1. Introduction

The dynamic analysis of arch dams, which are made by allocating large budgets and are in the category of important structures, are of great importance in countries with earthquake reality. The correct selection of the analysis parameters allows to obtain more reliable results about the behavior of the structure. Although it is difficult and complex to determine the damping ratio, it is very important in terms of determining the dynamic behavior of the structure in a realistic way. Structures can be exposed to different types of damping forces with the effect of earthquakes. Damping forces are affected by both material type and earthquake magnitude [1]. Especially in structures with dam-reservoir-foundation interaction, different damping rates occur and this affects the behavior of the structure. Although the damping rate of the liquid is smaller than the damping rate of the structure, it is not a realistic approach to analyze by considering a single damping rate [2]. Experimental studies are needed to determine the damping ratio of the structure in a realistic way. In experimental studies on concrete gravity dams, it has been observed that the damping rate varies depending on the water level in the dam reservoir and the height of the dam body. When the literature studies were examined, damping rates are obtained as 2.2-5.4% [3] for different water levels in Pine Flat dam, as 2.37%-5.40% [4] for different water levels in four different dams, as 10% in the first mode, 15% in the second mode and 20% in the third mode for the Koyna dam [5]. Oberti et al. [4] stated in their study that the damping ratio increased with the increase of the dam height but did not change much with the water level. In thesis, Karaahmetli [6] is examined the damping models used in the dynamic analysis of structures theoretically and experimentally. In this study, is used single and multi-degree-of-freedom building models with different materials and geometric properties. Karaahmetli [6] investigated the change of damping ratios in structures under the influence of different mass, stiffness and acceleration values, and investigated the effects of each parameter on the structure damping ratio. In the study, it is stated that damping ratios vary under different stiffness, mass and displacement conditions.

Within the scope of this paper, dynamic analyzes are carried out for the massless foundation state of Artvin Deriner Arch Dam, considering the dam-foundation model. Considering the damping ratio of 1%, 5% and 10% in dynamic analysis, the change of displacement and stress values in the crest region of the dam is examined.

2. Deriner Arch Dam

2.1. Finite element model

Deriner Dam is a double curvature concrete arch dam and was built on the Coruh River. The body height from the foundation is 249m and the crest length is 720m. With its body height, it is Turkey's highest and the world's 6th highest dam. The dam construction, which started in 1998, was completed and in 2012 the water started to be kept. The Deriner Dam, which produces 2.118 GWh of energy annually with a power of 670 MW, supply 6% of the hydroelectricity produced in Turkey. Figure 1 shows some views of the Deriner Arch Dam.

The finite element (FE) model of Deriner Arch Dam is modeled as a three-dimensional solid element in the ANSYS [7] program. Solid45 element type with 8 nodes is used in the dam and foundation. The visuals of the finite element models of Deriner Arch Dam are presented in Figure 2. In the finite element model of the dam, the dimensions of the foundation, which is modeled as massless, are taken into account as three times the dam height in the upstream part and the dam height in the downstream and vertical. Fixed support is assigned to all side and bottom surfaces of the foundation. The material properties used in the finite element model of Deriner Arch Dam are summarized in Table 1.
2.2. Time-history analysis

Dynamic analyses are carried out in the finite element model of Deriner Arch Dam by considering different damping ratios. In the linear time-history analysis of the dam, the North-South component of the acceleration record of the 1999 Kocaeli Earthquake is applied in the upstream-downstream direction. As a result of the analysis, the changes in the displacements and stresses values in the crest region of the dam are examined. The displacements, compression and tension stresses contour diagrams for 1%, 5% and 10% damping ratio of the dam as a result of dynamic analysis are given in Figures 3-5, respectively.

![Displacement contour diagram of dam (cm)](image)

![Compression stress diagram of dam (mPa)](image)

![Tension stress diagram of dam (mPa)](image)

Figure 3. Contour diagrams of the dam obtained for 1% damping

### Table 1. Material properties considered in FE model

<table>
<thead>
<tr>
<th>Element</th>
<th>Modulus of Elasticity (N/m²)</th>
<th>Poisson Ratio</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam</td>
<td>3.75E10</td>
<td>0.15</td>
<td>2400</td>
</tr>
<tr>
<td>Foundation</td>
<td>5.68E10</td>
<td>0.30</td>
<td>----</td>
</tr>
</tbody>
</table>

Figure 1. Some views of Deriner Arch Dam

Figure 2. Some views of Deriner Arch Dam FE model
When the contour diagrams are examined, it is seen that the maximum displacement is at the crest mid-point, the maximum compressive and tensile stresses are at the crest quarter distance and the values differ according to the damping ratios. Graphs summarizing the variation of displacement, compression and tension stress values at all nodes along the dam crest as a result of dynamic analysis for 1%, 5% and 10% damping rates are given in Figure 6.
c) Tension stresses of the arch dam along the crest

Figure 6. Displacement, compression and tension stress values at all nodes along the dam crest for 1%, 5% and 10% damping rates

Figure 7 presents time-history graphs depending on the 1%, 5% and 10% damping ratio of the maximum displacement, compression and tension stresses in the dam crest region.

As a result of the dynamic analysis performed according to 1%, 5% and 10% damping ratio, the maximum difference between the displacement, compressive and tensile stresses in the dam crest region is 56%, 44% and 60%, respectively. The values and maximum differences of the maximum displacement, compressive and tensile stresses in the crest region of the dam are presented in Table 2.

<table>
<thead>
<tr>
<th>Damping Rates (%)</th>
<th>Max. Displacements (cm)</th>
<th>Compression Stresses (MPa)</th>
<th>Tension Stresses (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.68</td>
<td>8.78</td>
<td>9.86</td>
</tr>
<tr>
<td>5</td>
<td>8.55</td>
<td>6.31</td>
<td>5.94</td>
</tr>
<tr>
<td>10</td>
<td>6.00</td>
<td>4.88</td>
<td>3.92</td>
</tr>
<tr>
<td>Max. Diff (%)</td>
<td>56</td>
<td>44</td>
<td>60</td>
</tr>
</tbody>
</table>

The results obtained show that the damping ratio used in the dynamic analysis to be performed is an important parameter. In order to obtain the behavior of the structure accurately and reliably, dynamic analysis should be performed by obtaining the damping ratios reflecting the structure as a result of more extensive studies.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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