Introduction

Cut-off walls are one of many seepage control measures currently used in dams to reduce the adverse effects caused by seepage such as:

- Piping
- Excessive uplift
- Internal flooding

Aim:
Expanding existing research by analysing the impact cut-off walls with unique geometrical alignments that accommodate branches stemming of a standard vertical cut-off wall has on seepage through the foundation of a concrete dam structure.

Methodology

A concrete diversion dam, under steady state conditions with a base and height of 10 metres had been considered as the base model. 2D finite element analysis (FEA) had been conducted utilising PLAXIS 2D LE to idealise the dam and conduct numerical analysis to simulate groundwater flow to analyse seepage.

Materials utilised were of the following:

<table>
<thead>
<tr>
<th>Material</th>
<th>Permeability Value (m/s)</th>
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<tbody>
<tr>
<td>Cut-off Wall</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>Foundation</td>
<td>$10^{-5}$</td>
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</tbody>
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Control variable would be:
- adjustment of the cut-off wall’s branches at varying angles (0-90°)
- Shape factor of cut-off wall (length & width)
- Position of cut-off wall under dam

This is to find the most optimum position and angle to reduce seepage and uplift pressure.

Results

Figure 4: Seepage reduction based on cut-off wall shape

Figure (4)'s importance is that there is a correlation which shows branch thickness has an "almost" equal effect on the seepage as does when changing the branch’s length (therefore dependant on total area).

Figure 5: Depiction of cut-off wall shape

Figure 6: Seepage reduction based on branch angle & location under dam

Figure (6), presents that the most effective cut-off wall location is at the heel of dam with a reduction of 48.5% when associated with branch angle of 65-70°. 7.5% more effective than having a standard vee cut-off wall at the same location. With the worst position being at the centre of the dam base.

Figures (7 & 8), show idealised pore water pressure (for uplift pressure) under the dam base (exaggerated). It was found from this experiment that increasing branch angle from vertical to perpendicular leads to a slight decrease in uplift pressure at the toe of the dam whereas at the heel there would be an increase.

Conclusion

- Adding a branch to either side of a vertical cut-off wall is shown to decrease seepage and altering that angle (10 to 90°) decreases seepage further with minimum at ~65° with a 7.5% reduction compared to no branches
- For uplift pressure, most conservative approach is placing cut-off at the heel leading to max. uplift reduction, with a max. reduction of 48% in comparison to just a vertical wall where it’s 40.5%
- Additional research presented that the branched arrangement at an optimum position and angle is more efficient and cost-effective than excavating two areas for the 10 m dam arrangement.

Recommendations

- Investigate the effects of having anisotropic soils on seepage with the branched cut-off wall arrangement and use cut-off walls made of various materials.
- Finally, observing effectiveness of a single branched cut-off wall arrangement on dam base greater than 10 metres.

References:


Figure 1, 2 & 3: Branched cut-off wall at different locations and angles within the foundation of a concrete dam

Figure 4, 5, 6, 7 & 8: Idealisation of uplift force under dam base for different position and branch angle of cut-off wall

Table 1: Stage Materials (adapted from: Mansuri et al. (2014))