Design of the Cua Dat CFRD in Vietnam, and innovative river diversion system

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(Some slides presented at “ASIA ’2006 Symposium”, Dec. 2006)
Cua Dat is a multipurpose scheme under construction in Vietnam. The main dam will be the highest CFRD in Vietnam (H= 119 m, L= 930 m, V = 13 hm³). The Design flood (1/1 000) is 13 200 m³/s and the Check flood (1/10 000) is 18 900 m³/s. The dam will be constructed in 5 years (2004-2009). The 20 year-flood, adopted as the Construction flood, has a peak inflow discharge of 1 230 m³/s during the dry season and 5 050 m³/s during the wet season.

To minimize the cost of the diversion structures, it was admitted to divert the flow during the most critical stage of the construction (wet season of 2007) by only one tunnel (L = 802 m, D=9 m) with an overtopping of the upstream and downstream cofferdams and of the main dam about 20 m higher than the river bed.

Extensive laboratory tests (scale 1/40), taking into account the zoning and materials of the three structures, have been performed in order to check their stability and to measure the pressure and velocity of the flows at different parts of the structures. Various alternatives have been tested : protection by concrete slabs, RCC, gabions or downstream stepped rockfill for different dam crest and water levels depending on the construction schedule and probability of floods. These tests have permitted to verify the resistance of the dams and to define precisely the most suitable protections for their crest, upstream/downstream faces and toe during the overtopping, with their respective advantages, drawbacks and costs.

This presentation provides some results of this study. Finally, the tests performed indicate that this solution leads to significant cost and delay savings compared with conventional method (high upstream cofferdam with several large diameter tunnels) and is therefore very promising for the future rockfill dams constructed in Asia, on large rivers with a marked seasonality regime.

(Viewers can see something about the Cua Dat Dam in details in this website (“Dams in Vietnam”) or directly [http://www.vnclold.vn/En/Web/Content.aspx?distid=231](http://www.vnclold.vn/En/Web/Content.aspx?distid=231))
Auxiliary dams

Dat tributary

Chu river

Previously suggested dam location

Headworks: (main CRFD, spillway, tunnels, hydropower plant)

Reservoir storage:
1 450 hm³

Flood Control

8 m³/s discharge for industry

Water supply source for 2.5 mil. people

87 000 ha irrigation

97 MW hydropower

Chu river in the dam area in dry season

Project area plan

3D Model of Cua Dat Headwork System

Cua Dat CFRD (H=119 m, L=930 m, V=13 hm³)

Cua Dat CFRD cross section
Some characteristics of the diversion works

- **Peak Flood (1/20) in the dry season = 1 230 m³/s**
- **Peak Flood (1/20) in the wet season = 5 050 m³/s**

- 1 diversion tunnel, in the right abutment, length = 802 m, diameter = 9 m
- 1 U/S cofferdam (E-R), height = 26 m
- 1 D/S cofferdam (E-R), height = 9 m
- Overtopping of the cofferdams and CFRD under construction (wet season of 2007) with:
  - The protection against erosion of the crest, the nose, and the toe of the three structures.
  - The placement of a compacted clay core upstream the bottom of the CFRD.

### Some features about the critical phase of the diversion

<table>
<thead>
<tr>
<th>Construction Year</th>
<th>Construction Period</th>
<th>Closing Date</th>
<th>Exceedant Probability</th>
<th>Diversion Discharge (m³/s)</th>
<th>Closing Discharge (m³/s)</th>
<th>Diversion Works</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st year</td>
<td>Dry season (Dec. to subsequent May)</td>
<td>5%</td>
<td>1230</td>
<td>Natural channel narrowed, Max WL = +3B.13m</td>
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</tr>
<tr>
<td></td>
<td>Flood season (June to Nov.)</td>
<td>5%</td>
<td>5050</td>
<td>Natural channel narrowed, Max WL = +3B.13m</td>
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<td></td>
</tr>
<tr>
<td>2nd year</td>
<td>Dry season (Dec. to subsequent May)</td>
<td>5%</td>
<td>1230</td>
<td>Tunnel 2 (TN), Max U/S WL = 43.36m, Max D/S WL = 30.50m</td>
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<tr>
<td></td>
<td>Flood season (June to Nov.)</td>
<td>5%</td>
<td>5050</td>
<td>Tunnel 2 (TN), Max U/S WL = 43.36m, Max D/S WL = 30.50m</td>
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<td></td>
</tr>
<tr>
<td>3rd year</td>
<td>Dry season (Dec. to subsequent May)</td>
<td>5%</td>
<td>7520</td>
<td>Tunnel 2 (TN), Spillway constructed to EL = 85.53, U/S WL = 89.67m, D/S WL = 50.50m</td>
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<tr>
<td></td>
<td>Flood season (June to Nov.)</td>
<td>5%</td>
<td>7520</td>
<td>Tunnel 2 (TN), Spillway constructed to EL = 85.53, U/S WL = 89.67m, D/S WL = 50.50m</td>
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</table>

- Inflow peak discharge ≅ 5 050 m³/s
- **Tunnel discharge variable with the MWL (≅ 700 m³/s)**
- **Overflow discharge variable with the MWL (≅ 4 400 m³/s)**
- River bed W.L = 28 m
- U/S WL, Dam crest L, MWL on the dam = variable according to the tests.
- D/S WL = 38.1 m

Cros section of the cofferdam & the CFRD crest is at level 45.0 m and the MWL on the dam is 50.0 m.
Purpose of the Laboratory Tests
(scale 1/40)

• To determine the flow conditions over the cofferdams and the CFRD under construction for different flood discharges and dam crest levels.

• To explore water velocities field and depths along various profiles of the reach between U/S and D/S cofferdams.

• To explore water pulsation at critical locations.

• To work out solutions to protect main dam as well as cofferdams.

• To examine eventual action of erosion.

• To adjust dimensions of diversion works, if necessary.

(1-2) Alternatives of downstream slope face protection by concrete slabs or gabion mats when overtopping

View (from upstream) of downstream concrete slabs protection

View (from upstream) of downstream gabion mats protection
Note that in these tests, the required resistances of the concrete slabs or gabion mats are not representative of the prototype. They are determined only by the values of the water velocities and pressure fluctuations measured on the models.

Detail on erosion at the end of the protection layer after the flood. The maximum water levels and velocities (max = 8.2 m/s) are indicated on the figure.

(3) Alternative of rock fill without protection.
This alternative was contemplated in order to avoid an expensive protection layer. The steps are 2.4 m high and 24 m large (1.6 m and 16 m respectively for alternative 2A). The maximum size of the rock fill is 0.8 m. This figure shows the rockfill steps levels (blue line) and the water levels (yellow line) at the beginning of the flood. The dam crest is at level 50.0 m and the MWL on the dam is 54.0 m.

Longitudinal profile after the flood. The figure shows the rockfill and water levels and the maximum water velocities, with the erosion of the upper part of the dam and the material deposit downstream the toe.
**Conclusion:** with such high head, important nappe depth and small size of the rock fill (0.8 m, limited by the low quality of the quarry), the dam cannot resist to the overflow without a protection layer.

(4) **Alternative with stepped gabions entirely on the downstream slope face of the dam** (no slope in the upstream slope part).

Note the thickness of the nappe compared with the height of the steps: the dissipation of energy is low on the steps and the erosion is still important at the toe of the dam.
View of the steps showing the disorganization of the compacted rockfill just under the gabions due to the piping of the small rocks through the gabions.

This type of protection requires the use of steel bars in place of wire mesh, a filter layer between the rockfill and the gabions and a reliable protection at the toe of the dam.

CONCLUSION

- CFRD can be overtopped during the construction if its crest, downstream face and toe are adequately protected against erosion.

- If the dam is constructed on a site with low discharge during the dry season, but with very large floods during some months of the wet season, it is possible to reduce, by this mean, the delay and cost of construction.

- As more and more CFRD will be constructed in Asia in such condition (monsoon), this practice seems very promising.

- It will be therefore interesting to collect in the future the experience of this method of construction to improve its economy and safety.