DESIGN REHABILITATION OF WONOGIRI DAM, CENTRAL JAVA PROVINCE – INDONESIA

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ABSTRACT

The Wonogiri Multipurpose Dam has been constructed at Upper Solo River basin in 1981 for flood control, irrigation water supply and hydropower with 1,350 km² of catchment area. The Wonogiri reservoir has been rapidly filled with sediment transported from the catchment especially from Keduang tributary. Bad land use of its catchment and intensive farming of annual crops using poor practices on the highly erosive and steep-sloped uplands as well as highly populated and intensely farmed areas are the main causes of the sedimentation of the Wonogiri reservoir. It could be said that any countermeasure is not taken for the sedimentation problem of the Wonogiri reservoir, it would lose because of decrease of the storage capacity in the near future. Especially, the intake structure that feeds water to the powerhouse and downstream irrigation system has been seriously affected by sediment deposits at and around the intake structure. The quantity of sedimentation reached 50.9% of the dead storage on 2005 that came from Keduang River as Bengawan Solo’s tributary.

To decrease the sedimentation and keeping the dam life time, have been planed sediment storage reservoir countermeasures such as new spillway for sand flushing at right abutment of main dam, closure dike and overflow weir in the reservoir.

Keywords: Wonogiri, sedimentation, Bengawan Solo

1. BACKGROUND

Administratively Wonogiri Dam located in the Solo River, Danuarjo Village Wonogiri District, Central Java Province. Located 7 km south of the Wonogiri City. Wonogiri Dam is a clay core rockfill dam. The high is 40.00 m from the deepest foundation excavation and 830.00 m length. The spillway is non-overflow with 4 gates of 30.00 m width net.

The Wonogiri Multipurpose Dam has been constructed at Upper Solo River basin in 1981. Since impoundment of the Wonogiri reservoir on December 29, 1980, the reservoir has been rapidly filled with sediments. The quantity of sedimentation reached 50.9% of the dead storage on 2005 that came from Keduang River as Bengawan Solo’s tributary.

To mitigate sediment problem in the Wonogiri reservoir, the Master Plan and the Feasibility Study on countermeasures for sedimentation in the Wonogiri Multipurpose dam reservoir were carried out from 2004 to 2007 by JICA continued by Ika Adya Perkasa Consultant until 2009 and continued for detail design and supporting report by Nippon Koei Co, Ltd and Yachiyo Engineering Co., Ltd until 2010.

2. PROPOSED PLAN

In the Master Plan stage, the sediment inflow from the Keduang River and other tributaries were estimated. And the countermeasures were proposed.

a) Urgent Plan

- Sediment storage reservoir with new gate (it is composed with the new spillway for sand flushing at right abutment of main dam and closure dike and overflow weir)

- Watershed conservation in Keduang River basin
- Periodic maintenance dredging at intake

b) Mid Term Plan

- Watershed conservation in other tributaries

c) Long-lasting Countermeasure

- Rehabilitation of watershed conservation areas

Design annual sediment balance in the Wonogiri reservoir is shown below;

Additional facilities as mentioned on point 1) a) are:

- New spillway with 2 gates will be constructed on the right abutment. With width 15.00 m (@ 7.5 m), design discharge at PMF is 1,270 m³/sec with maximum operation discharge is 400 m³/sec.

- Closure dike A from earthfill with 700.00 m counterweight length and 9.4 m height.

- Closure dike B from earthfill with 700.00 m counterweight length and 8.4 m height.

- Closure dike C from earthfill with 402.00 m counterweight length and 5.8 m height.

- Overflow dike with concrete fixed weir type with 298.00 m length and 2.0 m height.

Advantages of these countermeasure are to

a) Prevent the sediment entering into the intake

b) Make it possible to conduct sediment flushing/sluicing without reducing the water level of the main reservoir, resulting in few effects on the water use of storage capacity of the wonogiri reservoir

c) Reduce the impact on the environment and social activities
3. HIDROLOGY

The hydrology conditions are:

- Hydro-meteorology: tropical climate with 29.3 °C annually mean temperature, 77.4% annually mean humidity, kecepatan angin rata-rata tahunan 2.31 m/sec annually mean wind velocity, 5.3 mm/day annually mean evaporation.
- catchment area: 1,350 km².
- annually rainfall: 1,990.00 mm/year calculated from 1983 ~ 2005.
- Probable Maximum Precipitation (PMP) : 307.4 mm with Hershfield method.
- Probable Maximum Flood (PMF) : 9,710 m³/sec with LST (long and short-term runoff model) Runoff method.
- Flood routing in reservoir.
4. NEW CONCEPT OF RESERVOIR OPERATION

Before going to the new operation new concept, we can see the comparation between existing and the propose operation that is shown in the table below:

Table 1. Reservoir water level operation design

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Control Water Level (m)</td>
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<tr>
<td>Low Water Level (m)</td>
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<tr>
<td>Water Use Storage (MCM)</td>
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The new spillway should be operated as long as possible from the start of a flood for passing sediment inflow. The release water from the new spillway is maximum 400 m³/sec. The existing spillway gates have to be opened when the main reservoir water level reaches EL.138.2 m in order to prevent the existing gate from being overtopped. The existing gates are opened and the new spillway gates are closed at the same time when the main reservoir water level reaches this elevation. The discharge is kept at no more than 400 m³/s against a flood smaller than the Standard Highest Flood (SHF) magnitude. The existing gates are further opened when the water level of the main reservoir reaches the maximum water level of Standard Highest Flood (SHF) or the surcharge water level whichever is higher. Of the four gates, three are fully opened and one is kept at 2.5 m opening in order to keep the maximum outflow being not more than 1,360 m³/s.

5. SEDIMENTATION

Measurement of sedimentation has been done several times since the dam was built by Gadjah Mada University in 1985 and 1990, PBS (Bengawan Solo River Basin Development Project) in 1986, 1987, and 1989. And the last is by PT. Mandala image Agritrans (PT. CMA) in 1993 and re-measurement in 2004 and 2005 by PBS.
Table 2. Reservoir capacity lost in 1980 and 1993

<table>
<thead>
<tr>
<th>Reservoir Zone</th>
<th>Reservoir Capacity (10^6 m^3)</th>
<th>Capacity Lost due to Sedimentation</th>
<th>Value (10^6 m^3)</th>
<th>of Original (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood Control Storage (El. 135.3 – 138.3 m)</td>
<td>232</td>
<td>2005</td>
<td>230</td>
<td>0.9</td>
</tr>
<tr>
<td>Water Use Storage (El. 127.0 – 136.0 m)</td>
<td>433</td>
<td>2005</td>
<td>375</td>
<td>13.4</td>
</tr>
<tr>
<td>Dead Storage (below El. 127.0 m)</td>
<td>114</td>
<td>2005</td>
<td>58</td>
<td>49.1</td>
</tr>
</tbody>
</table>


Figure 5. Elevation-capacity curve in 1980, 1993 and 2005

6. STRUCTURE COUNTERMEASURES

6.1. NEW SPILLWAY

The spillway is used for discharging sediment and also flood control. The maximum outflow should not be more than 400 m^3/s to prevent flooding in the downstream. Sediment discharging is more effective as the water depth is smaller or the surface gradient is steeper. Accordingly, “400 m^3/s under free flow condition” is the design requirement for the spillway. The spillway gates are operated when the water level comes up to CWL EL. 136.3m for flood control. The existing spillway gates will be opened and the spillway gates will be closed when the Wonogiri main reservoir comes up to EL. 138.2 m (0.5 m below the top of the existing spillway gate). The existing spillway discharges flood water for dam safety.

The control structure of the spillway is located at about 130 m upstream from the Wonogiri dam axis on the right bank. It has 2 radial gates with 12.6 m height, 1,270 m^3/sec capacity, 24.0 m width, and 21.0 m length with the highest elevation is +142 m which is equal with dam crest elevation or 1.9 m higher than PMF water level. The overflow crest is at +127.0 m.
6.2. CLOSURE DIKE

Closure dike consists of closure dike A of 700.0 m long, closure dike B of 700.0 m long and closure dike C of 402.0 m long. Closure dike A with 298.0 m long overflow dike is placed at the section between the dikes B and C. As described hereinafter, sediment deposit foundation of the closure dike A is necessary to be stabilized by effective measures to get safety against possible sliding failure and lateral movement to be caused by different water levels between Wonogiri main reservoir and sediment storage reservoir and minimize settlement to be caused by weight of the closure dike A.

Most part of the closure dike A of 700.0 m long is on the sediment deposit accumulated after the reservoir impounding in 1980. The depth of the deposit is about 20 m at the deepest part.

A 700.0 m long and closure dike B is connected with closure dike A. This dike axis is designed on the consecutive ridge which separates Wonogori main reservoir and sediment storage reservoir. Since the foundation of the dike is composed of comparatively hard and impervious soil layers, the dike will be constructed with excavated materials from new spillway site or proposed borrow pit. Before commencement of the dike embankment, top soil layer should be removed to get well contact between the foundation soils and embankment materials.

A 402.0 m long closure dike have topographic and geologic conditions almost same as the closure dike B.
6.3. OVERFLOW DIKE

The overflow dike is located between Closure Dike B and Closure Dike C. The overflow dike is constructed to divert the water from the sediment storage reservoir to the Wonogiri main reservoir for water storage. For wet season period, excess water above NHWL in the main reservoir flows over the overflow dike toward the sediment storage reservoir. The water is used for the sediment discharging operation in the sediment storage reservoir.

The overflow dike consists of overflow main body, apron, cut-off wall, retaining wall, scouring protection and connection channel with a gate. The total length of the overflow dike is 298m. The crest is at NHWL 137.0 m for the 250.0 m long. At each end side, a 24.0 m long transition section with a slope of 1:10 from +137.0 m to +139.4 m is provided to connect the overflow dike to the closing dike for having access for future maintenance.

There are 2 design flood for this structure, they are 1,260 m$^3$/s for inflow into the sediment storage reservoir only and 730 m$^3$/s for inflow into the main reservoir only.

![Figure 7. Layout of the countermeasures](image)

7. CONCLUSION

The conclusions of this paper are:

a) Effectiveness of these structure countermeasures is still unknown because its still on construction stage.

b) There are some points that have to be rechecked based on Indonesia’s dam safety standards such as loading conditions and PMP value.

c) Overview of the Emergency Action Plan have not been done.