Mikhail I. Frolov

System Stress State Analysis of Hydraulic Structures

Москва
Книга по Требованию
2015

УДК 528
ББК 38.2

Frolov M. I.
System Stress State Analysis of Hydraulic Structures / Mikhail I. Frolov. — М.: Книга по Требованию, 2015. — 382 с.

ISBN 978-5-519-48988-1

High responsibility of hydraulic structures (HS) imposes to them increased requirements regarding the reliability of strength design and safety. This fundamental monograph incorporates 30 years of scientific researches of concrete underground culverts and dams conducted by the scientific school of Dr. Tech. Sci., Prof. M.I. Frolov. System analysis of HS stress state allows to save materials and money for HS constructing. For correct application of numerical methods for HS design it's necessary the considerable scientific experience for creating high-quality models and subsequent correct interpretation of results in order to adequately reflect the work of real HS.

УДК 528
ББК 38.2

ISBN 978-5-519-48988-1

CONTENTS

LIST OF ABBREVIATIONS

AID-4	automatic strain meter of Kucherenko Central Research Institute for Structural Construction (TsNIISK, Moscow)
ANSYS	universal finite-element software complex
AP-4	automatic switcher
BEM	boundary element method
CNR	construction norms and regulations
DIFN	computer program designed for stationary and non-stationary linearly elastic isotropic diffraction calculations of single, two-line and multi-line pipes on seismic impacts of *P*- and *SV*-waves (plane strain), *SH*-waves (anti-plane strain)
FDM	finite difference method
ERPL	equal radial pressure lines
FEM	finite element method
HS	hydraulic structure
HPS	hydroelectric power station
ITM	integral-transform method
JSC	joint-stock company
LIRA	universal finite-element software complex
NHL	normal headwater level
P-wave	longitudinal compression wave
REZON	computer program providing analytical solution for determining resonance wave numbers (own frequencies)
SIK	stress intensity coefficient
SPM	soil pressure meter
SS	stress state

SSS	stress strain state
SV-wave	transverse share wave (plane strain)
SH-wave	transverse share wave (anti-plane strain)

INTRODUCTION

Hydraulic structures (HS) are widespread and are among the most complex, time consuming and the expensive types of structures. HS high responsibility imposes to them increased requirements regarding the reliability of strength design and safety.

For the correct application of numerical methods for HS design it's necessary considerable scientific experience for the creating of high-quality models and the subsequent correct interpretation of results in order to adequately reflect the work of real HS.

The system analysis of HS stress state (SS) allows to develop scientifically based practical recommendations, which then may be used in the development of the normative documents of such structures.

This fundamental monograph incorporates 30 years scientific researches conducted at the Moscow University of Environmental Engineering and at the Institute of the Commonwealth of Independent States by the scientific school of Dr. Tech. Sci., Prof. M.I. Frolov.

Using the experience of the scientific researches prof. M.I. Frolov has developed six HS design criteria (given in the monograph) that allow to improve the accuracy and to decrease the computation time of calculation programs.

The book is based on seven dissertation works, on more than 50 scientific articles and on two monographs. Scientific research results presented in the book were awarded by the four medals of All-Russian Exhibition Center.

The section 1 of this monograph is written by prof. M.I. Frolov and is devoted to the analysis of static (soil own weight) loading and dynamic (seismic type) impacts on single and multi-line underground concrete and asbestos-cement circular culverts by analytical methods [205, 214, 215], by finite element method (FEM) [15, 50, 64, 89 to 91, 162, 169, 173, 188, 205, 214, 273, 304] and by the laboratory investigations of static response to soil pressure [205, 214].

The author first became interested in this problem in early 1980s through the global USSR project of transferring North and Siberian rivers ("perebroska").

The next sections based on dissertations and scientific articles written under Prof. M.I. Frolov's leadership.

Section 2 is based on the research of Cand. Tech. Sci. Y.A. Boev [28, 219 to 223, 237], Cand. Tech. Sci. A.N. Vasquez Ramirez [45, 224 to 227, 237] and is devoted to the static SS analysis of pressure and free-flow hydrotechnical tunnels without lining by boundary element method (BEM) in the form of fictitious loadings.

The third section is based on the research of Cand. Tech. Sci. D.T. Bautdinov [16 to 19] and is devoted to the FEM static SS analysis of hydrotechnical tunnels without lining laid in transversal isotropic rocky soil.

In section 4 the research results of Cand. Tech. Sci. N.G. Smirnova are presented. This section is devoted to the static SS analysis near cracks of concrete massive HS by BEM in the form of discontinuous displacements [21, 115, 176].

The fifth section is based on the research of Cand. Tech. Sci. A.A. Usacheva and is devoted to static SS analysis near the shells and the cavities of massive concrete HS by direct BEM in the form of boundary integrals [21, 115, 193].

The monograph was translated in English by prof. M.I. Frolov.

1. STATIC AND DYNAMIC STRESS STATE ANALYSIS OF SINGLE AND MULTI-LINE UNDERGROUND CONCRETE AND ASBESTOS-CEMENT CIRCULAR CULVERTS

Underground HS are widespread and are among the most complex, time consuming and expensive types of structures that make up waterworks, land reclamation and water supply systems [59, 60].

As water conveyance or culvert structures they are built underground in cases where open excavation is uneconomical, conduit passes through densely populated or densely built-up terrain, possible landslides, scree, rock falls [99].

The majority of structures on irrigation and drainage networks (regulators, culverts, crossings, water outlets and others) are of tubular type [23].

In hydraulic engineering during the construction of derivational and turbine conduits there are applied the culverts of large diameters [59, 60].

The considerable number of such structures is erected in areas with increased seismicity [53 to 57, 65, 137, 139, 159].

1.1. Research of Soil Own Weight Static Pressure upon Underground Circular Culverts

This section provides the overview of the analytical solutions, numerical and experimental studies of soil own weight static pressure on underground concrete and asbestos-cement circular culverts.

This section also provides the detailed data of our computer study results (with parametric analysis use) and experimental author's research [205, 214], not previously published in press in full.

Analytical solution data, received by Frolov, M.I., was published in monograph [215] and works [202 to 204, 210, 211, 216].

1.1.1. Analytical Solution Overview

At first plane problem for determining soil static pressure upon single conduit laid in embankment or trench was formulated and solved at the beginning of the XX century by Marston, A. [108, 110, 261, 296, 297]. The solution is based on the simplified limit equilibrium theory of granular media [242].