DESIGN OF RAW WATER RESERVOIR ON SANDY SOIL

Kondapalli Bairagi 1,
Niraj Kumar Mishra 2,
1Chief Engineering Manager, 2Engineering Manager, L & T Construction,
1kbr@lntecc.com, 2niraj.m@lntecc.com

P.V. Ramana 3,
Senior Design Engineer, L & T Construction.
ramanapv@lntecc.com

ABSTRACT:
This paper is a case study of a 5310 ML capacity Raw Water Reservoir (RWR), situated Rajasthan INDIA. This is a part of Rajasthan Rural Water Supply & Fluorosis Mitigation Project. This RWR embankment constructed with excavated soil on natural ground profile. Height of the embankment is varying from 2m to 10m. Water storage depth of the RWR is 9m. Embankment with 1V:3H slopes provided on both upstream and downstream sides. The available silty sand is used as a filling material for the embankment construction. Slope stability and Seismic analysis were carried out by using Conventional methods and by using Finite element software PLAXIS-2D. Horizontal filter has been provided at toe level where the embankment height is more than 7m from EGL. HDPE (High Density polyethylene) lining has been provided on upstream side and at bed level to control the seepage. Design of embankment dam for RWR is the critical one, site selection, properties of foundation soil & filling soil and seepage affect the design. All the safety measures were taken care while designing and the same has been ensured at site during execution.

KEY WORDS: Embankment dam, PLAXIS, Raw Water Reservoir, Seepage, Slope Stability.

1 INTRODUCTION

1.1 Reservoir
A Reservoir (etymology: from French reservoir a “store house“ ) usually means an enlarged natural, artificial lake, storage pond or impoundment creating a dam or lock to store water. Reservoir can be built by excavating existing ground and then constructing retaining embankment.

1.2 Embankment dam
A dam is composed of any type of soil including rock as per IS: 12169 (1987).

1.2 Large dam
A dam exceeding 15m in height above deepest river bed level and dam between 10m to 15m height provided volume of earth exceeds 0.75 million cubic meters and storage meters. 1 million cubic maximum water level exceeds 2000 Cumecs as per IS: 12169 (1987).

1.3 Small dam
A dam which is not satisfying the criteria of the large dams as per IS: 12169 (1987).
1.4 Safety

Embankment slope failure may occur if the soil shear strength is less. Other factors like earthquake may cause the dam failure given in IS: 7894 (1975). Overtopping or overflow of an embankment dam may also cause eventual failure. It is required to provide minimum free board to prevent overtopping failure as per IS: 8826 (1978).

2 CASE STUDY

2.1 Location

The present RWR is located at Jaimalsar village, Bikaner District, Rajasthan, India. The nearby railway station is Bikaner Railway station, which is 60 km away from the site.

2.2 Physiography

Topography of the area: Uneven, Soil Type: Silty sand
Climate: Arid-Sub-Arid, Earthquake Zone: Zone-II

2.3 Storage Capacity of the reservoir

Minimum free board provided = 1.5 m.
Top of the reservoir bund level (TBL) = RL. (+) 223.5m
Reservoir bed level (RBL) = RL. (+) 214.50 m.
Maximum water level (MWL) = RL. (+) 222.0 m.
Low water level (LWL) = RL. (+) 215.50 m.
Maximum depth of water, H = 6.5 m.
Surface area of the reservoir at LWL = 777523 m²
Surface area of the reservoir at MWL = 8639924 m²
Storage capacity = 5332238 m³
Required capacity = 5310000 m³

3 GEOTECHNICAL STUDY

Sub – soil Exploration
Bore holes of depth 15m and Trial pits of 3m x 3m x3m were taken at specified locations to ascertain the information about the sub-soil, its nature and strength. Soil samples were collected at different depths to identify the soil strata and to conduct laboratory tests. In-situ tests were conducted in Boreholes and disturbed samples are collected from boreholes and Trial pits were sent to laboratory for conducting various tests. Water table was not encountered during the maximum explored depth.

3.1 Laboratory Testing

Appropriate laboratory tests were conducted based on IS: 2720 (2006-07). The main tests are conducted which are listed out as following.

3.1.1 Tests on Borehole & Trial pit samples

- Atterberg limits (Liquid limit, Plastic limit)
- Natural moisture content, Bulk density
- Grain size analysis
- Specific Gravity
- Chemical tests on soil & water
- OMC & MDD
- Permeability test at 95% MDD
- Tri-axial test for determining \((c & \phi)\)

4 ANALYSIS

Based on the geotechnical investigation report Slope stability & Seismic Stability analyses were done for the embankment by conventional method and with PLAXIS-2D.

4.1 Introduction to PLAXIS-2D (2014)

PLAXIS is a finite element package that has been developed specially for the analysis of deformation and stability in geotechnical engineering projects.

4.2 Slope stability analysis

Maximum height of the embankment = 10 m.
U/s & D/s slope = 1V:3H
Cohesion varying from 8 kN/m² to 13 kN/m²
Angle of internal friction varying from 32 to 36 deg.
Saturated unit of the soil varying from 16 kN/m³ to 17 kN/m³

Stability analyses were done by Indian standard guidelines for both U/s and D/s side for different combinations of \(c & \phi\) and 4 trials were made. Figure 1 indicates Trial-1 of D/s side for slope stability analysis.
Minimum factor of safety considered for steady state seepage condition was 1.5 and for sudden drawdown condition was 1.3. Minimum factor of safety for overall stability and seismic stability were 1.3 and 1 respectively. The model was simulated with PLAXIS-2D. Table 1 gives the safety factors for the D/s side 4 trials and table 2 to gives the comparison of safety factors for conventional method and PLAXIS-2D.

Table 1 Slope stability analysis – Trial details

<table>
<thead>
<tr>
<th>Trial No</th>
<th>Radius (m)</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31</td>
<td>2.64</td>
</tr>
<tr>
<td>2</td>
<td>30.4</td>
<td>2.57</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>2.51</td>
</tr>
<tr>
<td>4</td>
<td>28.5</td>
<td>2.54</td>
</tr>
</tbody>
</table>

Fig. 1 Trial-1 for Slope Stability Analysis

4.3 Analysis with PLAXIS-2D

Embankment was simulated with PLAXIS software for steady state seepage (Figure 2) condition and sudden drawdown condition (Figure 3). Mohr-Coulomb Constitutive model was used for analysis.

Fig. 2 Critical slip circle for Steady state seepage

4.4 General considerations/ Specifications

- 600 mm foundation filling has been made with excavated earth filling in layers of 150mm compacted thickness, each layer shall be compacted to achieve 97% of modified Proctor density.
- The reservoir embankment shall be made with excavated earth filling in layers of 150mm thick to achieve 95% of MDD.

5 DESIGN

5.1 Typical section

Fig. 3 Critical slip circle for sudden drawdown

Table 2 Comparison of safeties between conventional method and PLAXIS-2D.

<table>
<thead>
<tr>
<th>SL No</th>
<th>Stability criteria</th>
<th>Conventional method</th>
<th>PLAXIS-2D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slope stability (steady state seepage)</td>
<td>2.51</td>
<td>2.08</td>
</tr>
<tr>
<td>1</td>
<td>Slope stability (sudden drawdown)</td>
<td>2.95</td>
<td>2.25</td>
</tr>
<tr>
<td>2</td>
<td>Overall stability</td>
<td>9.56</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Seismic stability</td>
<td>2.19</td>
<td>-</td>
</tr>
</tbody>
</table>

Fig.4 Typical section of the Embankment
5.2 Horizontal filter details

Fig. 5 Details of horizontal filter

5.3 Lining details for embankment slope

Fig. 7 Lining details of Embankment slope

5.4 Photograph at Construction site

Fig. 8 Photograph at construction site

6 SUMMARY

This case study explains the analysis and design procedures for RWR construction on silty sands. From Conventional method and finite element analysis results it is observed that finite element method is giving lesser factor of safety values due the accuracy and reliability. The design, concepts and analyses can be applied for similar type of structures.

REFERENCES:


IS: 7894 (1975), Code of practice for Stability Analysis of Earth dams, Bureau of Indian Standards, New Delhi, India.

IS: 8826 (1978), Guide lines for design of large earth and Rock fill dams, Bureau of Indian Standards, New Delhi, India.

IS: 12169 (1987), Design of small embankment dams, Bureau of Indian Standards, New Delhi, India.

IS: 2720 (2006-07), Methods of tests for Soils, Bureau of Indian Standards, New Delhi, India.