3D Sediment Physical Model Test Study for PLTU 2 JATENG 1 × 660 MW Adipala, Cilacap, Indonesia

F. Gao, H. B. Chen, and Y. Luo

Abstract

Adipala 1 × 660 MW power plant stands between Serayu River mouth and Bengawan River mouth, about 15 km east of Cilacap city, south Java Island, Indonesia. Marine structures constructed for the coal-fired power plant, include unloading wharf, breakwaters, C. W inlet, C. W outlet and other relevant structures. In order to improve and optimize design plane layout, it is necessary to forecast sediment movement. According to the Hydro-meteorology, sediment survey data and design option, based on the results of wave, current numerical models and sediment movement analysis, the siltation mechanism of harbor basin is analyzed. On the basis of verifying the siltation of opening channel and harbor basin on S2P CFPP (nearby this project), the siltation after project constructed and the effect of alongshore sediment is tested. Because of weakly tidal current (maximum velocity of field survey is less than 0.30 cm/s) and sediment concentration (less than 0.01 kg/m^3), the movable-seabed physical model(Horizontal scale is 120, vertical scale is 60) test is carried out under the wave action due to the strong swell and long wave period (exceed 10 s). The results shows that siltation thickness is about 0.02–1.91 m/a (the average value is 0.52 m/a) and the deposition volume is about 16.8 × 104 m^3/a in harbor basin after project constructed. And, siltation happened at the root of west breakwater, but it will be more than 30 years when the long-shore sediment transport around the breakwater's head.

Keywords

Sediment • Physical model • Deposition • Wave

1 Introduction

Adipala 1 × 660 MW power plant stands between Serayu River mouth and Bengawan River mouth, about 15 km east of Cilacap city, south Java Island, Indonesia (see in Fig. 1).

Marine structures constructed for the coal-fired power plant, include unloading wharf, breakwaters, C.W inlet, C.W outlet and other relevant structures. In order to verify the design plane layout, it is necessary to forecast sediment movement. Based on survey data and analysis on the characteristic of sediment in project area, moveable-bed physical model test have been carried out to simulate the sedimentation in dredged navigation channel and harbor basin.

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Fig. 1 Location of Adipala power plant project

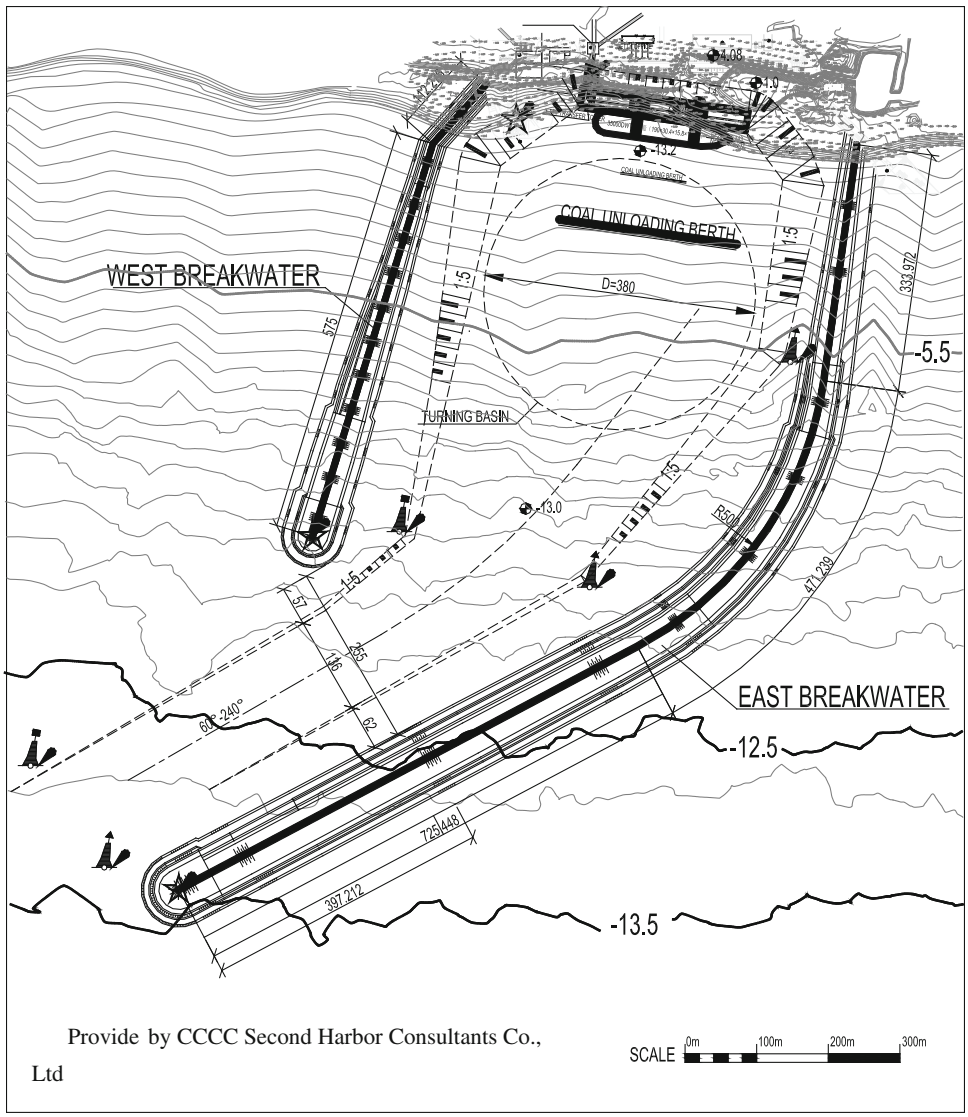

Fig. 2 Plane layout of design

Table 1 The eigenvalue on tidal level

Design water level(m)		Remarks
Design high water level	1.18	10 % high water frequency + storm surge
Design low water level	−0.83	90 % low water frequency
Mean sea level	0.00	MSL
Mean high water level	0.47	MHWL
Mean low water level	−0.52	MLWL
Mean tidal range	1.00	–

Table 2 The wave result at point of −40 m isobathe

Return period	$H_{13\ \%}$(m)	T_s(s)
Design wave	7.07	18.30
Ordinary wave	4.24	15.19

2 Foundation of Test Study

2.1 Plane Layout of Design

On the basis of former work, one plane layout is recommended, see Fig. 2. The design wharf berth is 35,000 DWT, the channel direction is 60–240°and the width is 136 m.The bottom elevation of channel is −13.0 m, the west breakwater(575 m long) head lies in −10.5 m, and east breakwater(1530 m long) head is −13.3 m. The inlet is located at harbor basin and outfall is located at the eastern of east breakwater foot.

2.2 Natural Condition

2.2.1 Tide and Current

According to the analysis on the tidal level of two stations (Dec. 2009–Jan. 2010), the result indicates that the tidal type is mixed tide with mainly semidiurnal tide. There are two high levels and two low levels during one day. And the diurnal inequality is obvious. Average flood tide duration is 6.3 h and average ebb tide duration is 6.2 h. Important water level result for project design is shown in Table 1. The maximum current speed is 0.26 m/s, and average flood velocity is 0.10–0.11 m/s, ebb velocity is 0.08 m/s.

2.2.2 Wave

According to the forecast data of national weather station and the description of local fisherman, the wave height in rainy season is small and those in dry season is strong, especially July and August. The maximum wave height can reach to 4.0–5.0 m. The survey (January. 2010) data shows the average wave height in project area is about 3.0–4.0 m. These indicate the wave is strong in project area. According to the result of wave numerical model, wave height and wave period of different return period at −40 m isobath is shown in Table 2.

2.2.3 Sediment

The sediment source mainly includes three parts, the first comes from the river nearby the project; the second comes from wave and current action; the third comes from ocean transportation and people activity. The SSC was measured during the site survey in Dec. The value is 0.0028–0.0074 kg/m^3 in projecr area, and 0.591–11.258 kg/m^3 in the area of estuary and wave breaking zone in offshore. The bottom material samples are analyzed by PW4400/40X ray fluorescence spectrometer in laboratory. Sea-bed sediments in this area contain SiO_2, Al_2O_3, CaO, MgO, K_2O, Na_2O, TiO_2, P_2O_5, MnO and TFe_2O_3 and other components, in which SiO_2 and TFe_2O_3 is the main component. The content of TFe_2O_3 of beach samples is up to 40 %, thus the density of sediment in this area reaches 2.77–2.96 g/cm^3.The density is more heavy than nature quartz sand (2.65 g/cm^3). The range of median grain size (D_{50}) is 0.0063–0.2502 mm in project area, and the average value is 0.0926 mm. The main component of samplings in this area is sand, and the proportion is about 68.1 %. Clay is about 27.1 %, and gravel is about 4.8 %. The range of median grain size (d_{50}) is 0.1312–0.7788 mm in breaking zone, and the average value is 0.3123 mm. The main component of samplings in this area is sand, and the proportion is about 93.7 %. Silt is about 3.9 %, and clay is about 1.7 %. The range of median grain size (d_{50}) is 0.0732–0.7838 mm at Searyu river, and the average value is 0.3484 mm. The main component of samplings is sand, and the proportion is about 93.4 %. Silt is about 5.2 %, clay is about 0.7 %.

3 Movable Bed Physical Model

3.1 Model Design

3.1.1 Scale and Layout

According to the test ground and the requirement of wave physical model test, the plane scale (λ_l) is confirmed as 120,

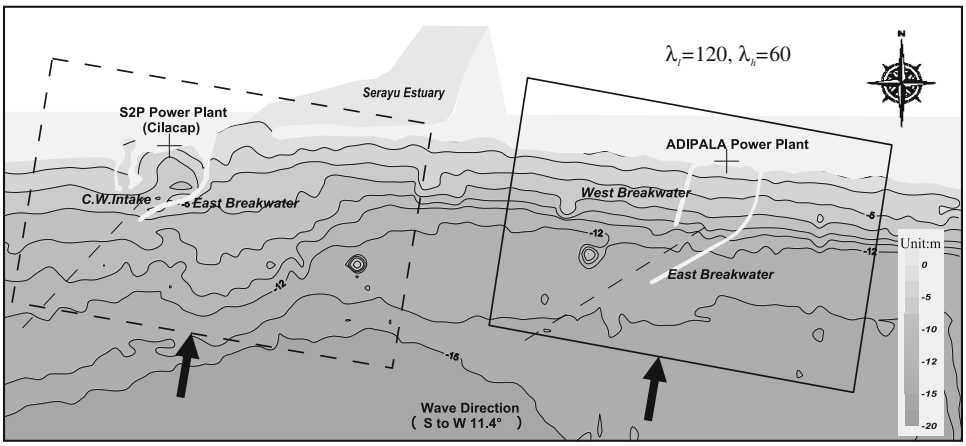

Fig. 3 The model range and plane layout

Table 3 The main scale relation in physical model test

Scale item	Sign	Calculate value	Adopt value
Horizontal	λ_l	/	120
Vertical	λ_h	/	60
Wave lengh	λ_L	/	60
Wave period	λ_T	$\sqrt{60}$	$\sqrt{60}$
Wave velocity	λ_C	$\sqrt{60}$	$\sqrt{60}$
Track velocity	λ_u	$\sqrt{60}$	$\sqrt{60}$
Grain density	$\lambda_{\rho s}$	1.93	1.93
Grain size	λ_D	1.022	1.0
Settling velocity	λ_ω	3.87	2.0

the vertical scale (λ_h) is 60, the rate is two, less than five (Wave model test regulation 2001). The model design plane layout is shown in Fig. 3. Model sediment selection is the key step to moveable physical model test.

3.1.2 Model Sediment Selection

According to the sediment median grain diameter of project area and similarity criterion (Technical regulation of modelling for tide-current and sediment on coast and estuary 2010; China professional committee 1992), the different model sediment grain diameter scale satisfied with initiating similarity and scouring and siltation location similarity synchronously(Cao 1992; Dou 2001) had been calculated. Bakelite powder (the density is1.45 g/cm^3) can satisfy with initiating similarity and scouring and siltation location similarity and sedimentation similarity. So, bakelite powder is confirmed as model sediment, the average grain diameter scale is 1.0. Of course, the above confirmed scale is primary, it will be modified and verified in the final test according to the model sediment transportation.

The final scale relation for physical model is shown in Table 3.

3.1.3 Simulation

- Wave: irregular wave is adopted in wave sediment physical model test (see in Fig. 4). The representing wave direction is 11.4 (from south to west),the representing wave height of this area is 1.75 m. Known from the calculating results of initiating wave height, when the wave height is 0.5 m (the wave period is 12 s),the sedimentation at the location of 7.5 m water depth can initiate. So wave is the main hydrodynamic factor, the above representing wave height calculated can satisfy with the requirement of initiating.
- Estuary: according to the analyzing results of numerical model, the flow dynamic of project area is feeble, the sediment coming from the estuary will disperse like fan shape under wave action, after project constructed, the sediment volume of long-shore transportation will change and the sand dam will be clashed out. Thus, the sediment coming from the Serayu River will disperse to the project area quickly, more earlier than before the sand dam clashed out. So, the estuary of Serayu will be simulated in the physical model test. The flux, sand dam and bottom material of Serayu River have been considered.

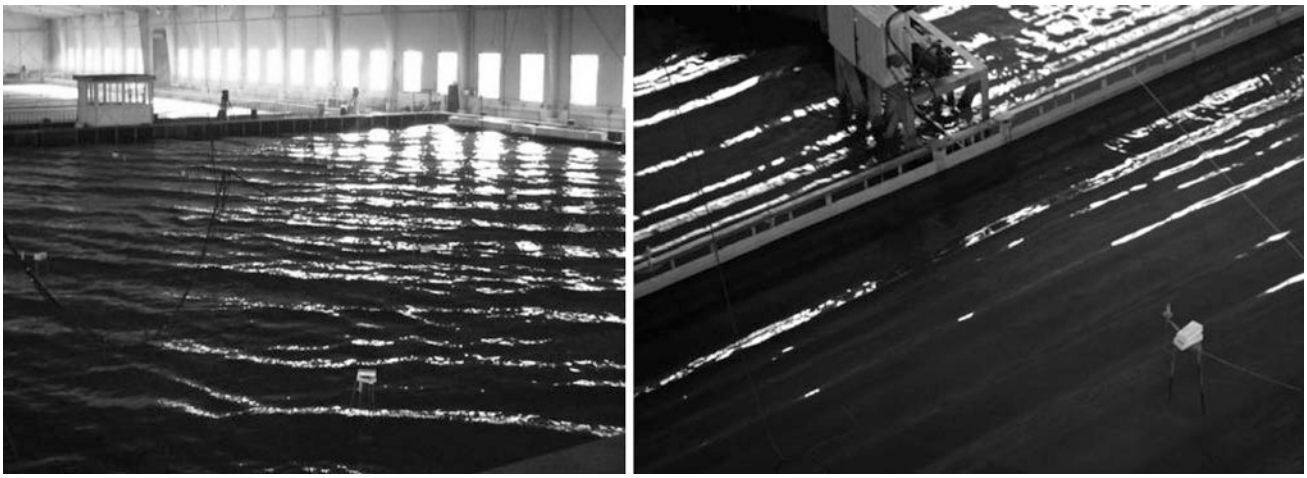

Fig. 4 Irregular wave generator in physical model test basin

- Sediment: The model sediment have been paved up at the range from the surf zone to the mouth of breakwater. So, two prototype bottom materials are considered in the physical model. They are: (1) The representing grain diameter near shore (including estuary and surf zone) is 0.15 mm (the average median grain diameter). (2) The representing grain diameter of project area (including mouth and navigation channel) is 0.08 mm (the average median grain diameter).
- The flux of C. W inlet and outfall: Two cases are considered in the model test, Adipala power plant (this new project) is 31.0 m^3/s (1 × 660 MW) and S2P power plant (exist) is 24.85 m^3/s (2 × 300 MW).

3.2 Verification Test of Movable Bed

The project of Adipala power plant locates in the parallel-straight coastline of silt-sandy beach. The breakwater would destroy the equilibrium sediment transport, if the layout of harbor plan is not reasonable (Yan 2002), serious sedimentation would happen in harbor basin such as deposition problem in water intake and basin of S2P power plant (nearby this project). According to the bed-load taken from the basin of S2P harbor, D_{50} is the range of 0.1–0.15 mm, the result shows that the grain size of sediment is more difference to estuary of Serayu river (0.03–0.06 mm). But the sediment is the same as that of outside area of basin. This phenomena show that the sediments came from bed load which transported by joint actions of wave and current, instead of suspended sediment from estuary directly, and the sediment concentration is low assuredly. So, the main deposition composition is bed-load.

Based on previous analysis, the water level alternation also had been considered in order to simulate the tidal prism, and to realize the change tendency of the coast from sediment stating off by wave and transporting by tidal current. And the process of silt in reality is just like this mechanism. There are about 160,000 m^3 sediment in water intake of S2P power plant. So, the sediment transport rate is about 51.1 t/h according to the average density of sediment in prototype (2.8 t/m^3). The physical model replays the deposition process of harbor basin and water intake of S2P power plant. The result shows that the siltation intensity and distribution are closed, and they are satisfied with the similarity relation ($i_l = 60$). So, the selection of dynamic condition and model sediment is reasonable, the result of verification test is perfect.

3.3 Deposition of Adipala Projects

Based on the result of verification test, the harbor of Adipala power plant was simulated in homologous position. The Adipala projects used same hydrodynamic condition which used in verification test (S2P). The breakwaters are designed to extend beyond the surf zone of 5.4 m wave height from E.L.W.L to +1.83 m water level which avoids the effect of active sediment movement, such as long-shore sediment transport and transverse transport. Because the opening area of basin and breakwater head had extend beyond of zone of sediment turbidity (<0.01 kg/m^3), so the deposition of basin expressed relative limitation. Physical model simulated one year (12 months) in prototype, continuously. The result shows that the sediment deposition occurred in the area of approach channel, opening zone and in front of pier, and the distribution of erosion and deposition is shown in Fig. 5. Siltation thickness in basin and channel of physical model is about 0.02–1.91 m/a (Ave. = 0.52 m/a) after 12 months in prototype, siltation

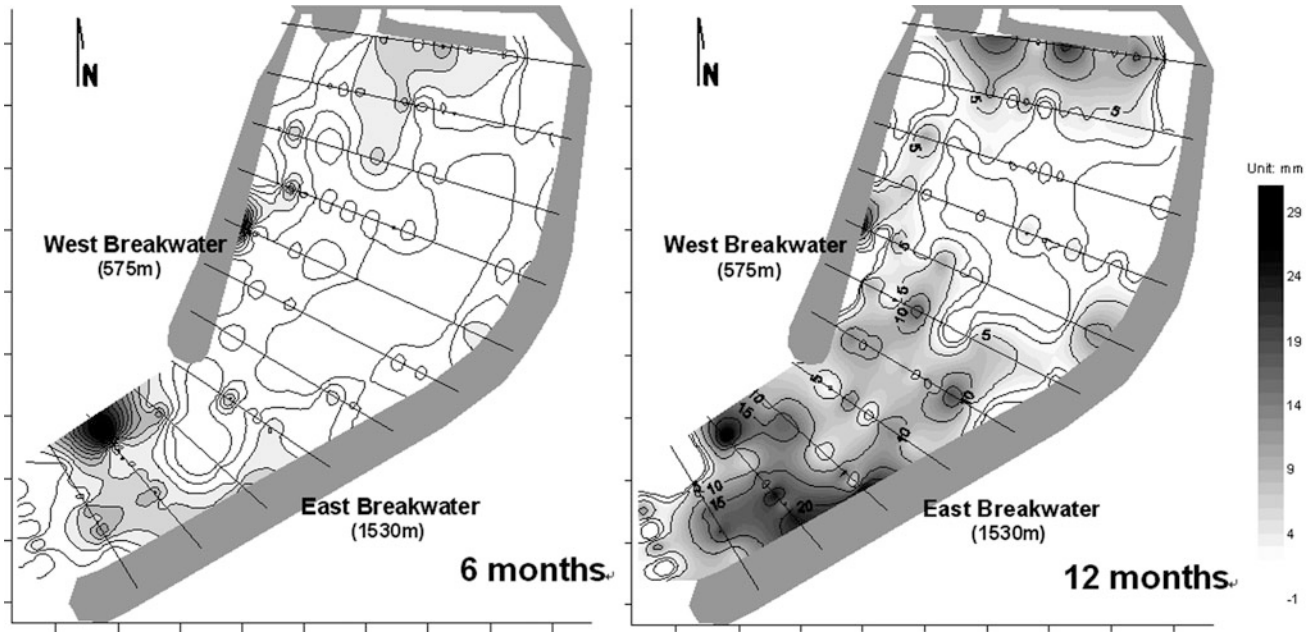

Fig. 5 Distribution of sediment deposition in harbor basin and approach channel9

Table 4 Result of physical model test

Item	Survey value in prototype by physical model test
Deposition thickness (m/a)	0.02–1.91(Ave. = 0.52)
Siltation volume(m^3/a)	16.8×10^4

volume is about 16.8×10^4 m^3/a, the results are shown in Table 4.

It should be mentioned that the maximum deposition is at inner side of and close to east breakwater, then occurs at the extend area of west breakwater. The navigation channel is between the two areas, and about half of maximum value. It shows the navigation channel direction is perfect. As the same time, there are siltation at the root of west breakwater. By calculate, it will be more than 30 years when the alongshore sediment transport around the breakwater head.

4 Conclusion

1. The siltation thickness is about 0.02–1.91 m/a (the average value is 0.52 m/a)and the deposition volume is about 16.8×10^4 m^3/a in harbor basin after project constructed.
2. When the deposition occurred in harbor basin, the alongshore sediment transport happened in the surf zone of near shore. But the sediment transportation had been blocked off by breakwaters because they all extended beyond of surf zone. And, the siltation at the root of east breakwater were more light than west breakwater due to the runoff of estuary.

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