In recent years many earth dams located in narrow and deep canyons have been designed and constructed in seismically active regions. The world's largest, the Soviet dams, Nurek (H = 280 m) and Rogun (H = 330 m) in Central Asia, are located at such sites.

Standardized calculations of the seismic stability of such dams, carried out using the calculation scheme of the two-dimensional problem (without consideration of the length limitation of the structure), lead to large seismic accelerations in the upper, near-crest zone. This greatly hampers the provision of seismic stability of dams, requiring either considerable flattening of the slopes (especially the saturated upstream slope) or taking special measures to change the characteristics of the soils in the upper part of the dam, which results in considerable costs in labor, materials, and time. Therefore, many specialists are paying great attention to an investigation of the effect of the length limitation of dams (effect of the canyon walls) on their seismic stability. Such investigations were conducted also at the computer center of the All-Union Planning, Surveying, and Scientific-Research Institute (Gidroproekt).

To estimate the seismic stability of earth dams, one usually uses the diagram of seismic accelerations obtained for application in the two-dimensional problem. This situation occurs regardless of the method of calculation (analytic solution for a triangular wedge of unlimited extent, numerical solution by the finite element method (FEM) for a profile of arbitrary form) within the scope of the dynamic spectral theory standardized by the construction specifications and regulations SNiP II-A.12-69 [1]. However, many analytic and experimental investigations show that the length limitation of the structure has a substantial effect on its stress-strain state under the effect of static and dynamic loads, changing also its dynamic characteristics — the frequency and mode of free vibrations. Corresponding Member of the Academy of Sciences of the Georgian SSR Sh. G. Napetvaridze [2] proposed relations which take into account this effect of natural periods. Dam length limitation was usually taken into consideration for a ratio of \( \frac{L_c}{H_d} \leq 4 \), where \( L_c \) is the dam's crest length and \( H_d \) is its height. In the limiting case (a dam in a rectangular channel for ratio \( \frac{L_c}{H_d} = 1.0 \)) the value of the natural period of the structure in the horizontal directions across the axis is 30% less than its value for a dam of unlimited length. Model and analytic investigations performed in Italy [3] show that consideration of the effect of the length limitation of dams

![Fig. 1. Natural period of a dam as a function of the value of the ratio \( \frac{L_c}{H_d} \). 1) According to data [4]; 2) according to calculated data for a 280-m-high dam.](image-url)
Fig. 2. Profile of dam (a) and its calculation scheme (b) for number of concentrated masses \( N = 14 \). 1) Shoulders of gravel-cobble soil; 2) loam core.

Fig. 3. Natural period of dam as a function of the density of the grid in the calculation scheme.

with ratio \( \frac{L_c}{H_d} = 1.5 \) increases by 28% the natural frequency with respect to the first tone in comparison with the frequency obtained when solving the two-dimensional problem.

Analytical investigations (FEM, three-dimensional problem of elasticity theory) performed in 1976 at the Institute of Engineering of the National University of Mexico [4] established the dependence of the natural frequencies (periods) of earth dams with respect to the first mode on the ratio \( \frac{L_c}{H_d} \) and on the gradient of the slopes. The investigations showed that the slope gradient has little effect on the natural periods of a dam. The natural period of a dam as a function of the ratio \( \frac{L_c}{H_d} \) for a slope gradient \( m = 2 \) is given below:

<table>
<thead>
<tr>
<th>( \frac{L_c}{H_d} )</th>
<th>0.500</th>
<th>1.000</th>
<th>2.000</th>
<th>3.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_n ), sec</td>
<td>0.406</td>
<td>0.585</td>
<td>0.833</td>
<td>1.00</td>
</tr>
</tbody>
</table>

If we extrapolate these data in the range of variation of \( \frac{L_c}{H_d} \) from 2 to 4 (Fig. 1), we see that in this case the natural period of the dam with respect to the first tone increases by about 25%. We see from Fig. 1 that an increase of \( \frac{L_c}{H_d} \) beyond 4 leads to a further increase in the natural period of the dam. Thus, the conditions for the two-dimensional problem probably hold at a considerably greater value of this ratio.

Interesting investigations of the limits of applicability of the two-dimensional problem based on an analysis of the stress and strain in dams under the main combination of loads (static) were conducted in Italy [3]. The maximum shear stresses in the dam for ratios \( \frac{L_c}{H_d} \) equal to 1, 3, and 6 and the values of the displacement of the crest in the middle plane (in the direction across the dam axis) were obtained with the use of an FEM program for solving the three-dimensional problem of elasticity theory. Upon increasing \( \frac{L_c}{H_d} \) in these limits the maximum displacement of the dam crest increases by a factor of 2.68, and the maximum shear stresses increase by 38%. On the basis of these investigations it was concluded that the two-dimensional scheme is applicable only for \( \frac{L_c}{H_d} \geq 6 \). Analogous investigations are described in another source [5].

Large-scale model investigations conducted in Japan [6] showed that the length limitation of dams substantially changes the distribution of seismic accelerations over the height of the structure as obtained for conditions of the two-dimensional problem. Thus, the peak of accelerations determined by a method analogous to SNiP II-A.12-69 occurs not at the dam crest but lower, at a depth of 0.25H from the crest.

To evaluate the effect of the length limitation of a structure on the dynamic characteristics of earth dams and on seismic accelerations, the author developed an algorithm and compiled a program in FORTRAN language and adapting it for the ES-1020 computer.