AN EFFECTIVE DESIGN OF A DOUBLE PARAPET PERMEABLE-TYPE SEAWALL USING THE CADMAS-SURF SIMULATION

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At Beppu port (Kitahama area 1), where Satohama creation is underway with considerations of protection against the high tide, utilization of the seashore, and the environment, a double parapet seawall for both utilization and protective effects was planned. For a double parapet seawall, vertical wave-dissipating blocks and a permeable layer structure for drainage were employed. To evaluate the multiple functions of protection for overtopping waves, (Super Roller Flume for Computer Aided Design of Maritime Structures) and a physical model were conducted. The calculated overtopping flow of CADMAS-SURF matched with that of the simulation model through CADMAS-SURF, and therefore the applicability of the physical model was confirmed. Since the physical model is often performed for representative cross-sections, reflecting the results of the physical model for parameter adjustment in the CADMAS-SURF computation resulted in improving the reliability of examinations of other parts of cross-sectional dimensions, and therefore enabled the omission of Unneeded cases in the physical model.

Keywords: overtopping waves, CADMAS-SURF, Double Para-pet, permeable layer, physical model

INTRODUCTION

A shore protection project against storm surge and waves is carried out along Beppu port, where careful consideration is paid for not only protecting functions but also utilization of the coastal areas of and preservation of natural environment. In Kitahama area, one of the Beppu port districts, existing seawalls are aged and lose their functions of protecting waves (Photo 1 and Photo 2). A double parapet seawall was planned to renovate an aging seawall which possesses a concurrent benefit both for protection and hinterland utilization.

Photo 1. Serious damage caused by Typhoon in hot-spring hotel area

Photo 2. A concrete of the seawall becomes aging (Originally constructed around 100 years ago)

The double parapet seawall is comprised of the front and back upright wave-absorbing walls and a permeable layer structure which drains overtopping water.

This work investigates the effective design of the double parapet seawall by numerical analysis and hydraulic experiments. For the numerical analysis, CADMAS-SURF (Super Roller Flume for Computer Aided Design of Maritime Structures) was used to analyze wave induced flows including overtopping around the seawall.

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ADOPTATION OF A DOUBLE PARAPET SEAWALL

Recently, coastal engineers are much concerned about the design of offshore structure for the sake of the local residents. In Beppu area, the shore protection works should be effective in restraining overtopping waves because there are many located along the east coast of Kyushu Island, apartments and hotels adjacent to the coastal area (Figure 1).

Figure 1. Study Site (Kitahama 1 Area)

Figure 2 show a profile of the double parapet seawall. There are navigation paths close to the works, so the reflecting waves from the structure should be suppressed. To fulfil these demands, technical committees and workshops were organized to obtain the consensus with the local people. Through the discussion on the most effective structure form from various aspects of cost, function, sceneries, etc., we have adopted a double parapet seawall with upright wave-absorbing blocks.

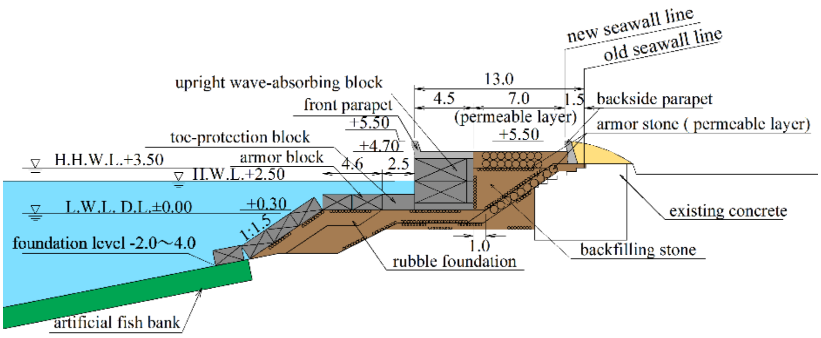

Figure 2. Profile of double parapet permeable-type seawall

DESIGN AND STRUCTUAL CONDITIONS

The front of the project area has a steep bottom slope where the high waves arrive without much dissipation. The existing seawalls are found to be incapable to suppress the overtopping rate under 0.01m^3/m/s, an allowable wave overtopping rate. Therefore, a low-reflection structure (upright wave absorbing walls) and adequate drainage equipment (permeable layer structure) between the double parapets (OCDI, 2009) should be used to satisfy an allowable wave overtopping rate of 0.01 m^3/m/s, which is determined by considering the hinterland conditions (OCDI, 2009). However, there is another restriction demanded by the local residence, that is, the height of seawall not to exceed that of existing seawall.

Table 1. Design condition

Item		50-year return wave
Design depth (m)		−2.0
Bottom slope		1/10
Study tide level (m)		H.H.W.L. +3.5
Design wave	H_0' (m)	3.1
	$H_{1/3}$(m)	3.3
	$T_{1/3}$(sec)	7.6
Allowable wave overtopping rate (m^3/m/s)		0.01

CHARACTERISTICS OF VELOCITY FIELD AROUND DOUBLE PARAPET PERMEABLE SEAWALL

The velocity field around the proposed double parapet seawall structure is simulated using CADMAS-SURF. Figure 3 illustrates the snap-shot results of 1 second interval. The following characteristics are observed: the proposed structure is able (1) to suppress the overtopping rate by reflection of the wave absorbing blocks, (2) to drain the overtopped water mass over the front wall into the permeable layer, (3) to hold the undrained water mass by the back wall. The effects of (2) and (3) were considered to vary with the distance between the front and back walls and size of the permeable layer. Consequently, sensitive analyses were implemented by varying these parameters to determine the most effective design of the sea wall.

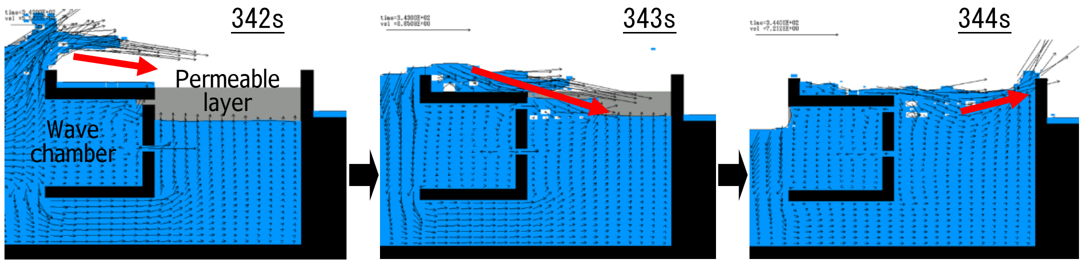

Figure 3. Mechanism of wave overtopping control in double parapet seawall.

NUMERICAL ANALYSIS USING CADMAS-SURF

The dimensions of the double parapet seawall was determined by applying Goda's wave overtopping rate presumption chart (Goda, 2008) for conventional type seawalls. We adopted input parameters for CADMAS-SURF calculation by referring the existing examples (CDIT, 2001, 2008). The computation area was taken 450m (including dissipation region) in the horizontal and 35m in the vertical directions, and grid size was set as delta-x =0.5m, and delta-z=0.25m (Table 2).

The permeable layer to drain the overtopped water was treated as the porous elements as illustrated in Figure 4 (where grey portions are porous and black portions are solid). The porosity was set as the same value as that of the rubble foundation and backfilling stones. The porosity of the wave absorbing blocks was given corresponding the size of the blocks. The height of the back wall is fixed as DL+5.5m same as the design height of the existing wall.

As the computation time passes, the water level of the offshore side of the front seawall lowers due to the storage of the water mass behind the seawall. As the result, the overtopping discharge would decrease as the time passes. To prevent this, the amending procedure to regulate the front water level responding the overtopping discharge is included in the program.

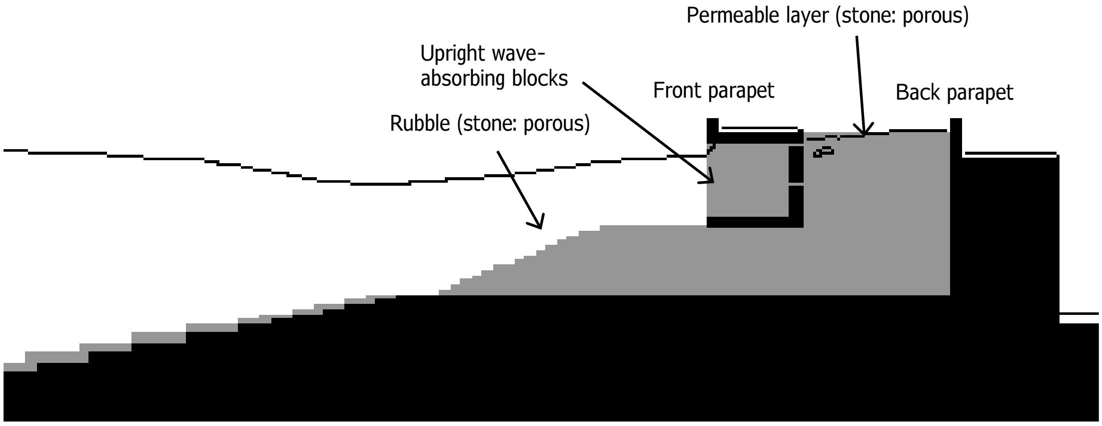

Figure 4. Assumed Design the Double Parapet Seawall for CADMAS-SURF Simulation

Table 2. Parameters of Analysis Model

Calculation region	Horizontal: 450 m, vertical: 35 m
Mesh width	Δx=0.5 m , Δz=0.25 m
Number of wavelength divisions	L/80 - 100 (approx.)
Void ratio (porosity) of permeable structure	Void ratio (V1): 0.43 inertia coefficient (C_M): 1.2 drag coefficient (C_D): 1.0
Other adjusted items	Adjustment of front water level corresponding to wave overtopping rate

RESULTS OF CALCULATED WAVE DISCHARGE

We have found the two governing factors to determine the overtopping wave discharge: the front parapet height, and the permeable layer width. Figure 5 shows the results of wave overtopping discharge when the front seawall height and permeable layer width are varied. The results indicate that the discharge decreases with increase of the front seawall height and increase of the permeable layer width. The condition that the overtopping discharge should be less than 0.01m3/m/s is fulfilled for the combinations; the wall height Hw is 5.2m and permeable layer width Wp is 8.5m, and Hw=5.65m and Wp is 6.0m.

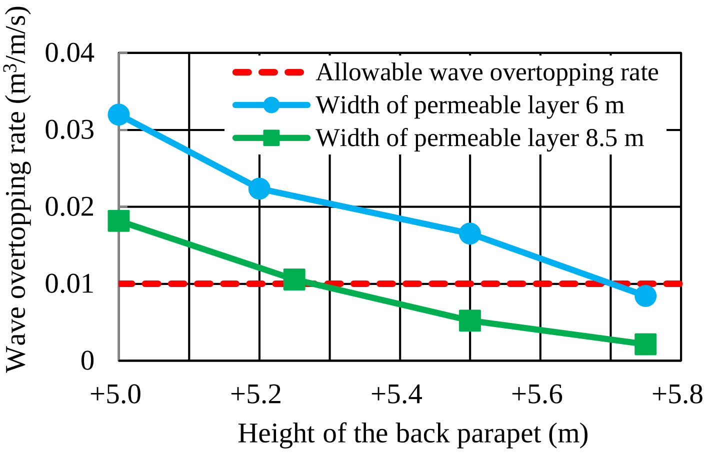

Figure 5. Wave overtopping results of CADMAS-SURF with variation of back parapet and permeable layer width

Figure 6 illustrates the relationship between the overtopping discharge and the permeable layer width when the front parapet height is kept constant as DL+5.5m. The permeable layer width should be greater than 7.0m to fulfil the allowable wave overtopping discharge if the front wall height is set as the same height as the existing sea wall height.

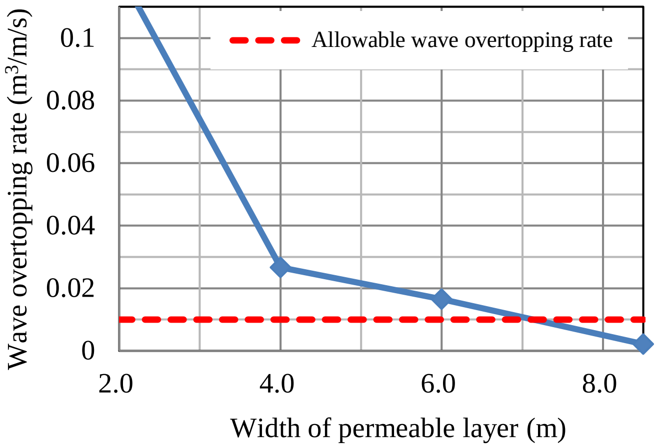

Figure 6. Wave overtopping results of CADMAS-SURF with variation of permeable layer width

Figure 7 shows the relationship between Hw and Wp to satisfy the allowable overtopping rate. The results were brought up at the technical committee and workshop. They determined the optimum design from the scenic and land utilization aspects. As the results, the optimum design that the back parapet height was D.L. +5.5 m and the permeable layer width was 7.0 m was determined. (Figure 2).

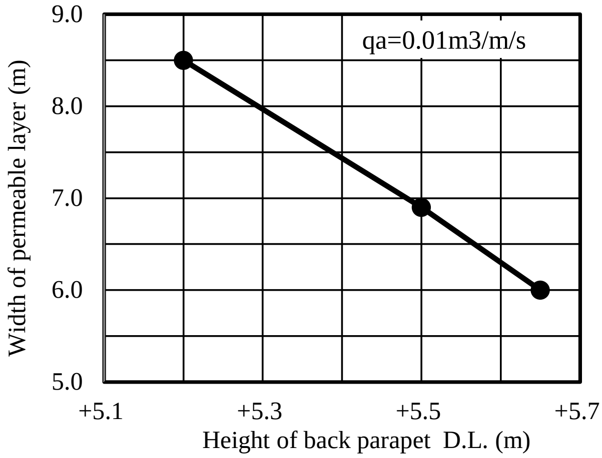

Figure 7. Wave overtopping results of CADMAS-SURF

EXPERIMENTAL VALIDATION OF THE NUMERICAL RESULTS

Physical models to measure the wave overtopping rates with a scale of 1 to 25 were conducted. The basic design of the cross section of the double parapet seawall was determined by referring the setting of the numerical analyses. In the experimental model seawall, the height of the front and back walls were variable and permeable layer were removable. Three test wave sequences which were considered to be equivalent to the design waves were adopted. The experimental runs are summarized in Table 3. The overtopping discharge for the case setting the heights of the front and back seawall as DL+5.5m (Case-1) resulted in 0.0119m^3/m/s, which slightly exceeded the allowable condition for the wave overtopping discharge. Whereas, the height of either the front or back seawall was raised up to DL+5.7m (Case1-2, Case1-3), the overtopping discharges satisfied the allowable condition. The case without permeable layer, the overtopping discharge increased around 10 times as much as the cases with permeable layer. This indicates that the permeable layer possesses the great reduction effect against wave overtopping.

Table 3. Results of physical Models

Case	Height of Front Parapet	Width of Permeable layer	Height of Back Parapet	Wave overtopping rate (m^3/m/s)
				Physical model
Case1-1	+5.5m	7.0m	+5.5m	0.0119
Case1-2	+5.7m	7.0m	+5.5m	0.0086
Case1-3	+5.5m	7.0m	+5.7m	0.0080
Case1-4	+5.5m	6.0m	+5.7m	0.0080

Photo 3 illustrates the wave overtopping situation when the high waves in the irregular wave sequence acted on the wall. It is observed that the broken waves in front of the front sea wall are fallen into the shoreward area of the Back seawall.

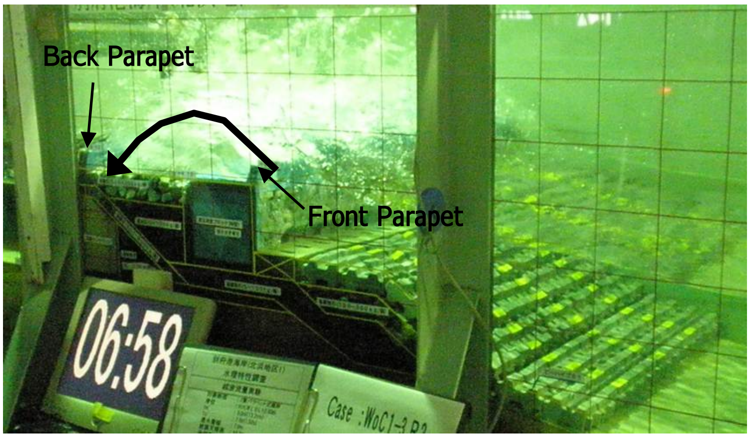

Photo 3. The Wave Overtopping Situation

Flow motions of the overtopping water mass in the permeable layer were visualized by using dye tracer (Photo 4). The plunging water mass into the permeable layer was driven to the downward by the water surface gradient, then passed into the foundation gravel layer (left photo), and further proceeded to the end of the slope of gravel layer (central) and finally drained to the offshore side (right).

Photo 4. Flow motions of overtopping water

CROSS SECTIONAL DESIGN OF THE SEAWALL BASED ON THE EXPERIMENTAL RESULTS

We have obtained the experimental wave overtopping rate of 0.0119 m^3/m/s as the average rate of the three wave groups. The value, however, was slightly greater than the numerically obtained result of 0.01 m^3/m/s. Thus, we have to reconsider the cross sectional design which was based on the numerical results using CADMAS-SURF. We have amended the previously obtained relationship between the front parapet height and permeable layer width by considering the experimental overtopping rate was bigger by 19% than the numerical results. Figure 9 illustrates the amended relationship to satisfy the allowable overtopping rate of 0.01 m^3/m/s. This figure indicates that the front parapet height should be raised from +5.55m to 5.60m provided the permeable layer width is kept as the same size of 7m.

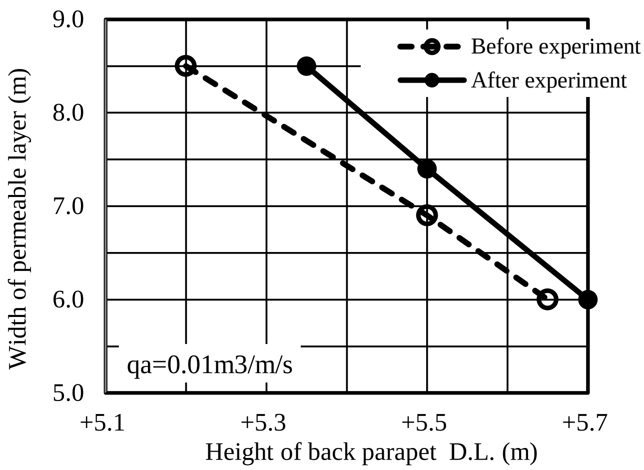

Figure 8. Relationship between Permeable Layer Width Satisfying Allowable Wave Overtopping Rate of 0.01 m^3/m/s and Back Parapet Height (South Section)

SEAWALL DESIGN FOR THE OTHER ZONES

The above discussion of the seawall design was focused on the southern part of the construction area. Seawall design of the other zones was based on the same idea as that of the southern part. The numerically obtained parapet height was amended by the correction rate as 19% increase. In the northern part, the placing depth is shallower and due to the energy dissipation after breaking the overtopping rate is less than that of the southern part. The design parapet height was determined as +5.6m. The condition of this height combined with the permeable layer width 6.0m is found to satisfy the allowable overtopping rate of 0.01 m^3/m/s., as indicated in Figure 9.

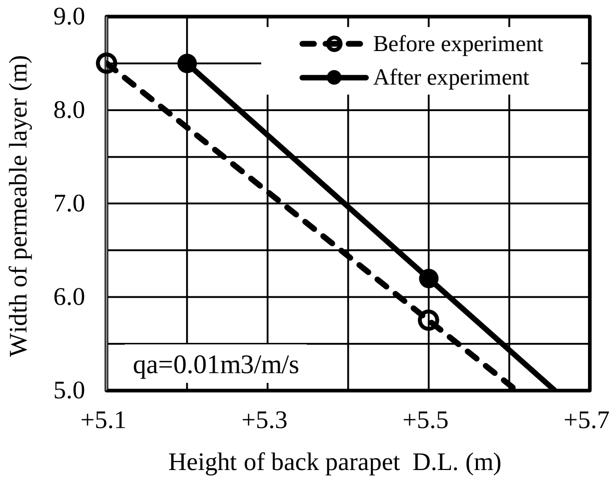

Figure 9. Relationship between Permeable Layer Width Satisfying Allowable Wave Overtopping Rate of 0.01 m^3/m/s and Back Parapet Height (North Section)

MAIN CONCLUSIONS

1) It is difficult to perform a large number of physical models due to cost and schedule restrictions. However, by using CADMAS-SURF in combination with physical models, it is possible to exclude unnecessary study cases from physical models.
2) Use of CADMAS-SURF as an alternative method in the preparatory study, followed by a sensitivity analysis, enables easy setting of the study cases for physical models. (Specifically, narrowing of parameters such as parapet height and permeable layer width).
3) Figure 10 shows the approach of this study. This approach is especially effective in determining cross-sectional configurations of newly-developed coastal protection measures.

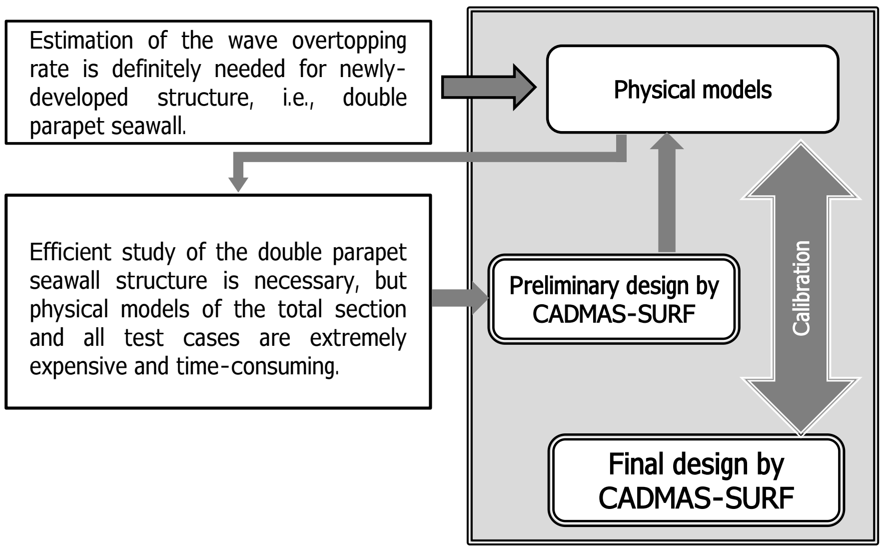

Figure 10. Approach of this study

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