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Coastal Circulation and Bottom Change due to Ocean Resort Complex Development

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Abstract : *On the basis of the potentials for the growth of local economy and the result of investigation of the ocean space development status, an ocean resort complex was proposed at the small harbor with a parallel beach in the east coast of Korea. As the development plan needs to reclaim the noticeable amount of coastal water area together with the applied shore facilities, it is necessary to analyze their impacts. Here, it was intended to analyze the coastal environment change such as water circulation and bottom change because of the development plan. A horizontal two-dimensional numerical model was applied to represent the combined impact of wind waves and tidal currents to sediment transport in that coastal region. Based on the result of 30 days tidal current simulations considering major four tidal components of* M_2,S_2,K_1 *and* O_1 *for the upper and lower boundaries and wind field data, bottom change was discussed. Flow velocities were not changed much at outer breakwater of Yangpo harbor. Bottom was eroded by maximum 1.7m after construction but some locations such as lee side of outer breakwater and some islets near the entrance shows isolated accretions. Although it needs more field observations for bottom change in the period of construction, the numerical calculation shows that there exist small impacts near the entrance area and coastal boundaries because of the development.*

Key words : *ocean resort, tidal current, sediment transport, accretion, bottom change, wind wave*

1. Background and Object

Recently, the increase of the size of GNP and expansion of the foreign tour opportunities by the common 5 days work system in a week and reduction of the cost burden for visiting resort area caused the driving force to develop ocean resort complex for all seasons at the out of date fishery ports and coastal areas. On the basis of the potentials for the growth of local economy and the result of investigation of the ocean space development status, an ocean resort complex was proposed at the small fishery port with a parallel beach in the east coast of Korea. The planned project site is located at Yangpo harbor in the east of Pohang city as shown in Fig.1. Yangpo coast area belongs to Pohang-city and it is easy to access to KyoungJu historical city. General arrangement plan includes marine-fishery exhibition building, ocean leisure and sports center, ocean therapy, country club, accommodations, sea world, mooring facilities, ocean training center for young generation, center for skin scuba, recreational and cultural center, etc. Here, it was intended to analyze the coastal environment change such as water circulation and bottom change because of the development plan. As the development plan needs to reclaim the noticeable amount of coastal water area together with the applied shore facilities, it is necessary to analyze their impacts. The sediment transport and bottom changes in coastal waters are greatly influenced by water movement.

Water movement in coastal waters is affected by various forces such as winds, waves, tides, and land boundaries

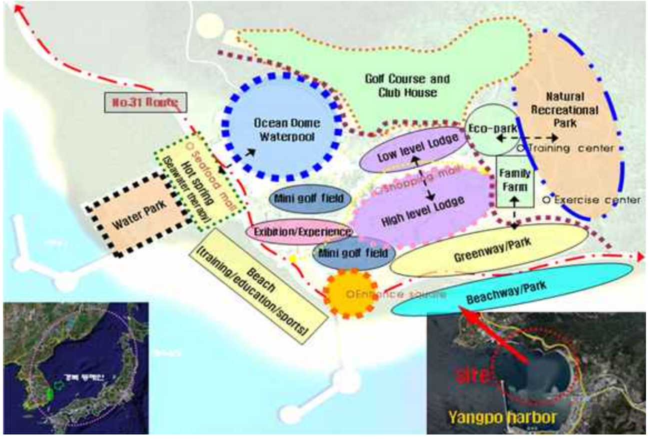

Fig. 1 The proposed ocean multiple resort complex at Yangpo harbor

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(Park and Oh, 1998). In order to analyze the variation of fluid flows, and compare the sediment transport patterns between before and after renovation for this site, it was decided to use here a numerical tool, after evaluation of the model with or input of the field measurement and observations. Numerical hydrodynamic model, MIKE 21 (DHI, 2007), which is adopted for this study, have been widely used to study the water movement and the associated changes in coastal waters (e.g., Lee, 2000; Lee et al, 2008; Kim et al., 2008).

2. Basic Theory of Numerical Model

In this numerical study for the dynamics of coastal circulation the governing equations are expressed in vertically integrated velocity in Cartesian coordinates. The tidal forcing enters the momentum equations (2) and (3) as an additional term representing the gradient of the equilibrium tidal elevation η. Introducing the wind and bottom friction stress components, the system of equations becomes as follows.

$$\frac{\partial h}{\partial t}+\frac{\partial h\bar{U}}{\partial x}+\frac{\partial h\bar{V}}{\partial y}=hS \tag{1}$$

$$\frac{\partial h\bar{U}}{\partial t}+\frac{\partial h\bar{U}^2}{\partial x}+\frac{\partial h\overline{UV}}{\partial y}=f\bar{V}h-gh\frac{\partial \eta}{\partial x}-\frac{h}{\rho_0}\frac{\partial p_a}{\partial x}$$
$$-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial x}+\frac{\tau_{sx}}{\rho_0}-\frac{\tau_{bx}}{\rho_0}-\frac{1}{\rho_0}\left(\frac{\partial s_{xx}}{\partial x}+\frac{\partial s_{xy}}{\partial y}\right)+\frac{\partial}{\partial x}\left(hT_{xx}\right)+\frac{\partial}{\partial y}\left(hT_{xy}\right)+hU_sS \tag{2}$$

$$\frac{\partial h\bar{V}}{\partial t}+\frac{\partial h\bar{V}^2}{\partial y}+\frac{\partial h\overline{VU}}{\partial x}=-f\bar{U}h-gh\frac{\partial \eta}{\partial y}-\frac{h}{\rho_0}\frac{\partial p_a}{\partial y}$$
$$-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial y}+\frac{\tau_{sy}}{\rho_0}-\frac{\tau_{by}}{\rho_0}-\frac{1}{\rho_0}\left(\frac{\partial s_{yx}}{\partial x}+\frac{\partial s_{yy}}{\partial y}\right)+\frac{\partial}{\partial x}\left(hT_{xy}\right)+\frac{\partial}{\partial y}\left(hT_{yy}\right)+hV_sS \tag{3}$$

where, D is the still water depth, η is the surface elevation, $h=D+\eta$ is the total water depth, (U,V) are the velocity components in the x and y direction, ($\bar{U}=1/h\int_{-D}^{\eta}Udz$, $\bar{V}=1/h\int_{-D}^{\eta}Vdz$) are the depth averaged velocities. f is the Coriolis parameter, g is the acceleration of gravity, ρ is the density of sea water, P_a is the atmospheric pressure, (τ_{sx}, τ_{bx}, τ_{sy}, τ_{by}) are the x and y components of the surface wind and bottom stresses, (S_{xx}, S_{xy}, S_{yx}, S_{yy}) are components of the radiation stress tensor for combination the circulation model with wind wave induced flow. S is the magnitude of the discharge due to point sources and (U_s, V_s) is the velocity by which the water is discharged into the ambient water. T_{xx}, T_{xy}, T_{yy} are the lateral stresses based on the eddy viscosity proposed by Smagorinsky (1963). More detail descriptions are shown in Lee et al. (2008).

The sediment transport calculations are based on the hydrodynamic conditions for combined current and waves and sediment properties. The sediment transport modeling is divided into bed load and suspended load due to characteristic differences. The bed load is mainly controlled by the bed shear stress and the suspended load is characterized by a phase lag in the transport compared to the flow. Therefore, the transport of suspended sediment is characterized by a sediment concentration. The Engelund and Hansen (1967) formula only predict total load S_{tl}, whereas information about both bedload S_{bl} and suspended loadS_{sl} is required. The total load formula can still be applied by using the calibration factors K_b and K_s for bed load and suspended load, respectively, in order to differentiate between the two modes of transport. By specifying K_b= 0.1 and K_s= 0.9, it is understood that 10% of the transport takes place as bed load. Depending on the field condition it will be changed. The transport rates are obtained from the relations:

$$S_{bl}=k_b\cdot S_{tl}$$
$$S_{sl}=k_s\cdot S_{tl} \tag{4}$$

where the total sediment transport is obtained by:

$$S_{tl}=0.05\frac{C_e^2}{g}\theta^{\frac{5}{2}}\sqrt{(s-1)gd_{50}^3} \tag{5}$$

The equilibrium concentration $C_e(g/m^3)$ is simply specified as the suspended load divided by the water flux and converted from volumetric concentration to mass concentration :

$$C_e=k_s\frac{S_{tl}}{V\cdot h}\cdot s\cdot 10^6 \tag{6}$$

where, s is the relative density of sediment, and V is the velocity (m/s).

The shields parameter θ is defined as:

$$\theta=\frac{\tau}{\rho g(s-1)d_{50}} \tag{7}$$

where, $\tau=\rho gV^2/C^2$ is flow shear stress (C is the local Chezy number), ρ is the density of water, ρ_s the is density of sediment, for quartz sand 2650kg/m^3, and s is the relative density of the sediment(ρ/ρ_s). The details of description on model are shown in DHI (2007) and Lee et al. (2008).

3. Numerical Model Formulation

3.1 Investigation of field environment

According to the data of KHOM (2010), the mean sea level is 11.8cm at the study area. The tide shape factor for this area is 1.31 and the mixed tide but diurnal tide is dominant in this area. Mean high water interval is 4h-50m. Table 1 shows analyzed tidal constants at three stations and these will be used for the boundary values of tidal model. These stations are selected for the verification of the surface elevations.

Table 1 Summary of observed tidal components at 3 stations (KHOM, 2010).

Location	Guryongpo		Yangpo		Gampo	
Latitude, Longitude	35°59′17″(N), 129°33′36″(E)		35°53′38″(N), 129°32′06″(E)		35°47′60″(N), 129°30′36″(E)	
Tidal Constant	Half Tidal Range	Phase Lag	Half Tidal Range	Phase Lag	Half Tidal Range	Phase Lag
M_2	2.90 cm	135.00°	3.80 cm	140.00°	4.70 cm	158.80°
S_2	1.00 cm	187.50°	1.30 cm	195.30°	1.80 cm	216.40°
K_1	4.10 cm	1.50°	3.50 cm	10.10°	3.60 cm	7.00°
O_1	3.60 cm	331.50°	3.20 cm	330.70°	3.90 cm	331.00°

Winds from S direction to this area are common with the average speed of 2.32m/s. Fig.2 shows the observed wind of every 30 minutes average at Janggi weather station between April 29 and June 3, 2009. The blue arrows are wind direction and red lines indicate the wind speed. The maximum wind speed and direction during May 29 was introduced into wind wave simulation module after conversion to equivalent neutral wind speed of 10m above the sea surface.

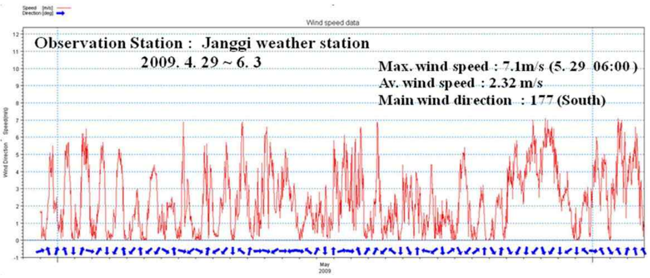


Fig. 2 Time series of wind speed and direction from weather station during the simulation period

Table 2 shows the summary of observed waves (Division of Fishery, 1988). The dominant wave period is 8sec (25%) and 57% of wave heights are 0.5~1.5m. This data will be used to analyze the wind wave model result.

Table 2 Summary of observed wave

H(m) \ T(sec)	3~4	4~5	5~6	6~7	7~8	8~9	9~10
~0.5	0.47	1.63	1.94	4.78	5.95	8.07	2.04
0.5~1.5	0.95	3.28	5.48	7.12	10.92	14.07	10.87
1.5~2.0	0	0	0.90	1.08	1.47	1.68	1.68
2.0~2.5	0	0	0.04	0.47	0.73	0.73	1.08
2.5~	0	0	0.09	0.09	0.35	0.48	0.69
(%)	1.42	4.91	8.45	13.54	19.42	25.03	16.36
H(m) \ T(sec)	10~11	11~12	12~13	13~14	14~15	15~	(%)
~0.5	0.26	0.08	0	0	0	0	25.22
0.5~1.5	2.46	1.12	0.26	0	0.09	0.04	56.66
1.5~2.0	1.29	0.82	0.13	0	0	0	9.05
2.0~2.5	1.38	0.39	0.26	0.04	0	0	5.12
2.5~	0.65	0.69	0.56	0.13	0.13	0.08	2.94
(%)	6.04	3.10	1.21	0.17	0.22	0.12	100.0

Fig. 3 shows the location of tidal current measurement with RCM-9. Flood current (NW direction) passes about 45 minutes longer than ebb current (SSE direction) at Yangpo harbor breakwater. The maximum flood current speed is 0.125m/s and ebb current speed is 0.149m/s at spring tide.

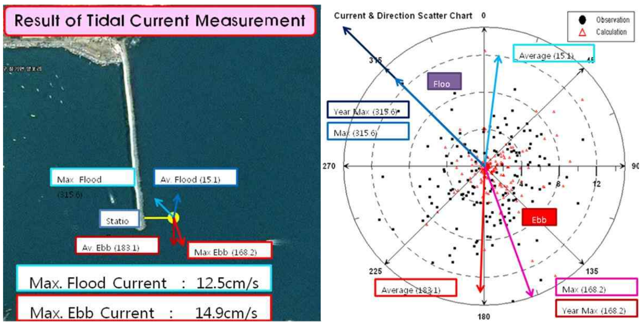


Fig. 3 Result of tidal current measurement (Observed : 2009.5.29)

In terms of the one day observed data on May 21, 2009 at the maximum tidal range, the ebb current indicates slightly high in this domain. However, tidal current is small and therefore, it is necessary to combine tidal current with wind wave for sediment transport analysis. In this study, in order to analyze the sediment transport pattern in this area, it was introduced the mean grain diameter down to 0.2mm to the numerical model.

3.2 Model formulation

In order to simulate the tidal circulation and sediment transport of the bottom materials we set the coastal waters into the numerical model, including the northern part of Guryongpo and southern part of Gampo for the open boundaries and the western coastal boundary and the eastern parallel open boundary, which is located 5.5km away from the coast. This coastal region 6km×22km covers the water area between 129°33.36'∼129°30.36'E. and 35°59.1'∼35°47.6'N. The simulation domain, bathymetry, and flexible mesh appear in Fig. 4.

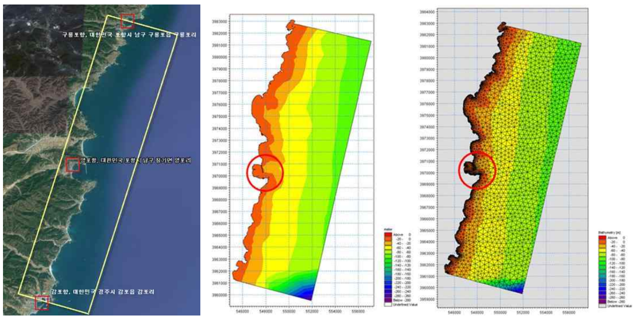


Fig. 4 Location map of study area and bathymetric chart and FEM mesh

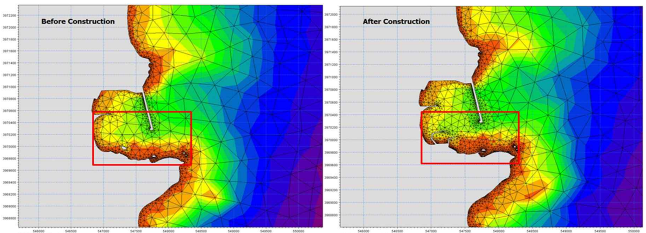


Fig. 5 Bathymetry and FEM mesh for the present and after construction plan

We adopted meshes of 20m interval near the harbor and near the coastal area to get high resolution and 150m for offshore area. Model simulation made for 30days which included the spring, neap, and medium tides. Table 3 shows the summary of model simulation set up. The FEM mesh near the project site was shown in Fig. 5.

Table 3 Summary of model simulation condition

Items	Simulation conditions (before/after construction)	
Whole Simulation Condition	Cal. area	6km×22km, △S (Mesh Size): 20∼150m
	FEM Mesh scheme	Before : Elements :13132 Nodes : 7980 After : Elements : 13635 Nodes : 8292
Wind & Wave	Open boundary	Input North, East, South boundaries
	Wind	Wind Speed and Wind Direction (2010/04/29∼2010/06/03)
Tidal Circulation	Cal. Time	30days (+3 remain day M2+S2+K1+O1)
Sand Transport	Grain diameter : 0.2mm, Porosity : 0.4 Relative density :2.65	

4. Model Simulation and Analysis

4.1 Model verification

In order to verify the numerical model, the computed tides were compared with the observed tides at Guryongpo, Yangpo and Gampo as shown in Fig. 6. Furthermore, the calculated maximum tidal currents were compared with the field measurements at the outer breakwater (Fig. 3). The computed water levels are very close to the measured values.

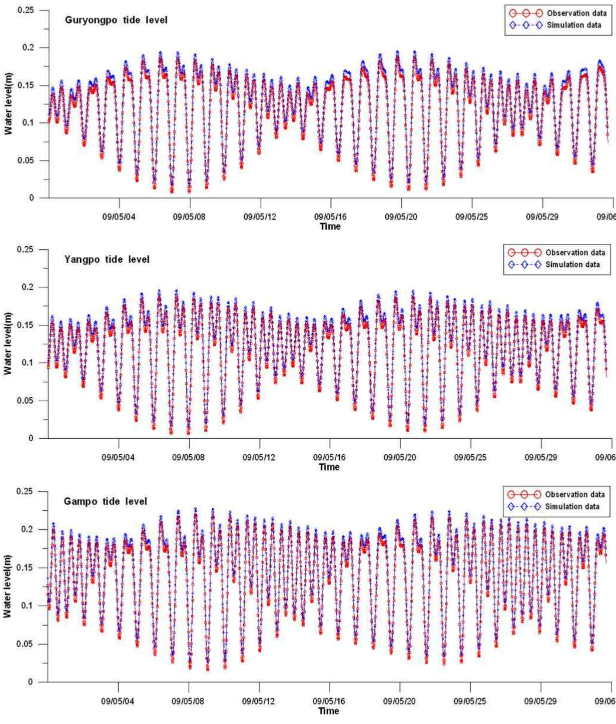


Fig. 6 Comparison of time series of surface elevation at three stations

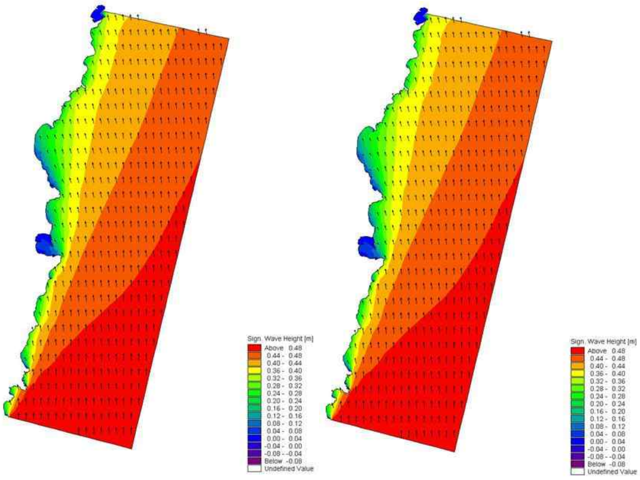


Fig. 7 Result of wind waves to the study area (wide area)

Fig. 7 shows the wave direction and height diagram before and after construction from the input of wind data at the offshore open boundary. and Fig. 8 is for the coastal and harbor area. The maximum wind speed and direction during May 29 was introduced into the model. These results are to be input to the circulation module for the final sediment transport calculation.

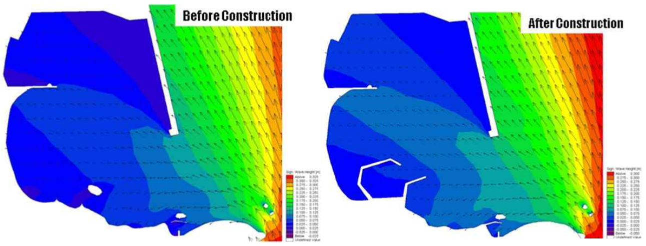
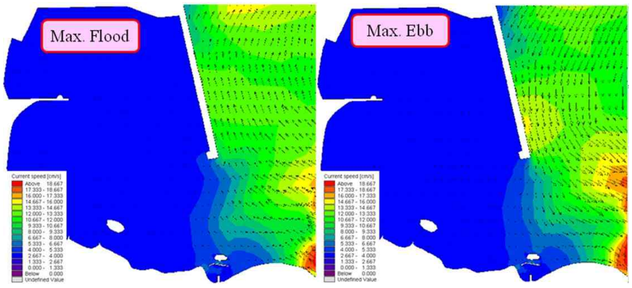


Fig. 8 Result of wind waves to the study area (narrow area)



	FLOOD		EBB	
	VEL.	DIR.	VEL.	DIR.
MEAN HIGH WATER	11.7	15.1	12.9	183.1
OBSERVED MAX.	12.5	315.6	14.9	168.2
CALCULATED MAX.	12.8	10.2	15.1	180.5

Fig. 9 Maximum flood and ebb currents before construction

Measured tidal current records were analyzed for the model verification as shown in Fig. 3. The simulation result shows that the ebb currents are stronger at the whole domain, too as Fig. 9. Here it also shows that the direction of the vectors is changing almost at every time steps. The maximum flood velocities for observation and simulation at the measured station are 12.5cm/s and 12.8cm/s, respectively, and the maximum ebb velocities are 14.9cm/s and 15.1cm/s. The vector sizes of currents show similar to the values of measurement.

4.2 Simulation on sediment transport and bottom change

The change of current speed and wave in the project site due to construction of structure or reclamation work will in turn result in the increase of sediment transport capacity, resulting in erosion or accretion. Bottom profile change is appeared near the entrance of harbor and the natural or artificial objects. The following Fig. 10 shows a comparison of the simulated bathymetry for the present and after construction, in and in front of the harbor entrance, after a 30-day period. Line 1, 2, 3, and 4 indicate cross sections for bathymetry development analysis.

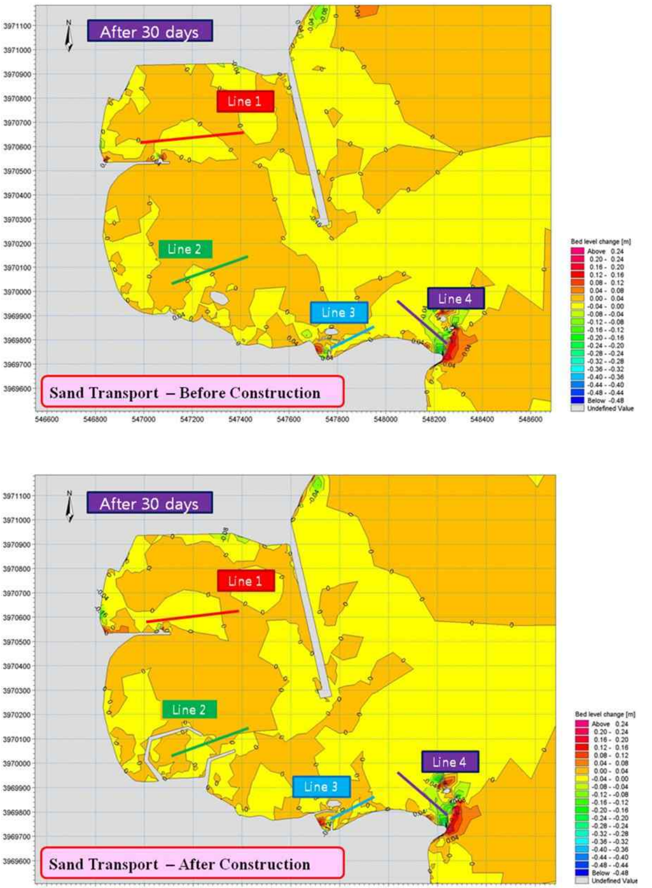
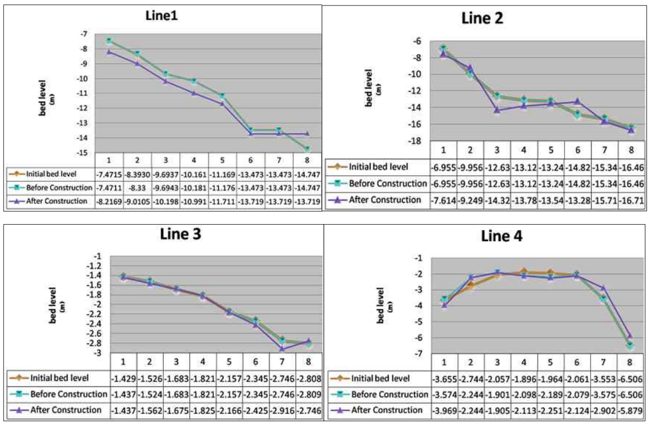


Fig. 10 sediment transports and bottom change after 30 days (Mean grain diameter: 0.2mm)

The analyzed bottom profiles across several sections are shown in Fig. 10 and Fig. 11. Sections Line 1 and Line 2 are located inside the harbor and Line 3 and Line 4 are located at the entrance of harbor. Although the waves and current are not strong, the general trend of sediment transport shows that the sediments are moving from the inner harbor to the mouth of the harbor. This is due to the higher ebb flow, in which the flow is moving out to the harbor mouth. Compared with the present and after project, approximately 1m of erosion at the cross section of Line 1 appeared and accumulation of sand in the section Line 4 was appeared. There is some erosion in the small basin after construction as shown in Line 2 but it also shows accretion in front of the small basin. There is no significant change in the cross section of Line 3. Although there shows some erosion in the middle of the cross section Line 4, accretion is dominant after construction plan. Although more analyses for other sections were made, the difference was found within 0.5m. Therefore, it was summarized that the proposed plan for ocean multiple resort complex at Yangpo harbor would not make a serious change in wave climate, tide, circulation pattern, and bottom of coastal waters.



Line1

	1	2	3	4	5	6	7	8
Initial bed level	-7.4715	-8.3930	-9.6937	-10.161	-11.169	-13.473	-13.473	-14.747
Before Construction	-7.4711	-8.33	-9.6943	-10.181	-11.176	-13.473	-13.473	-14.747
After Construction	-8.2169	-9.0105	-10.198	-10.991	-11.711	-13.719	-13.719	-13.719

Line 2

	1	2	3	4	5	6	7	8
Initial bed level	-6.955	-9.956	-12.63	-13.12	-13.24	-14.82	-15.34	-16.46
Before Construction	-6.955	-9.956	-12.63	-13.12	-13.24	-14.82	-15.34	-16.46
After Construction	-7.614	-9.249	-14.32	-13.78	-13.54	-13.28	-15.71	-16.71

Line 3

	1	2	3	4	5	6	7	8
Initial bed level	-1.429	-1.526	-1.683	-1.821	-2.157	-2.345	-2.746	-2.808
Before Construction	-1.437	-1.524	-1.683	-1.821	-2.157	-2.345	-2.746	-2.809
After Construction	-1.437	-1.562	-1.675	-1.825	-2.166	-2.425	-2.916	-2.746

Line 4

	1	2	3	4	5	6	7	8
Initial bed level	-3.655	-2.744	-2.057	-1.896	-1.964	-2.061	-3.553	-6.506
Before Construction	-3.574	-2.244	-1.901	-2.098	-2.189	-2.079	-3.575	-6.506
After Construction	-3.969	-2.244	-1.905	-2.113	-2.251	-2.124	-2.902	-5.879

Fig. 11 Cross section bathymetry changes for selected locations after 30days

5. Summary and Recommendations

This paper presents a result of preliminary impact study for ocean resort complex design to give the basic information of current and bottom change with the use of numerical tool. The current available data for winds, waves, tides, and currents in the vicinity of study area do allow us to perform circulation model calibration and verification in some degree. Especially for current, the field measurement was done at a selected station to make comparison with the numerical result. A horizontal two-dimensional numerical model was applied to represent the combined impact of wind waves and tidal currents to sediment transport in that coastal region. The tide model was calibrated for the average tidal characteristics at three locations from the preexisting field data and the current was verified using the time-series measurement done for the spring of 2009. Based on the result of 30 days tidal current simulations considering major four tidal components of M_2, S_2, K_1 and O_1 for the upper and lower boundaries, bottom change was discussed. It was considered the wind wave because the tidal current is not dominant in this area. Flow velocity near the region of interest was about 0.125~0.149m/s and the ebb current suppressed a little bit the flood current. Flow velocities were not changed much at outer breakwater of Yangpo harbor. Bottom was eroded by maximum 1.7m after construction but some locations such as lee side of outer breakwater and some islets near the entrance shows isolated accretions. Therefore, it was concluded that the design did not make a serious change in wave climate, tide, circulation pattern, and bottom of coastal waters.

References

[1] DHI(2007), MIKE 21: Hydrodynamic Module and Sand Transport Module.

[2] Engelund, F. and Hansen, E.(1967), A monograph on sediment transport in alluvial streams, Teknisk Forlag, Danish Technological University, Copenhagen, Denmark.

[3] KHOM(2010), Analyzed Tidal Measurement at Chart Datum Stations.

[4] Kim, K. D., Lee, J. W., Lee, H. S., Kang, S. J. and Jeon, M. S.(2008), Behavior of Suspended Solids for the Development of Coastal Industrial Complex, J. Navigation and Port Research, Vol. 32, No. 6, pp. 489-497.

[5] Lee, J. M.(2000), Suspendid load transport at Pohang Songdo beach using Mike 21, Research Institute of Ocean Resource, Dong-A University.

[6] Lee, S. C. Lee, J. W., Kim, K. M. and Kim, K. D.(2008), Impact Analysis on the Coastal Erosion and Accretion due to Relocation of Breakwaters, J. Navigation and Port Research International Edition, Vol. 32, No. 4, pp. 305-313.

[7] Park, K. and Oh, J. H.(1998), Calibration and Verification of a Hydrodynamic Model in Chunsu Bay and Adjacent Coastal Water, J. Korean Society of Coastal and Ocean Engineers, Vol. 10, No. 3, pp. 109-119.

[8] Smagorinsky, J.(1963), "General Circulation Experiment with the Primitive Equations", Monthly Weather Review, Vol. 91, No. 3, pp. 99-164.

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