of many complicating circumstances, but with the minimum participation of specialists in
the area of engineering geology. Under these conditions the necessary accuracy of the calcu-
lation can be provided by if engineering methods checked by practice are used in the calcula-
tion, the conditions of their use and limits of use being concretized according to [9, 10].

2. It is necessary to substantially increase the requirements imposed on the existing
and newly developed engineering methods of calculating earth slopes which are to be used
with the aid of computers. To provide accuracy of the calculation and reliability of struc-
tures in this case, these engineering methods should take into account requirements of a
geological, technical, and economic character.

LITERATURE CITED
1. SNiP 2.06.05-84. Earth Dams [in Russian], Gosstroi SSSR (1985).
2. Modern Methods of Evaluating the Reliability and Stability of Earth Dams during Con-
soft Ground Foundations of Hydraulic Structures [in Russian], Énergiya, Leningrad (1980),
pp. 3-10.
4. A. A. Nichiporovich, "Slide of the downstream slope of the Nikopol dam during its con-
5. N. N. Maslov, Soil Mechanics in Construction Practice [in Russian], Stroiizdat, Moscow
7. É. G. Gaziev, "Principles and methods of evaluating the stability of various rock slopes,
8. V. D. Braslavskii, "Role of cohesion of clays in the degree of stability of slopes and
9. E. P. Emel'yanova, Main Regularities of Slide Processes [in Russian], Nedra, Moscow
(1972).
10. E. P. Emel'yanova, K. A. Gulakyan, V. V. Kyunftsel', and G. I. Tarasova, Index of Lit-

CALCULATION OF AN ARCH DAM ON THE BASIS OF SOLVING THE THREE-DIMENSIONAL
PROBLEM OF THE THEORY OF ELASTICITY AND THEORY OF SHELLS

V. N. Lombardo and B. V. Fradkin

Arch dams are often the most economical and reliable types of dams when constructing
hydro developments under mountain conditions. In our country a number of such dams have
been constructed and design studies are carried out in all cases when the construction of
arch dams is possible. Therefore, problems of developing reliable methods of estimating
their stress-strain state are quite urgent.

Whereas 10-20 years ago the problem was related to the absence of calculation methods
and programs, at present, to judge from the publications, several dozen calculation programs
based on various mathematical formulations and algorithms for a numerical solution have been
developed for calculating the stress-strain state of arch dams. Here we can mention various
modifications of the arch and cantilever method [1, 2] (including the trial load method and
method of arch-cantilever directions); crown cantilever method; method of application of
fictitious orthotropic systems; variational bar method [3]; a group of methods based on solv-
ing different variants of the theory of thin shells [4-6]; methods based on solving equations
of shells of average thickness [7, 8]; and, finally, methods based on solving three-dimensiona
problems of the theory of elasticity [9, 10].
TABLE 1. Parameters of Geometric Configuration of Dam

<table>
<thead>
<tr>
<th>Eleva-</th>
<th>Central part</th>
<th>Left bank</th>
<th>Right bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>$r_u$ m</td>
<td>$r_d$ m</td>
<td>$c_R$ m</td>
</tr>
<tr>
<td>612</td>
<td>462,00</td>
<td>443,00</td>
<td>0</td>
</tr>
<tr>
<td>592</td>
<td>441,70</td>
<td>426,50</td>
<td>18,5</td>
</tr>
<tr>
<td>572</td>
<td>435,35</td>
<td>414,75</td>
<td>31,52</td>
</tr>
<tr>
<td>552</td>
<td>430,30</td>
<td>404,80</td>
<td>41,2</td>
</tr>
<tr>
<td>532</td>
<td>425,50</td>
<td>397,50</td>
<td>48,0</td>
</tr>
<tr>
<td>512</td>
<td>420,70</td>
<td>391,20</td>
<td>53,0</td>
</tr>
<tr>
<td>492</td>
<td>414,75</td>
<td>384,75</td>
<td>57,02</td>
</tr>
<tr>
<td>472</td>
<td>407,00</td>
<td>376,60</td>
<td>61,5</td>
</tr>
<tr>
<td>452</td>
<td>397,25</td>
<td>368,75</td>
<td>65,0</td>
</tr>
<tr>
<td>432</td>
<td>---</td>
<td>---</td>
<td>70,0</td>
</tr>
</tbody>
</table>

So far, when designing and evaluating the designs of arch dams situations have constantly occurred in which the results obtained by various calculation methods and experimental investigations differed qualitatively, despite the identity of the physical premises (elastic work and continuity of the material). Attempts have been made repeatedly either to average the data obtained by different methods or to explain the various differences by the assumptions made in the calculations, which reduce mainly to various methods of taking into account the work of shearing forces. It is necessary to note that practically all methods of calculating arch dams are rather cumbersome and therefore the calculations are performed either directly by the program developers or with their participation. Therefore, design organizations developing an arch variant of a dam are faced each time with the problem of selecting the appropriate calculation apparatus for designing a rational configuration of the dam and estimating its stress-strain state. This selection is made difficult also by the fact that the use of an improved theory still does not guarantee that more reliable calculation results are obtained. For example, calculation of a dam on the basis of solving the three-dimensional problem of elasticity theory by the finite-element method (FEM) with a small number of element method (FEM) with a small number of elements can produce a greater error than the crown cantilever method.

Not being able to give a complete analysis of the assumptions underlying each of the developed methods and of the errors to which they lead, we will propose a test problem: the calculation of one of the variants of the arch dam of the Katun hydroelectric station.

The dam is calculated by two methods: by solving the three-dimensional problem of elasticity theory by the FEM (the "PROSE" program set); according to the thin-shell theory, by the variate difference method ("ARC" program set).