	Weight measuring control	Measuring device of mixture	Real time
	Compaction energy control	Tracking control of roller compaction machine	Real time
	In-situ density	RI method, Sand replacement method	Once (3 points) / day
	Specimen strength and density	Large-scale specimen density	One set / day (3 specimens)
		Large-scale specimen (age of 27 days, compressive strength test)	
		Standard specimen (age of 7 days, compressive strength test,)	

The grain size distribution of CSG material-II is measured by imaging and image processing in the dark-room. The Quality Control System can automatically calculate the surface moisture content of CSG material using of these measurement results. The mixture of CSG is corrected based on the surface moisture content of CSG material, and the amount of water supplied to CSG is adjusted as needed. The Quality Control System permits confirmation of the quality quickly at the rate of once per 15 minutes. The continuous correction of CSG mixture can allows the improvement of the quality control of CSG if necessary.

5.2.2. Grain size distribution

Grain size distribution is measured applying image processing technology [5]. The equipment includes imaging apparatus (high performance digital camera), personal computer, lighting apparatus, a conveyor belt that disperses, and separately transports CSG material measured, and equipment that drops CSG material down to image each grain clearly. Basically, at certain intervals, CSG materials are separated from the main line of a conveyor belt and imaged with a digital camera, then, the image is processed. Finally, the grain size distribution of the materials was estimated by statistically processing the parameters shown in Fig. 16.

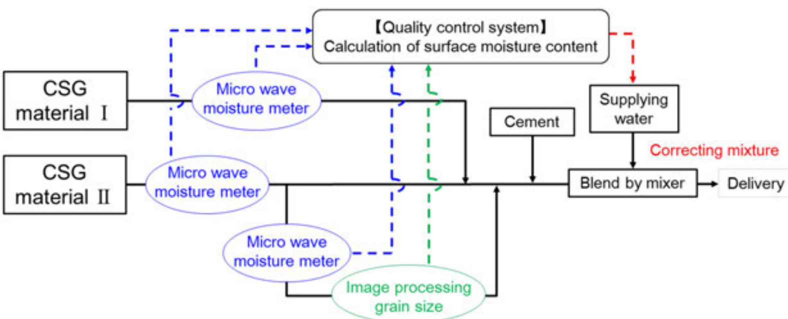


Fig. 15
Quality control system
Système de contrôle qualité

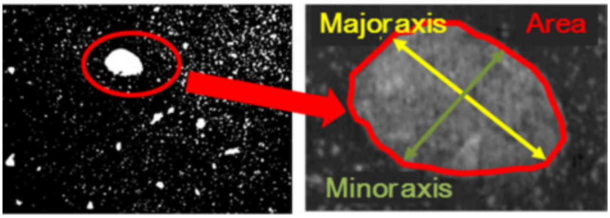


Fig. 16
Parameter for image processing
Paramètre de traitementd'image

The influence of the unevenness of grain size distribution of CSG material to the estimation by this system was investigated. The study was performed using terrace deposits with their grain size adjusted to finest grain size, average gain size and coarsest grain size. But the moisture content is fixed. Fig. 17 shows the comparison of the estimated and the known grain size distributions and it is confirmed this system estimates the grain size very well

5.2.3. Surface moisture

The total surface moisture content of CSG material is obtained by summing up the surface moisture content for each grain size category. The surface moisture content is calculated by measuring moisture content of CSG material. Moisture content is measured using the microwave moisture meters which are non-contact measuring devices and having the characteristics that their microwaves are absorbed by water. Fig. 18 shows the measurement principle of the microwave moisture meter and a schematic diagram of calculation of the moisture content.

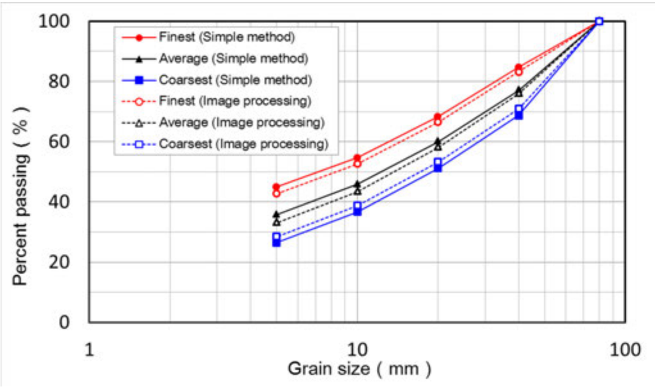


Fig. 17
Comparison of grain size distributions
Comparaison des distributions de taille de grain

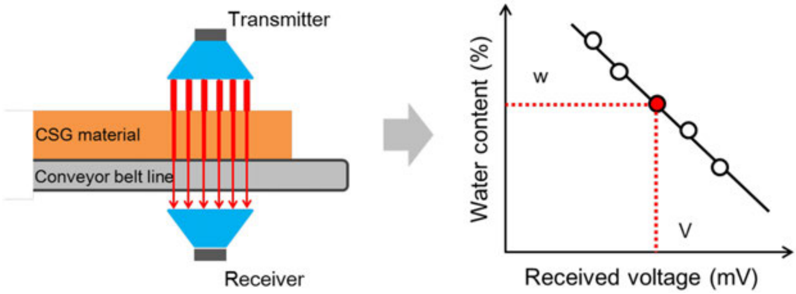


Fig. 18
Microwave moisture meters and their measuring principal
Appareils de mesure de l' humidité à micro-ondes et leurs principales mesures

Microwaves are electromagnetic waves with wave length from 1 m to 1 cm, and frequency ranging from 300 MHz to 30 GHz. During measurement, the microwaves attenuate as they pass through the material containing the moisture. Obtaining the received voltage (Mv) by the microwaves for a specimen with known moisture content, permits measurement of the moisture content of the materials used. Fig. 19 shows the relationship between the moisture content of CSG material by dry method and that by a microwave moisture meter.

5.3. Results of trial operation with an in-situ production plant

An element test of the Quality Control System described above verified that it can measure moisture content and grain size distribution of material. In this section, the measurement of surface moisture content and grain size distribution of CSG material is described using the Quality Control System attached to the in-situ production plant. The data used for this study is covering an approximately 1 month actual construction in April 2017 and mudstone was used as CSG material-II in this construction period. Figure 20 shows temporal change of the percent passing of each grain size of CSG material. In the current manual simple method, the same materials are sampled from the materials measured by this system. Figure 21 shows temporal change of total surface moisture content obtained from the manual simple method and from the Quality Control System. Figs. 20 and 21 showthat the Quality Control System presumably can clarify very wellthe change of surface moisture content and grain size distribution obtained from the current manual simple method.

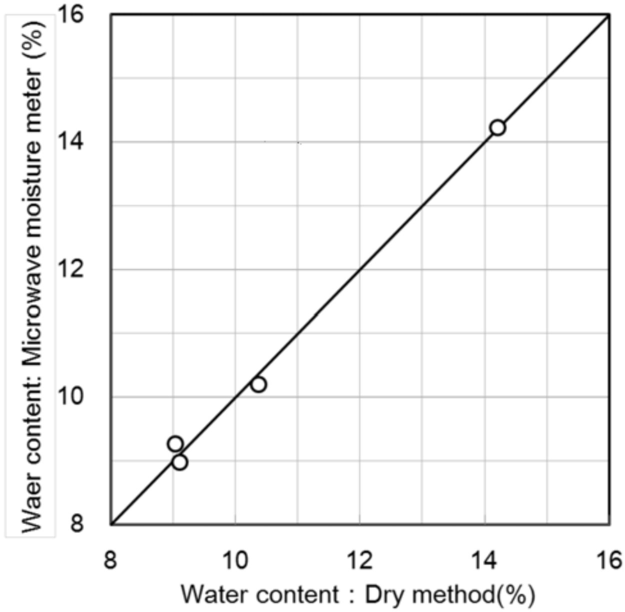


Fig. 19
Calculation of water content by two different methods
Calcul de la teneur en eau par deux méthodes différentes

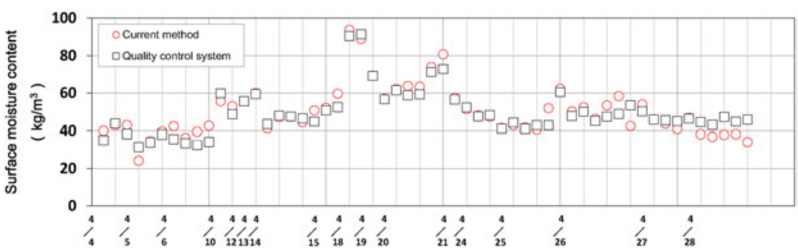
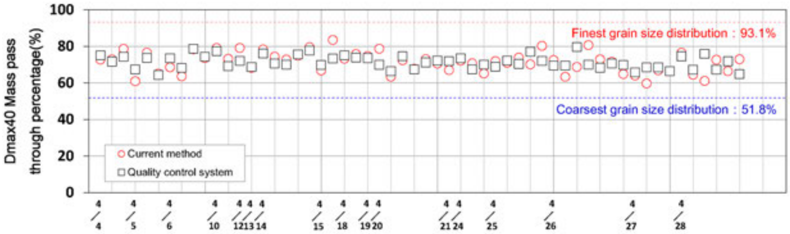
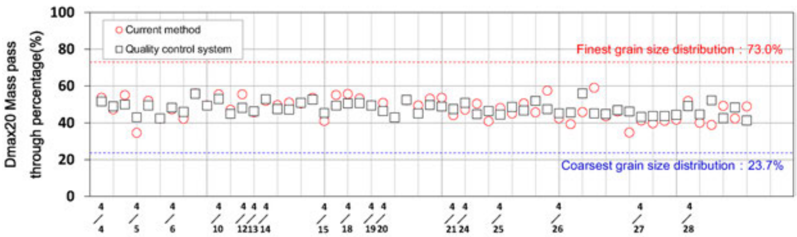


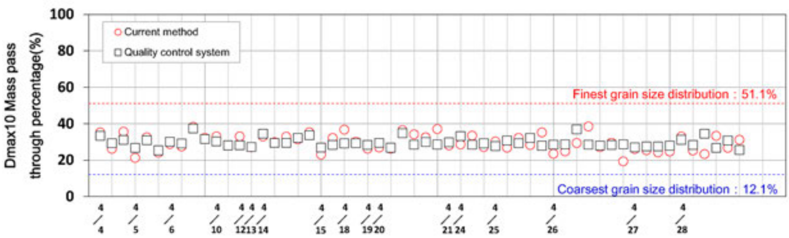
Fig. 20
Temporal change of surface moisture content
Variation temporelle de teneur en humidité de surface



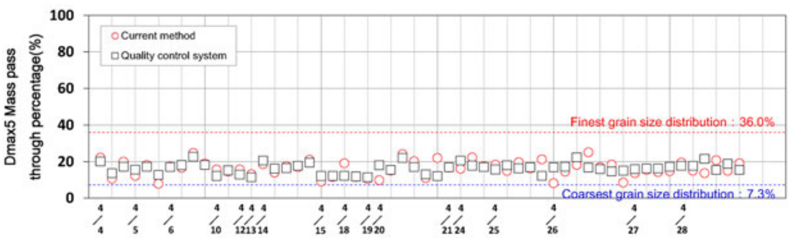
(1) D_{max} ; 40 mm



(2) D_{max}; 20 mm



(3) D_{max}; 10 mm



(4) D_{max}; 5 mm

Fig. 21
Temporal change of grain size distribution
(Comparison of two measuring method using same material)
Variation temporelle de la distribution de taille de grain
(Comparaison de deux méthodes utilisant le même matériel de mesure)

6. CONCLUSION

In order to mitigate giant tsunami damage predicted to occur on the Hamamatsu City Coastline, a coastal levee higher than Level-1 Tsunami is being constructed about 17.5 km from Lake Hamana to the mouth of the Tenryu River. The planned coastal levee is required to have tenacity enabling it to withstand overflow of Tsunami, but strength equal to that of a concrete structure is not needed, so a CSG structure, which has been developed by dam engineering, is adopted for the internal portion of the levee. The Quality Control System as ICT was investigated in order to rationalize the quality control of CSG materials and good performance was obtained. This system has operated since last September in this field. The construction work of the Hamamatsu Coastal is being executed vigorously aiming for completion in 2020.

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