Construction of a Coastal Levee at Hamamatsu City Coastline using Trapezoidal CSG Dam Technology

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ABSTRACT:
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 about17.5 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 with a seaside protection forest parallel to it on the north side. Considering the conservation of valuable plants and animals, the seriously eroded shoreline, and the scenic appearance of the site, basically the ground level of the seaside protection forest is raised and CSG (Cemented Sand and Gravel) is placed at the center of the levee section and the outer sections are constructed as earth dikes. 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.

Keywords: CSG, Coastal Levee, Hamamatsu City Coastline

1. INTRODUCTION

Terrace deposits and mudstone quarried at Mt. Akura in Hamamatsu City shown in Fig. 1 are used for the CSG material, but to achieve effective usage of material in the field, it is mixed with locally produced sand material from excavation work executed to construct the coastal levee.

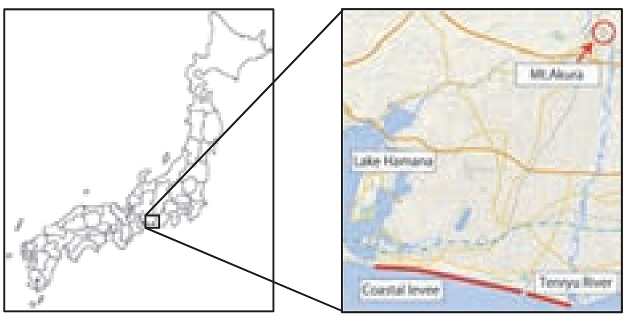


Figure 1. Locations of the coastal levee and Mt. Akura

To surely design and construct the CSG structure on sandy ground, the results of plate loading tests, standard penetration tests, and Swedish sounding tests performed before construction have been summarized and analyzed to develop a method of evaluating bearing capacity and the foundation elevation of the CSG structure, which can be performed simply at the site.

2. STRUCTURE 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. 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 period and the usage of materials obtained from the vicinity of the field with less restriction (Yoshizawa, et al. 2016).

Here, Level-2 Tsunami is a tidal wave which occurs as the result of a disastrous earthquake of Magnitude (M) 9

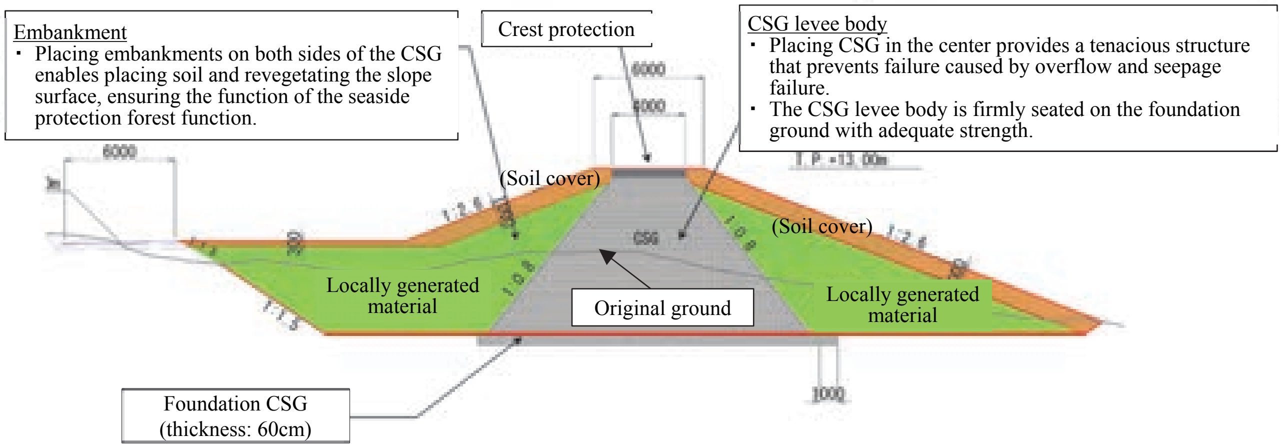


Figure 2. Typical cross section of the coastal levee

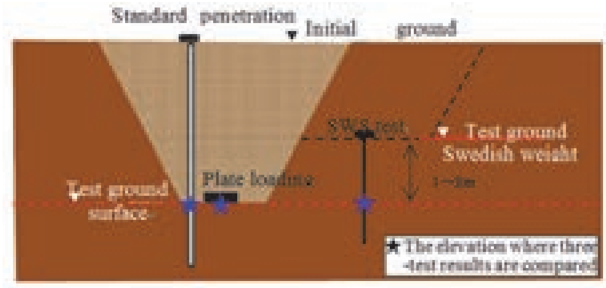


Figure 3. SPT test, Plate loading test and SWS test

Figure 4. View of SWS test

with a return period of several thousand years, and which can cause enormous damage when it occurs.

Secondly, the location of the coastal levee is 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 conditions (see Fig.2). Finally, the coastal levee has the following special characteristics.

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 this material can resist the failure by seepage or overflow.

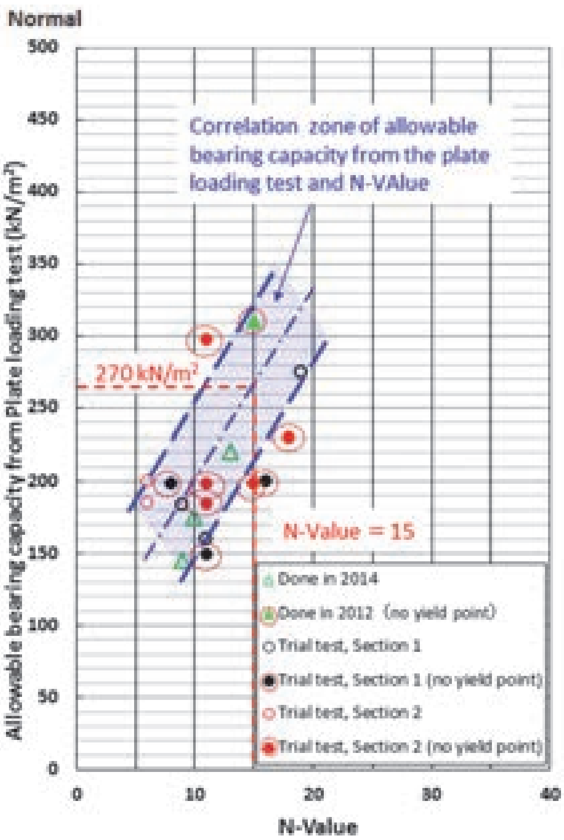


Figure 5. Relationship of N-value and bearing capacity from plate loading test

c) As a result of the above factors, the levee structure with extremely large yield strength against Level-2 Earthquake and 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, the 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 the 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.

3. BEARING CAPACITY OF FOUNDATION

3.1. 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.

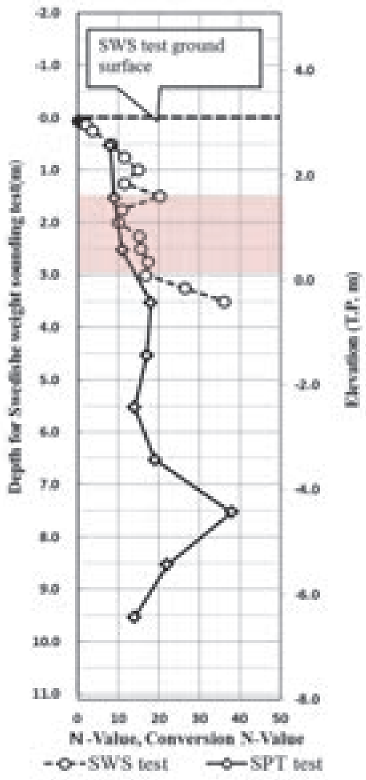


Figure 6. Relationship of SWS test results and N-values of standard penetration test

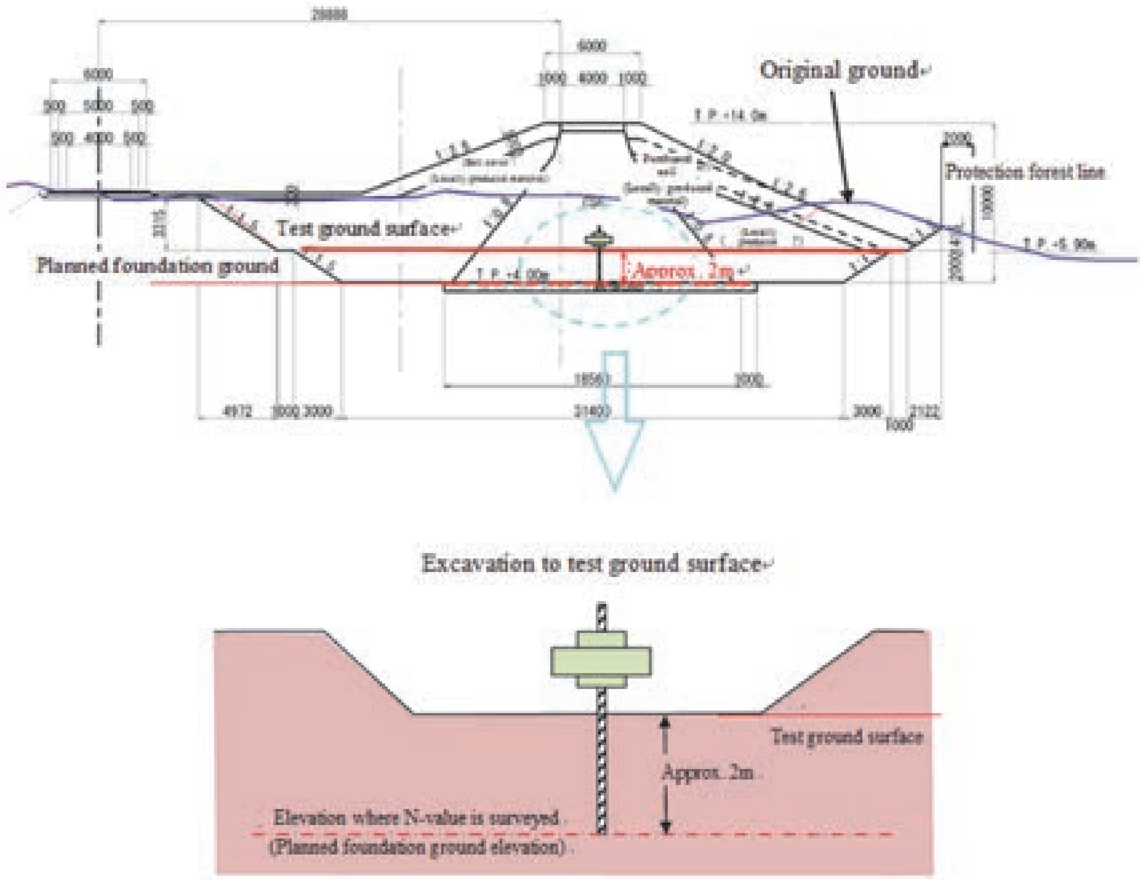
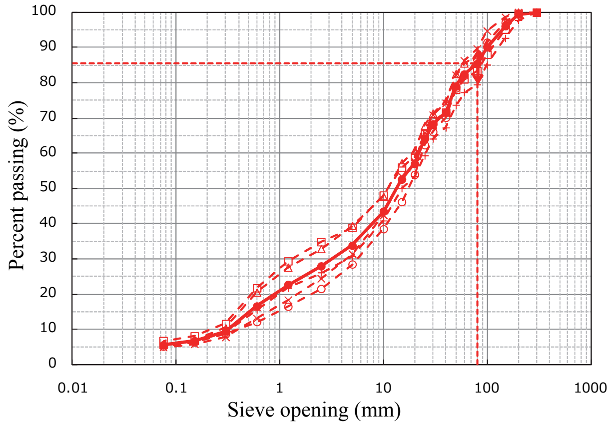
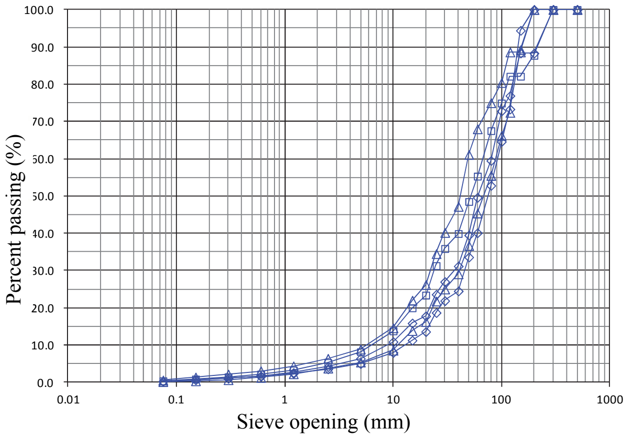


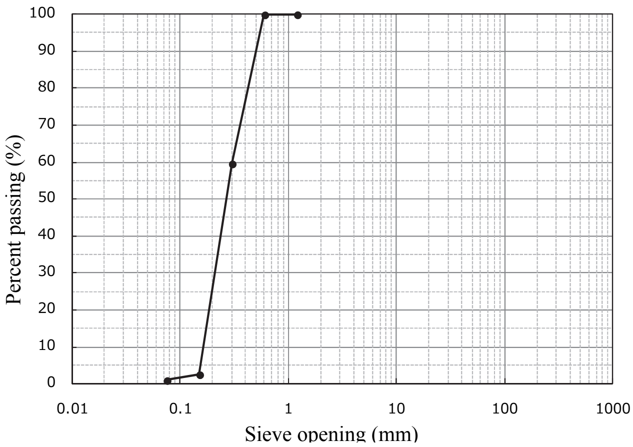
Figure 7. Confirming bearing capacity at planned foundation ground elevation



[1] Terrace deposits



[2] Mudstone



[3] Beach sand

Figure 8. CSG materials

Figs. 3 and 4 show the positional relationship of the tests and the test procedure is shown below.

1) A standard penetration test (SPT) is done 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.

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. 5.

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 (normal condition) and 405 kN/m^2 (seismic condition). 405 kN/m^2 at seismic condition is 1.5 times as much as 270 kN/m^2 at normal condition.

Figure 9. CSG mixing plant

[1] Applying cement paste

[2] Transportation of CSG

[3] Spreading of CSG

[4] Roller compaction

Figure 10. Views of CSG execution

3.2. Survey during execution

During execution, the SWS-test was done at 25m long intervals along the axis of the levee, confirming that the required bearing capacity can 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 and 2m or thicker conform to the values of SPT as shown in of Fig. 6. Therefore as shown by Fig. 7, 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. CSG PRODUCTION AND CONSTRUCTION

As CSG material, terrace deposits and mudstone quarried at Mt. Akura have been used. Each sediments and mudstone is efficiently mixed with 20% or 40% of beach sands produced during excavation of the levee foundation.

The gradation of the terrace deposits and mudstone is shown in Fig. 8. The materials with 80mm of the maximum grain size are produced by the crushers. The mixtures of adjusted sediments and sands, or adjusted mudstone and sands having the specified weight ratio are blended by the CSG production equipment.

The CSG is produced by adding cement and water to the blended CSG material, and transported to the construction sections and placed at the site. The CSG is made at the mixing plant shown in Fig. 9, and supplied to multiple construction sections at one time. The mixing of CSG centralized in one plant so that the quality control of CSG is performed efficiently.

As stated above, placing of CSG placing is done simultaneously, in several construction areas. The construction procedure majorly consists of cement paste and transportation, spreading and compaction of CSG, as shown in Fig. 10 [1] to [4], respectively.

5. CONCLUSIONS

The CSG structure is constructed using material obtained from the vicinity of the levee, and unlike a concrete structure, using a low unit volume of cement. The CSG is made from cement, water, rocky materials, and has been developed as the new design and construction methods at dam engineering.

As a result, this type of levee ensures stability against external forces that include the predicted wave force or the overflow of the tsunami and the earthquake motion, and it enables the restoration of the seaside protection forest to protect the environment and landscape of the region.

Three of eight construction sections in the coastal levee were completed in March, 2016. The construction work has been carried out aiming the whole completion in March, 2020.

REFERENCES

Yoshizawa, Y., Itoh, N. and Hakamata, M. (2016): Construction of a coastal levee at Hamamatsu City Coastline, Engineering for dams, No. 354, pp.75-106, (in Japanese).