Undergraduate Research Symposium

Seismic analysis of double curvature arch dams

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Introduction:

- A double curvature arch dams are curved in plan(horizontally) and in elevation(vertically).
- In double curvature dams the radius of the curve of the circular arch in plan view and that of the abutments arches are changed. Both the arches are single centred and the thickness of the dam changes from the bottom to top.
- We considered the dimensions of the idukki dam which is a double curvature dam in Kerala. Height: 168.91 meters; Length of the dam on its top: 365.85 meters; Bottom width: 19.81 meters; Top width: 7.62 meters.
- The geometry of the dam we are considering is a simplified geometry as the detailed topographic information is not taken for the study and considered wide-U valley as the geographical condition.
- For a arch dam located at a branch fault, seismic analysis is done for different models of arch dams with varying radius of curvature.

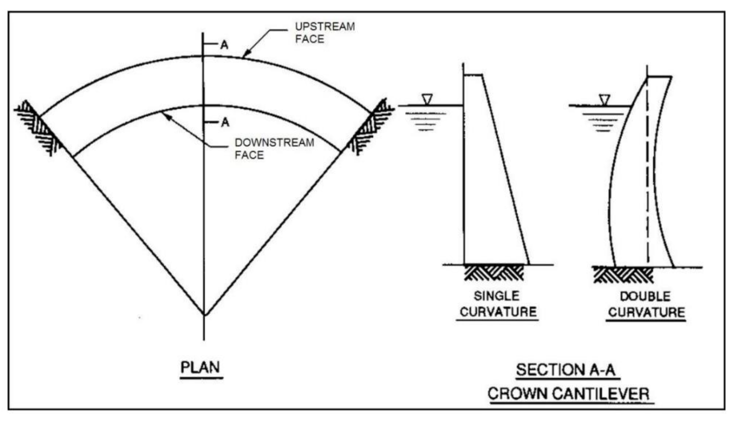
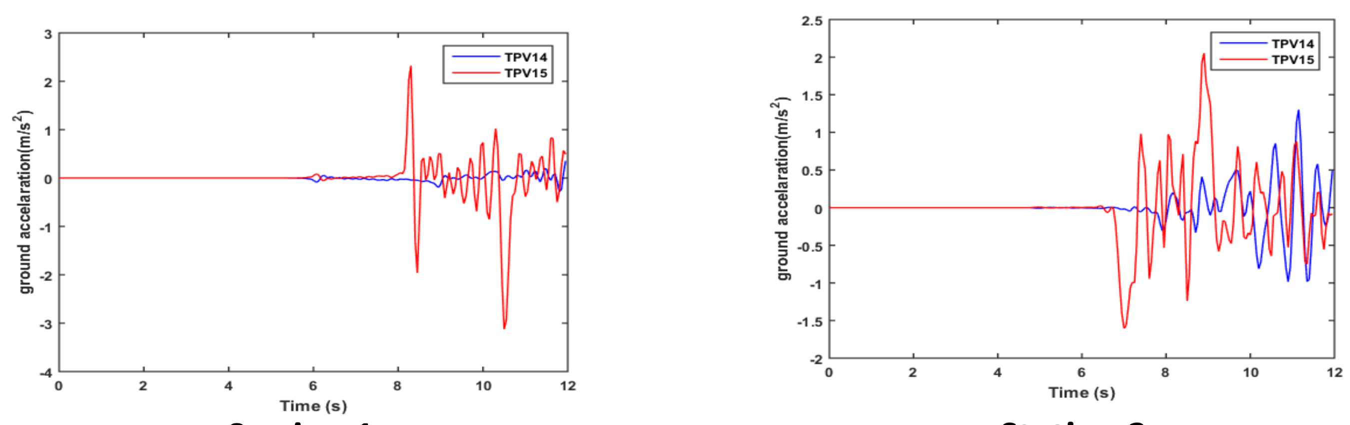


Figure 1. *single and double curvature arch dam*

Earthquake data:

- We considered a earthquake rupture for branched fault system
- Where the TPV14 is the situation where the earthquake wave propagates in straight path and in TPV15 the maximum wave propagation is into the branch fault.
- The station 1 is situated at 20 km from the centre of the fault in x-direction and station 2 is at 20 km from centre at angle of 30°.
- We only considered the horizontal acceleration data (i.e. in X-direction).

(a) Right-lateral strike slip rupture(TPV14) (b) Left-lateral strike slip rupture(TPV15)



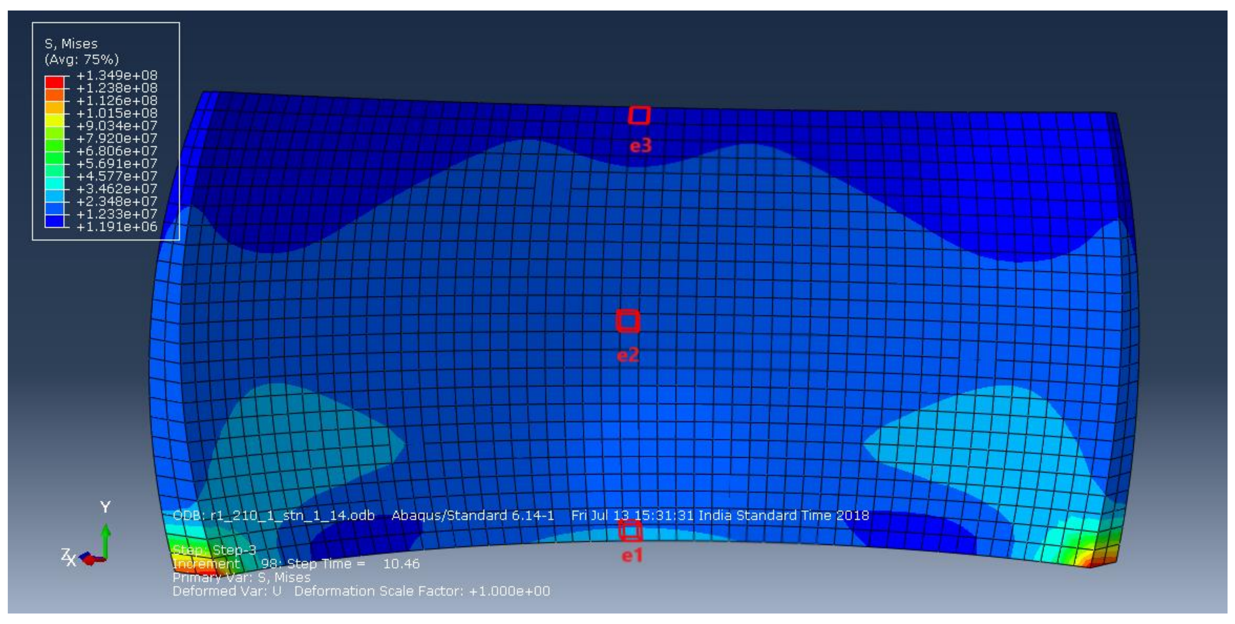
Station 1 Station 2

Model Characteristics:

- Due to computational effort we considered only density of the concrete and elastic properties for the model.
- Gravity load is applied to the whole model. Reservoir and dam interactions are considered as hydrostatic interactions.
- The bottom part of the dam is fixed with no translations and rotations in any directions. The abutment sides are fixed with no displacements.
- The earthquake boundary condition is applied for station 1 at tpv14 and tpv15; station 2 at tpv14 and tpv15. For the earthquake boundary condition step the bottom fixed boundary condition is deactivated.
- Mesh size is 7m. We considered hexagonal element with 8-nodes (C3D8R).

Methodology:

- We observed the maximum stress on the dam at three different points e1, e2 and e3.
- Where e1 being the bottom point at the centre of the dam, e2 at the middle part in the same plane and e3 at top part of the dam in the same plane.



- We kept the radius r1 of the plan view arch constant at 210m and changed the abutment side arch radius r2 with ratios r1/r2 at 0.8, 1 and 1.2

Results:

- $Percentage\ change = \frac{(Max.Stress(R1\ changing) - Max.Stress(R2\ changing))}{Max.Stress(R1\ changing)} \times 100$
- For point e1 at both the stations at higher ratios it is experiencing lower maximum stresses.
- For point e2 at both stations the maximum stresses are slightly lower at higher ratios, but this result can be more fine tuned with more data at different ratios.
- For point e3 at higher ratios it is experiencing lower maximum stresses except at some cases where R2 is changing in station 1.

Table 1. *At Station 1*

	TPV 14			TPV 15		
R1/R2	e1	e2	e3	e1	e2	e3
0.8	33.31%	7.77%	35.66%	42.22%	-8.23 %	-7.58 %
1	0%	0%	0%	0%	0%	0%
1.2	17.86%	-3.41 %	15.10%	-13%	14.5%	-51.75 %

Discussions:

- The model we took into considerations are the circular arches at plan view and at abutments. We can consider parabolic equations for the geometry of the double curvature arch dam. The main difference between circular formulas and parabolic formulas is circular formulas cannot describe the abutment thickening as efficiently as parabolic formulas.
- As a result, more concrete volume is used when circular formulas are applied resulting in a more expensive structure.
- Higher order formulas may be used as well, but there are several issues that have to be taken into account. The computational effort and the complexity of the geometry are significantly increased.
- The drift of the elements can be observed and calculated for the elements at different ratios.

Important References:

- An Interactive Tool for Automatic Predimensioning and Numerical Modelling of Arch Dams *D. J . Vicente, J. San Mauro, F. Salazar and C. M. Baena*
- Design of Double-Curvature Arch Dams in Terms of Geometric and Stress Constraints by Using Script-Based Finite Element Modelling - *Goulas, E*
- Design of Double-Curvature Arch Dams Planning, Appraisal, Feasibility Level *U.S. Department of the Interior Bureau of Reclamation Technical Service Centre Denver, Colorado*
- Arch Dams: Designing and Monitoring for Safety *edited by Jose O. Pedro, National laboratory of civil engineering*
- Seismic analysis of a concrete gravity dam - *An example in SIMULIA User Assistance 2017*

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Internship/research carried at IIT HYDERABAD