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The Enginering Important Components of Jatibarang Dam, Semarang, Indonesia

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Abstract-Semarang City suffers from inundation caused by storm rainfall and high tide due to its low-lying topography along the coastal area. The Jatibarang Dam purpose is to develop a new source of water for Semarang City and to control the flood discharge of West Floodway as the biggest river in Semarang. Also, it has been recognized that the combination of the Jatibarang Dam and the rivers improvement is the most feasible flood control measure. The flood control scheme will be established to protect Semarang City from the 50-year return period flood and the water resources development scheme is planned to assure the water to the 10-year draught. The design flooding will be controlled by the Jatibarang Dam. About 270 m^3/s of 50-year return period flood at Jatibarang dam will be controlled by the dam and the discharge from dam will be reduced to 100 m^3/s. The Engineering important components of the Dam are diversion tunnel, dam structure, spillway and conduit of power works. Each component will be elaborated in this article.

Keywords: Engineering components, Dam, Semarang

1. Introduction

Semarang City has a population of about 1,500,000 and therefore it plays an important role as the regional urban centre in Indonesia and West floodway/Garang River is one of the important sources for the city. There exists a large-scale water intake weir named Simongan about 5.3 km upstream from the river mouth, and the river channel below the weir changes its name to West Floodway from Garang River. The West Floodway / Garang River originates from Mt. Ungaran (El. 2,050m) and flows through Semarang City and finally pours into Java Sea. However, the water supply is hardly secured due to the extremely low flow during the dry season. As a result, the number of population covered by the public water supply is limited to 34% of the whole population of Semarang. Thus the City and his vicinities currently suffer from the chronic shortage of the municipal water use in particular.

Semarang also experienced a large-scale of flood overflow in 1990, which resulted in the disastrous damages including death of 47 people, and asset loss of about Rp. 8.5 billion (700 000 euros). Nowadays, Semarang City is still exposed to menace of recurrence of flush flood from the River and even increasing the flood damage potential in proportion with increment of the population in the flood potential area (Jonathan Planchot et al., 2012).

In addition of the chronic shortage of water supply and the damage by the flood overflow of the West Floodway/Garang River, Semarang City also suffers from inundation caused by storm rainfall and high tide due to its low-lying topography along the coastal area. Indeed, Semarang City lacks of adequate drainage facilities and, thus, encounters land subsidence. The land subsidence tends to grow year by year acceleration the extent of inundation area. The annual rates of land subsidence have increased from 4 cm in 1998 to 20cm in 2003 at Tanjung Emas Harbor located near to the river mouth of West Floodway.

The main reason of land subsidence is the excessive abstraction of groundwater (S. Imam Wahyudi, 2010)

The project is composed of a flood control plan and a water resources development plan. The flood control scheme will be established to protect the Semarang City from the 50-year return period flood and the water resources development scheme is planned to assure the water to the 10-year draught (CTI Eng., 2000)

As for the water resource development, besides a new municipal water development for the new demand in the target area, it is desired to develop the surface water instead of the ground water use at the industrial area along the sea shore because the ground water sanction for the industrial use has been one of causes of the land subsidence which is the critical problem of the city of Semarang. The area has been waiting the surface water supply but there is no supply at present (Ginting, D. M., 2012).

Mainly, the objectives of the whole Jatibarang Dam and River Project are to mitigate the damage caused by the flush flood from the West Floodway/Garang River, to develop water resources for the municipal use in Semarang City, to improve the environmental conditions along the river and the urban area and to upgrade the living conditions of inhabitant in the project area

However, this article will only focus on the Project undertaken by the Directorate General of Water Resources (DGWR) of Indonesia Public Work namely the Jatibarang Multipurpose Dam.

2. Fundamental Data and Plan

The Jatibarang Dam purpose is to develop a new source of water for Semarang City and to control the flood discharge of Garang River. The flood control scheme will be established to protect Semarang City from the 50-year return period flood and the water resources development scheme is planned to assure the water to the 10-year draught.

The design flood will be controlled by the Jatibarang Dam. About 270m^3/s of 50-year return period flood at Jatibarang dam site will be controlled by the dam and the discharge from dam will be reduced to 100m^3/s. Finally, the discharge at the Simongan Weir will be reduced to 740m^3/s from 970m^3/s. The distribution design flood in the Garang river basin is shown in Figure 1.

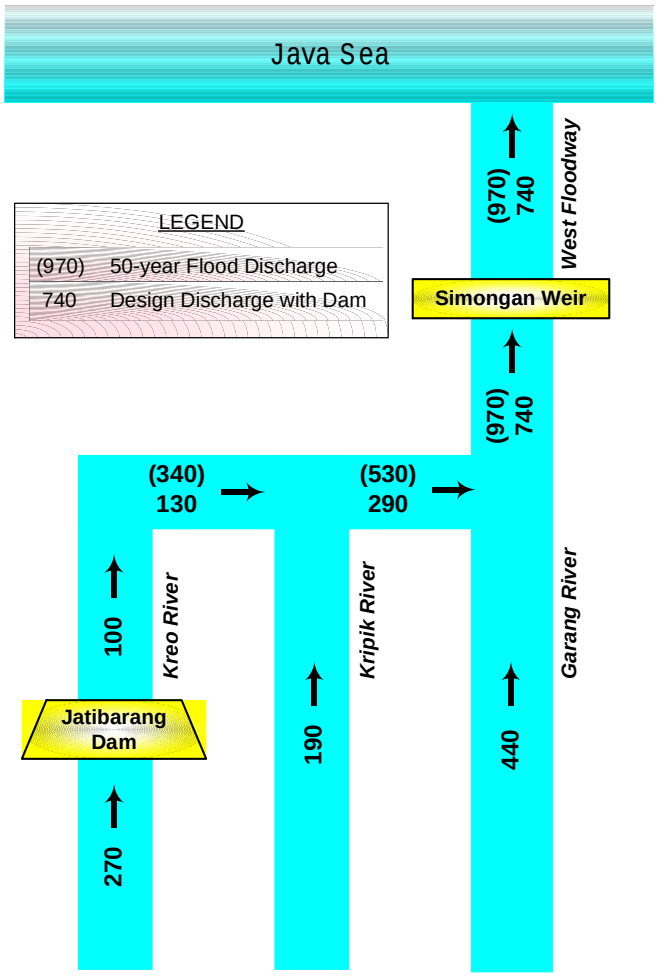

Figure 1 Scheme of River Flood Discharge Distribution

The construction site of Jatibarang Multipurpose Dam is located on the Kreo River about 13 km upstream from the confluence with the Garang River or 23 km upstream from the river mouth of the West Floodway.

The effective storage capacity of the reservoir is located from Low Water Surface to Surcharge Water Surface. Low Water Surface securing a 6,800,000 m3 of sedimentation for project life is EL. 136.0 m. The Surcharge Water Surface is calculated as Dam Crest EL 157.00 m, Maximum Water Surface EL 155.30 m (rounded), PMF Overflow Depth 3.50 m (result of flood routing simulation), Surcharge Water Surface EL 151.80 m, The reservoir capacity between EL. 151.80 m and EL. 136.00 m is 13,600,000 m3 as Effective Capacity with Flood Control Capacity 2,700,000 m3 and Water Use Capacity 10,900,000 m3 (CTI Eng., 2008a).

3. Research Methodology

A hydraulic test has been hung out to find the better position for the spillway. The test has been conducted by the Experimental Station for Hydraulic Structures and Geotechnics, Research Centre for Water Resources, Agency for Research and Development, Ministry of Public Works from April to August 2008 in Bandung City. The construction of the model had been finished the first week of May 2008 and the test had been carried out (CTI Eng., 2008b)

Figure 2 Hydraulic Model Test of Jatibarang Dam

Problems on original model are

- The capacity of overflow section is a bit lower than design condition.
- Difference of discharges from right and left overflow section.
- Dead water area at right upstream of overflow section due to the shape of approach channel.
- Stable water flow can't be obtained at the control point and chute because of the channel bend at just upstream of the control point.
- Due to the difference of discharges from right and left overflow sections, the flow in the bath-tub is disturbed when the discharge is smaller than design discharge.
- Due to the drift current at control point, the flow water along the chute overtops the side wall of chute during PMF.
- Hydraulic jump occurs at the energy dissipater but water overtops the side wall because of drift current from chute.

To settle the above problems on hydraulic condition of the spillway, following two issues shall be improved:

- Discharge from left overflow section shall be same as that from right overflow section to minimize the drift water. If the discharge from left overflow section were increased and make it same as right overflow section, it is assumed that the capacity of overflow section will meet with original design condition.
- To obtain the stable flow in the bath-tub and to minimize the drift water along the chute way, the drift water shall be controlled at the control point which is just downstream of the bending portion.

The proposed modifications are to cut and open the left approach channel not to obstruct the approach current to the overflow section, then to heighten the control weir at the control point to obtain the stable flow in the bathtub (M.F. Niam et al., 2002). The control weir shall be heightened not to affect the discharge from service spillway. The water level in the bathtub must be lower than the crest elevation of the service spillway to secure the perfect overflow condition at the service spillway.

3. Results and Discussion

Here are the different engineering components of the Project consisted on diversion tunnel, dam site, spillway and conduit of power work.

3.1. Diversion tunnel

The objectives of the diversion tunnel are to divert the stream-flow around or through the dam site during the construction period. They can minimize serious potential flood damage to the work in progress. The tunnel is designed to be capable of managing about 25-year probable flood that has been worked out as 280 m3/s. The trace of diversion tunnel is selected in the figure 3.

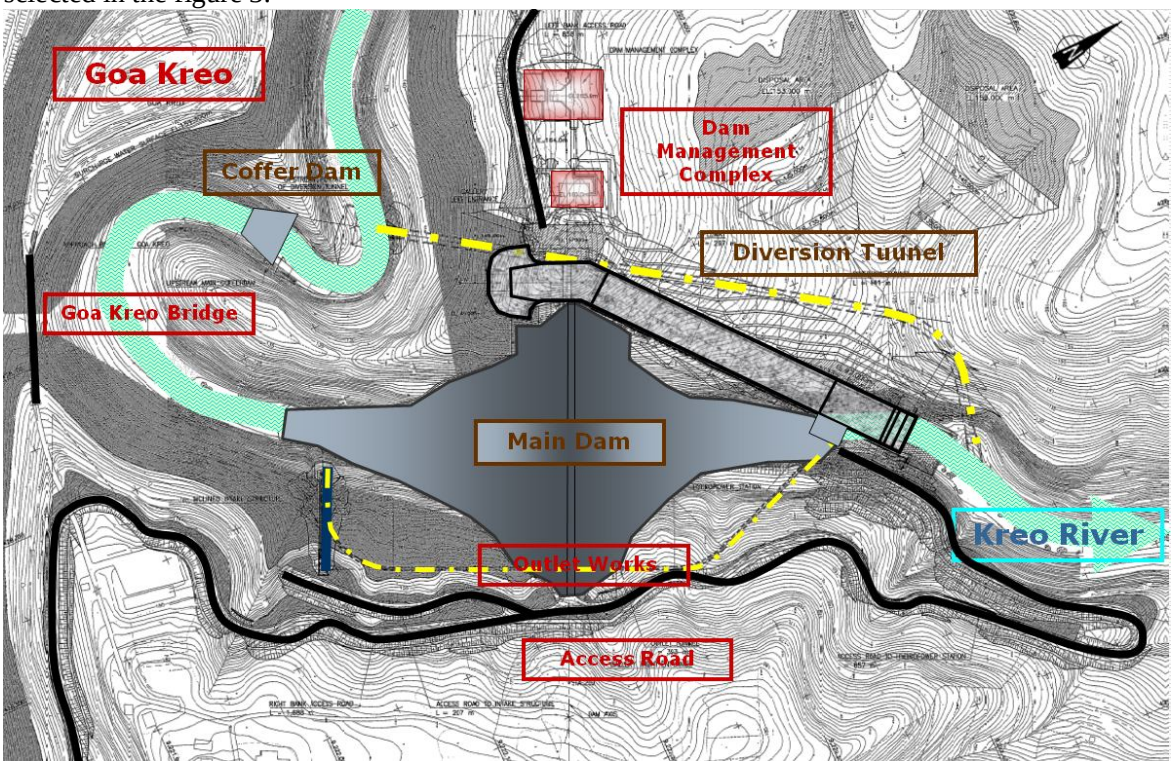

Figure 3 Scheme of Jatibarang dam Components

The diversion tunnel is located at the left bank of the dam site with a total length of about 441 m, the shoe section of the internal diameter of 5.60 m and longitudinal gradient of the tunnel is 1/30.

Figure 4 Intake and Outlet of the diversion tunnel

4.2. Dam Site

The main dam construction works consist of many kinds of works like excavation, foundation treatment by grouting, gallery construction and embankment. The feature of the dam can be described in the following. Dam Height above foundation is 77.00 m, with 157.00 m crest elevation and 80.00 m foundation elevation. Dam crest length is 200.00 m and crest width is 10.00 m with 1 : 2.6 upstream slope and 1 : 1.8 downstream slope.

Comparative study focusing on dam construction manners has been carried out. The construction plans for two alternatives are studied to clarify their advantages and disadvantages. It is concluded that the centre core rockfill type is the most suitable alternative for Jatibarang Multipurpose Dam due to the following reasons (CTI Eng., 2008b):

- Center core rockfill dam and concrete face rockfill dam are almost equivalent from constructional aspect considering their advantages and disadvantages. The construction periods of both types are also equal.
- Concrete face rockfill dam is just a little more expensive than center core rockfill dam. Concrete face rockfill dam has a saving of about 25% less embankment volume than the center core rockfill dam, but the expensive impervious membrane offsets the savings in embankment.
- In case of the concrete face rockfill dam, there is a possibility of initial leakage. When the reservoir is filled with water for the first time, the excessive leakage will develop through the face slab because of cracks in concrete. As the foundation of Jatibarang Multipurpose Dam consists of soft rock, the post construction settlement of the foundation may be so great that the face slab can't remain intact. The leaks may require that the reservoir be emptied for repairs. The maintenance cost may increase.

The structure of the dam can be found in figure 5.

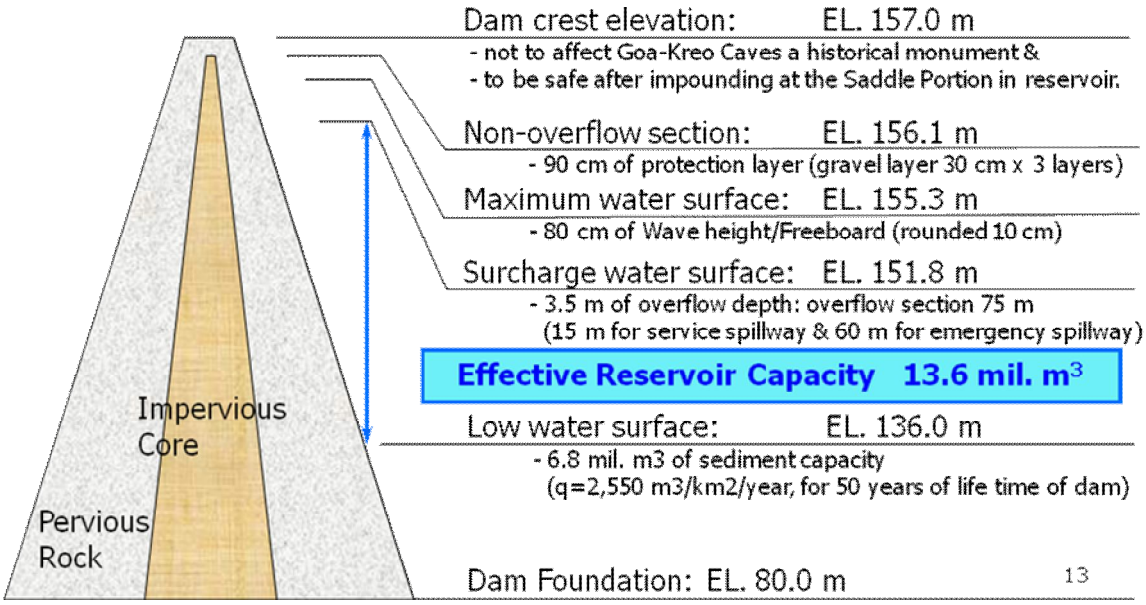

Figure 5 Cross of Jatibarang Dam structure

Basically, the impervious core will be composed of impervious material and semi-impervious material and the pervious rock will be composed by pervious material. The dam crest level was set at EL. 157.0 m from the following reasons:

- The historical monuments of Goa Kreo Caves are located at the elevation of EL. 162 m. It is preferable to set the dam crest about 5 m below the monument caves, considering the existing access road to the caves.
- The saddle portion at the right bank of the reservoir forms ridge which is 200 m long and 161.29 m of lowest elevation. In case the crest elevation is set at EL. 157.0 m, the deference of the crest elevation and the saddle portion is only 4.69 m and that of the saddle portion and the Surcharge Water Surface (EL. 151.8 m) is 10 m. Furthermore, the width of the saddle portion at the EL. 151.8 m is 150 m. Taking into account of the seepage water through the saddle portion, it is recommendable to set the crest elevation 10 m below the saddle portion.

Moreover these work schedules are complex and the progress of the grouting work is very important. Therefore, grouting works for foundation treatment are described, even though that is executed in the spillway also.

4.3. Spillway

Spillways are provided to release surplus or flood water, which can't be contained in the allotted storage capacity of the reservoir. Since Jatibarang Multipurpose Dam is planned to have a flood control function as one of its purposes, the following two features are considered:

- Probable Maximum Flood, Inflow to reservoir is 1,600 m3/s and Outflow from Emergency Spillway is 1,300 m3/s

- Design Discharge: 50-year Probability Flood, Inflow to reservoir is 270 m3/s and Outflow from Service Spillway is 100 m3/s
- Overflow Crest (Service Spillway): Crest Elevation (NWS) is in 148.900 m elevation and Crest length is 15.0 m
- Overflow Crest (Emergency Spillway): Crest Elevation (SWS) is in 151.800 m elevation and total Crest Length 60.0 m

The Spillway structure can be described in Figure 6.

Figure 5 Spillway structure seen from the downstream

4.4. Conduit of Power Works

As we can see on the figure 3, the conduit Works will be set out at the right bank of Jatibarang Dam. It will be composed of Intake structure (Inclined intake), Outlet tunnel (with embedded steel conduit) and Outlet structure (Hydropower station and two control gates)

The outlet works are to assure the reservoir yield, which is required for municipal water supply to Semarang City and river maintenance flow to the area downstream of the dam. The maximum out flow discharge is 2.70m^3/s which corresponds to the required flow at the Simongan Weir site.

For the emergency drawdown of reservoir water level, the capacity of outlet works are set at 6m^3/s at the Low Water Surface, to drawdown the reservoir water level from Normal Water Surface (EL. 149.3m) to Low Water Surface (EL. 136.0m) within 0.5 to 1 month. The Table below shows a simulation of the emergency drawdown. The red curve shows the effect of the width of the control gate on the flow generated and the green curve

shows the period related to drawdown the water level from Normal Water Surface to Low Water Surface.

Table 1 The Simulation of the emergency drawdown

Control Gate (mm)	Q (m3/s)	Period (days)
900	7,98	18,37
850	7,74	19,07
800	7,46	19,99
750	7,11	21,22
700	6,7	22,9
650	6,22	25,24
600	5,67	28,58
550	5,06	33,53
500	4,4	41,2

The emergency gate was first set at EL. 115.0 m than in the design review the intake elevation was changed from EL. 115.0 m to EL. 125.0 m. The reasons for this change are the following one:

- For the emergency drawdown of water level and emergency draught, it is preferable to set the lintel elevation as low as not to be affected by the sedimentation.

- Since the crest elevation of coffer dam is set at EL. 113.0 m, the lintel elevation must be higher than EL. 113.0 m.

The elevation was examined from Sedimentation, Water Use during emergency draught and Safety against dam break. As for the water use and dam safety, the lowest intake elevation is preferable but the intake elevation shall be safe against the sedimentation.

5. Conclusion

- The diversion tunnel is located at the left bank of the damsite with a total length of about 441 m, the shoe section of the internal diameter of 5.60 m and longitudinal gradient of the tunnel is 1/30.
- Dam body will be composed of impervious material, semi-impervious material and the pervious rock. The feature of the dam can be described that Dam Height above foundation is 77.00 m and Dam crest length is 200.00 m with crest width is 10.00 m.
- Spillways are provided to release surplus from reservoir. Design spillway Discharge of 50-year return period is 100 m3/s from + 151.80 m crest elevation with 60 m crest length.
- The outlet of power works are is required for municipal water supply to Semarang City and river maintenance flow to the area downstream of the dam. The out flow discharge is 2.70m^3/s, and for the emergency drawdown of reservoir water level, the capacity of outlet works are set at 6 m^3/s at the Low Water Surface.

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