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Principle References:

Angelov, M., & Asr, A. A. (2021). The effect of cut-off wall angle on seepage and uplift pressure under dams (Version 1). Loughborough University. https://doi.org/10.17028/rd.lboro.14587398.v1

Mansuri, B., Salmasi, F., & Oghati, B. (2014). Effect of location and angle of cutoff wall on uplift pressure in diversion dam. *Geotechnical and Geological Engineering*, *32*(5), 1165-1173.

Effects of Cut-off Wall Geometrical Alterations on Seepage & Uplift Pressure

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.

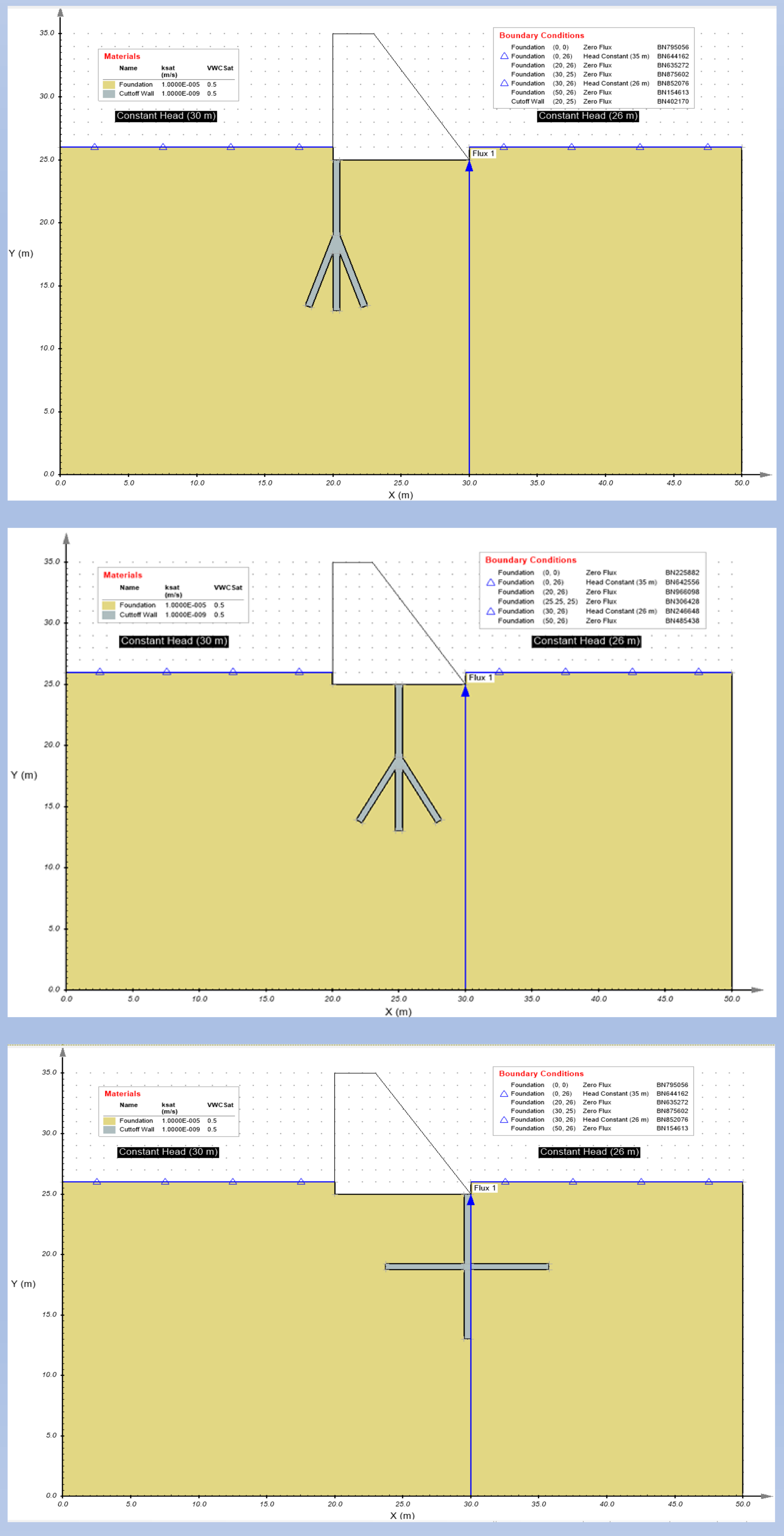

Figure 1,2 & 3: Branched cut-off wall at different locations and angles within the foundation of a concrete dam

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:

Material	Permeability Value (m/s)
Cut-off Wall	10^{-9}
Foundation	10^{-5}

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

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

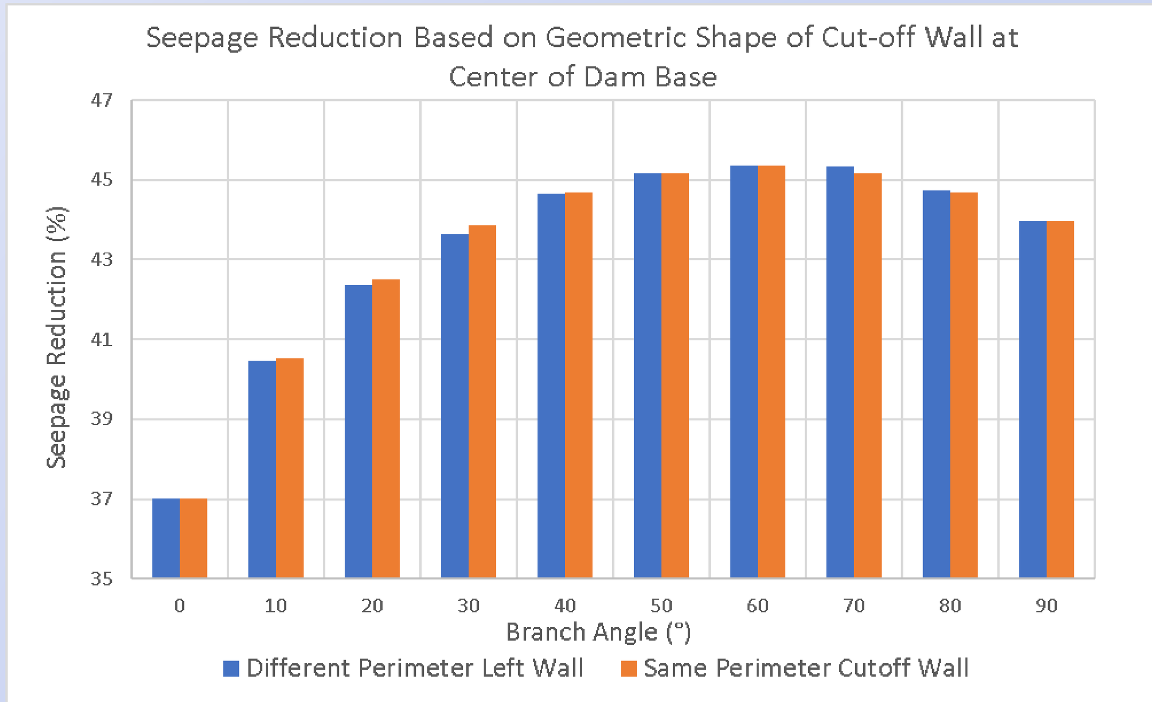

Figure 4: Seepage reduction based on cut-off wall shape

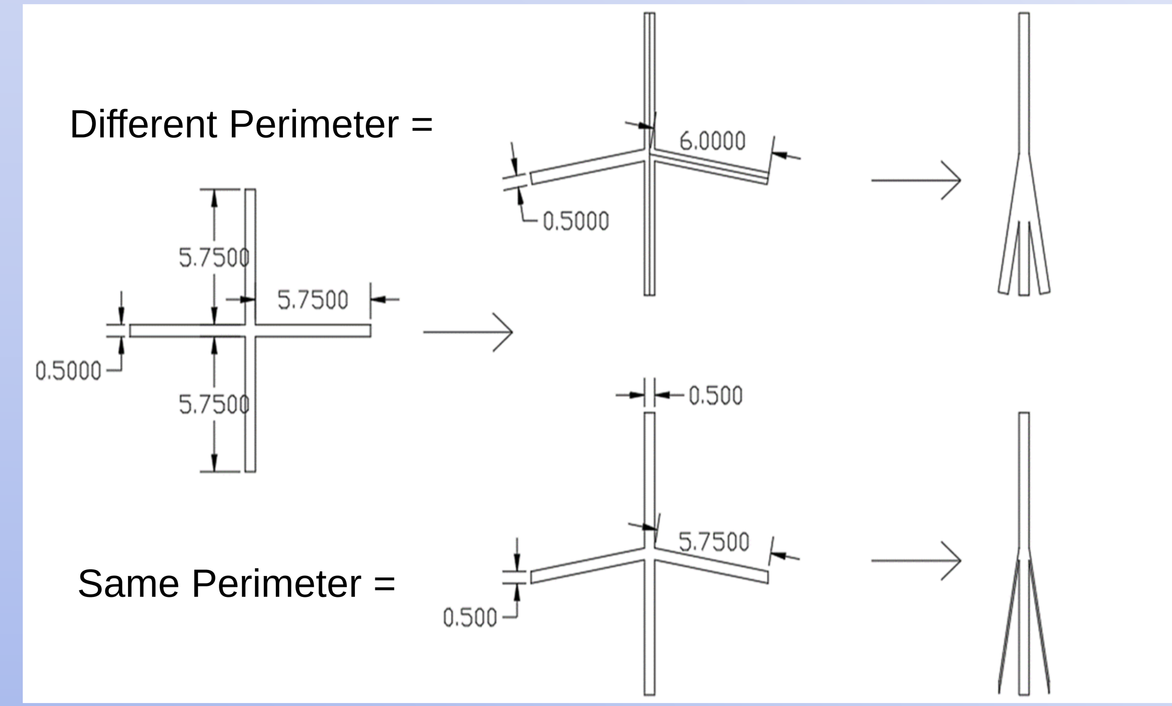

Figure 5: Depiction of cut-off wall shape

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).

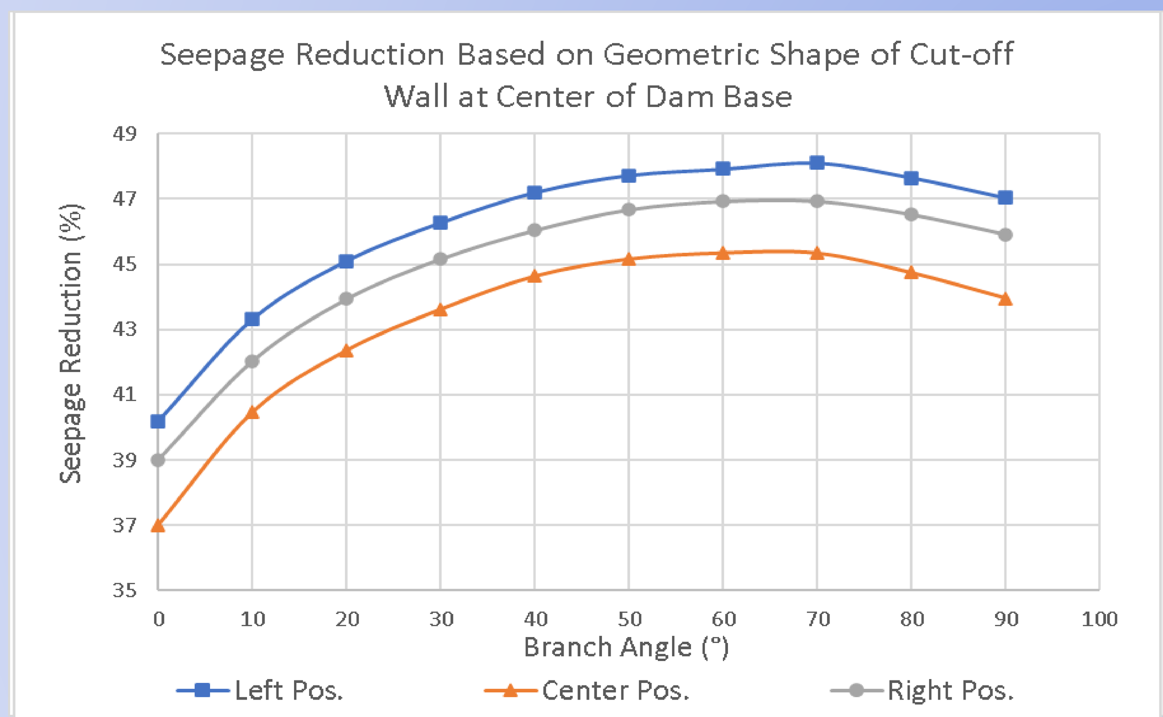

Figure 6: Seepage reduction based on branch angle & location under dam

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 vertical cut-off wall at the same location. With the worst position being at the centre of the dam base.

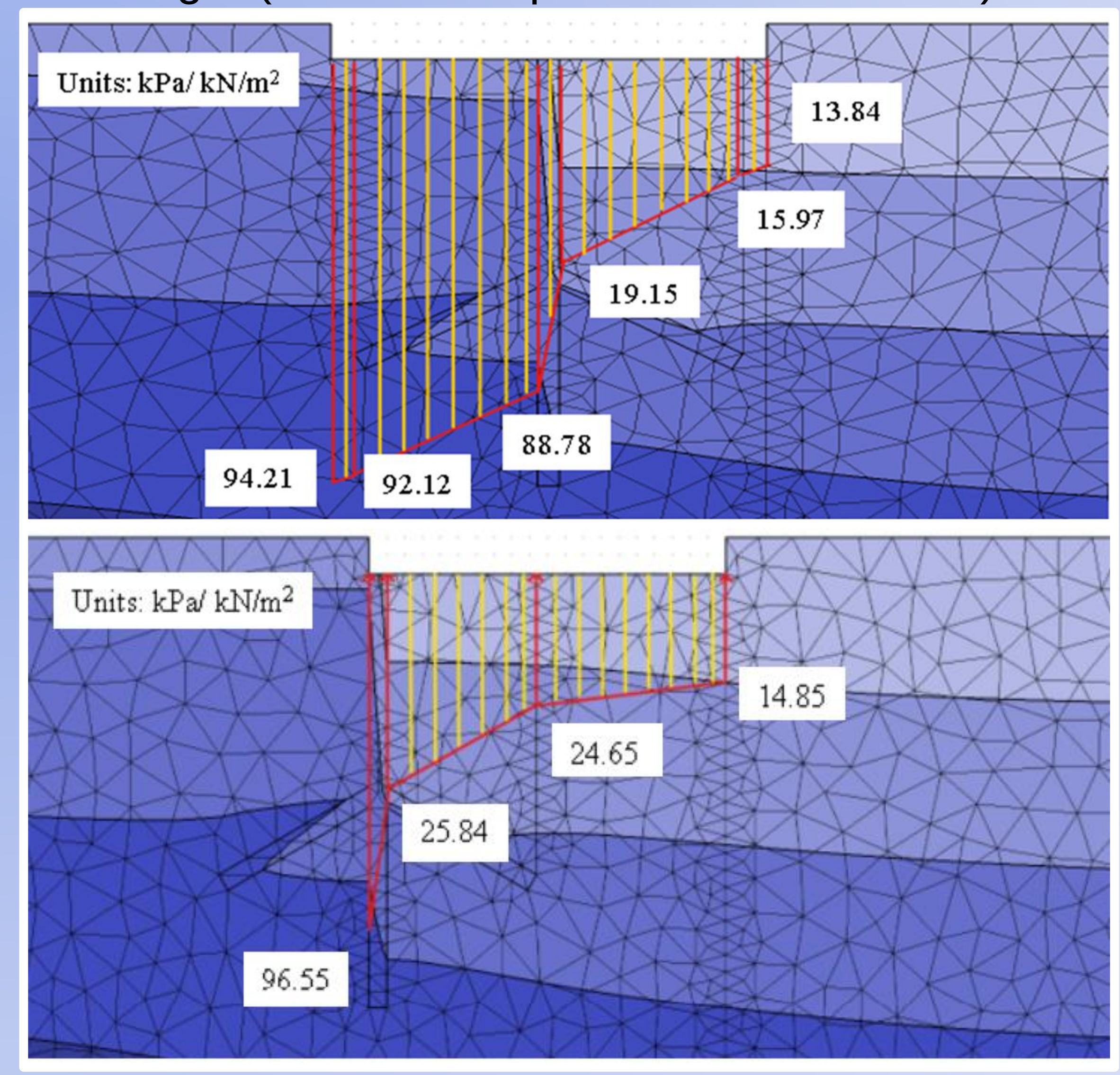

Figure 7 & 8: idealisation of uplift force under dam base for different position and branch angle of cut-off wall

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 heal 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.