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Investigation of the structural performance of an arch dam

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1. Motivation

Due to static requirements and the shape of the valley dams are often designed as concrete arch dams. Before the availability of the finite element method as a numerical method arch dams were approximately calculated using the shell theory. Since the application of shell theory is limited to structures with a high radius of curvature to shell thickness ratio (R/t-ratio), arch dams are nowadays analyzed computer-aided by finite element models with volume elements. The motivation is to create a comparison between a volume and a shell model of an arch dam using the example of the Enguri arch dam and to calibrate a model based on measurement data.

2. Modeling

The Enguri arch dam is modeled as a volume and a shell model (cf. Fig. 1). In the volume model the entire dam body is captured by tetrahedral elements with quadratic shape functions. In the shell model the central surface of the uniformly curved part of the Enguri arch dam is modeled using 4-node shell elements without considering the foundations.

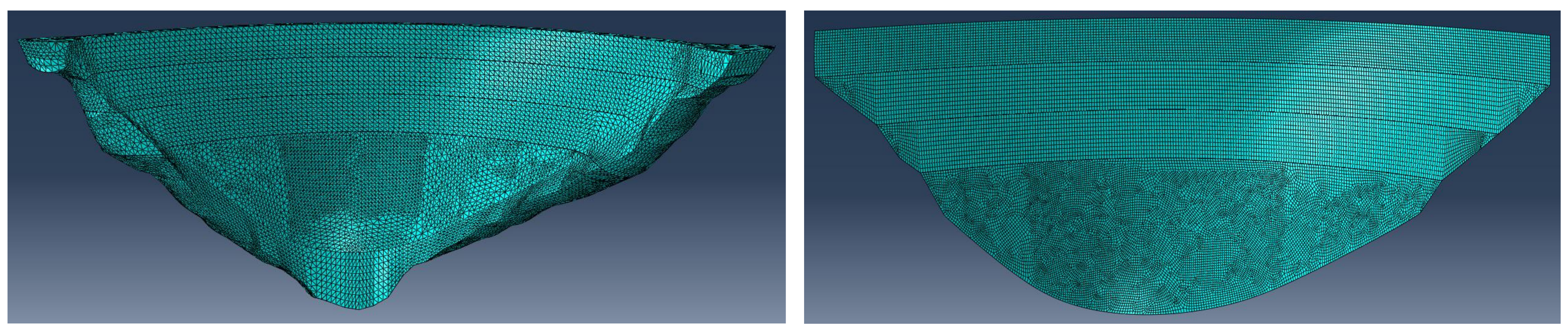

Figure 1: volume and shell model

3. Comparison of volume and shell model

Because of the low R/t-ratio in the Enguri arch dam only the upper middle area of the dam can be reliably represented with shell elements.

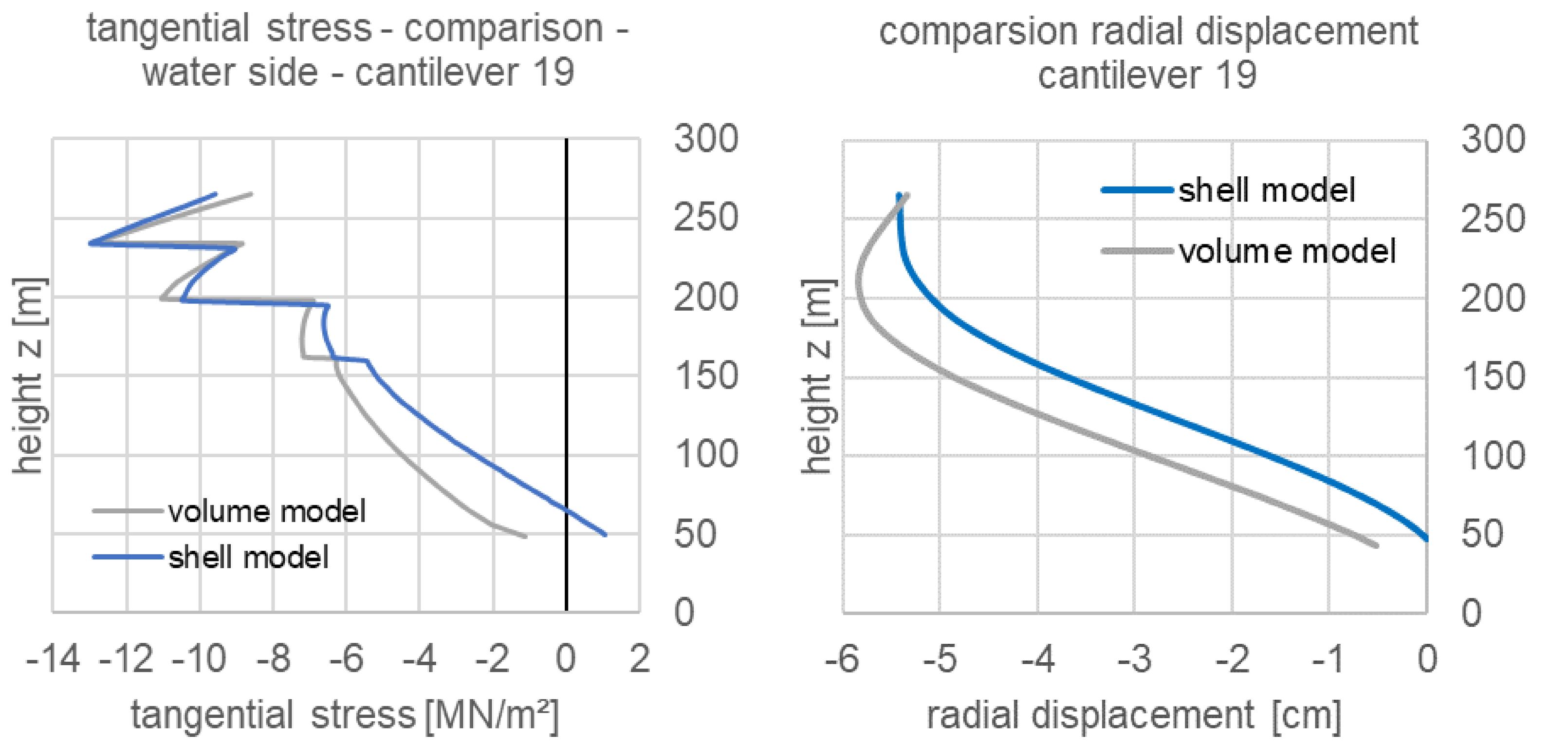

Figure 2: comparison of the models at cantilever 19

When comparing the water-side tangential stresses in the middle of the arch dam the behavior of the shell model becomes apparent, because the stresses of the shell model from a height in the model of 200 m no longer correspond to the tangential stresses of the volume model. The radial displacements of the two models only match at the top of the dam, as the spherical formation of the radial displacement is not reflected in the shell model (cf. Fig. 2). Modeling the Enguri arch dam including foundations is only possible with a volume model, beacause the shell model is limited to the upper middle area of the arch dam. To consider the interaction between arch dam and bedrock, the volume model has to be used for further analysis in the case of the Enguri arch dam.

4. model calibration

As a result of the rigid support of the initial models the pliability of the bedrock is not reflected. For the model calibration spring stiffnesses are determined based on measured values from plumb lines of the Enguri dam. During model calibration the spring stiffnesses and the Young´s modulus of the concrete are modified based on the differences between the measured values and the displacements from the model.

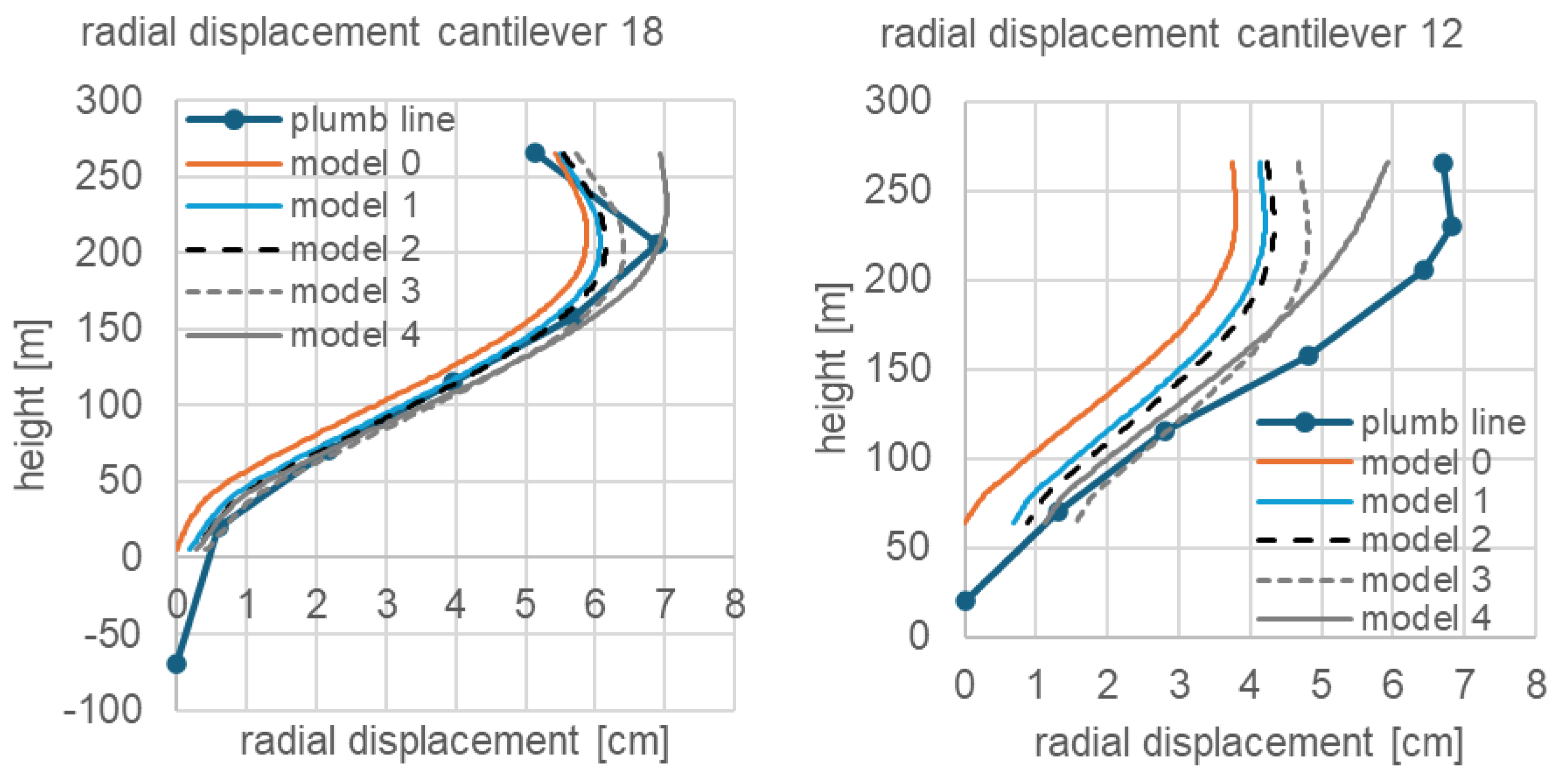

Figure 3: model calibration at cantilevers 18 and 12

Despite the simplifications and the assumptions for the models, the fourth model provides a sufficient approximation for the load-bearing and deformation behavior of the Enguri arch dam (cf. Fig. 3). For the best possible approximation a finer subdivision of the stiffness in the bedrock and in the arch dam is required for further model calibrations.

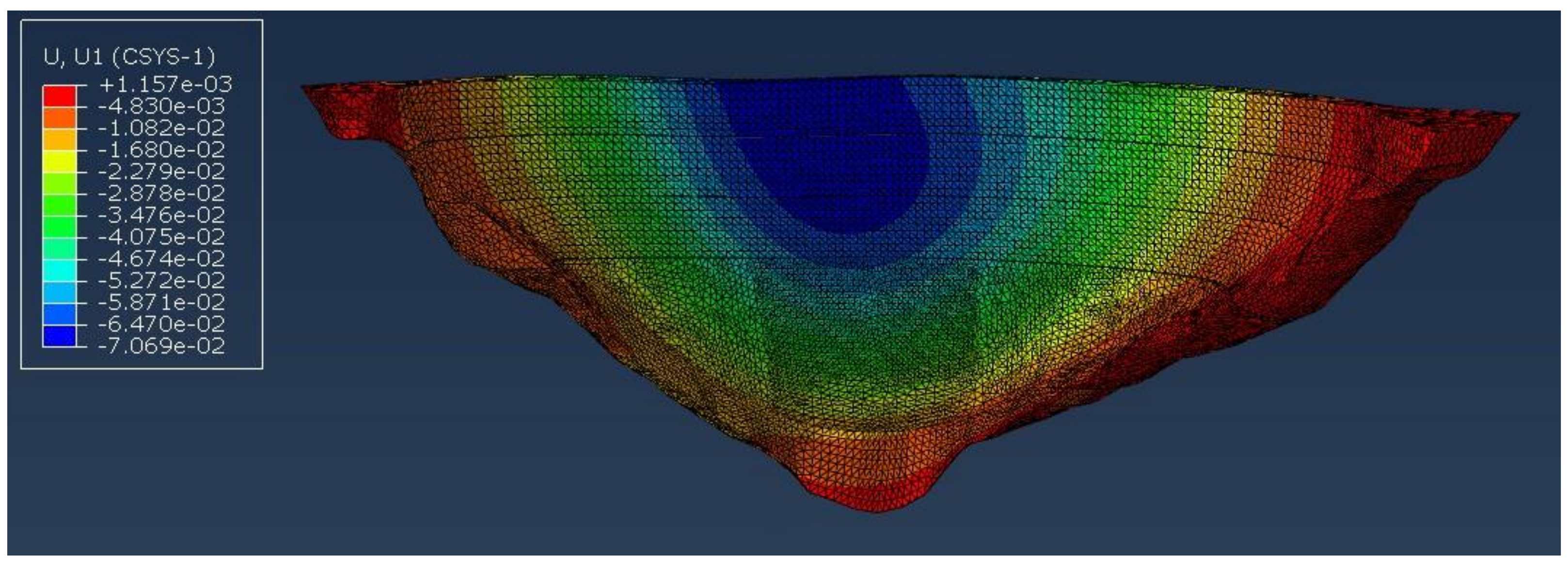

Figure 4: radial displacement [m] (model 4)

The maximum radial displacement in the fourth model is 7.07 cm. At the Enguri arch dam the radial displacements are not symmetrical, because the maximum displacement occurs offset from the center of the dam towards the right bank (cf. Fig. 4).