Finite-element simulation of possible natural disasters on landfall dams with changes in climate and seismic conditions taken into account

M A Bandurin¹, V A Volosukhin¹, V V Vanzha², A V Mikheev¹ and Y V Volosukhin¹

¹ Platov State Polytechnic University (NPI), 132, Prosveshcheniya St., Novocherkassk, 346428, Russia
² Kuban State Agrarian University named after I T Trubilin, 13, Kalinina St., Krasnodar, 350044, Russia

E-mail: chepura@mail.ru

Abstract. At present theoretical substations for fundamental methods of forecasting possible natural disasters and for quantitative evaluating remaining live technical state of landfall dams in the mountain regions with higher danger are lacking. In this article, the task was set to carry out finite-element simulation of possible natural disasters with changes in the climate as well as in modern seismic conditions of operation in the mountain regions of the Greater Caucasus with higher danger. The research is aimed at the development of methods and principles for monitoring safety of possible natural disasters, evaluating remaining live technical state of landfall dams having one or another damage and for determination of dam failure riskiness, as well. When developing mathematical models of mudflow descents by inflows tributaries into the main bed, an intensive danger threshold was determined, taking into consideration geomorphological characteristics of earthflow courses, physico-chemical and mechanical state of mudflow mass and the dynamics of their state change. Consequences of mudflow descents into river basins were simulated with assessment of threats and risks for projects with different infrastructures located in the river floodplain.

1. Introduction

Studies of possibilities for river bed closure as a result of different breakdown kinds of disturbance of natural landscapes and evaluation of consequences for these blockages are quite actual but they are not studied enough in domestic and foreign science. Such blockages can be formed from large-scale landfalls of river valley slopes that resulted in the Sarezskoe lake forming with 600 m depth (Ferganskaya valley) or in catastrophes that took place on Vaiont dam (240 m - Italy) and in Karmadon canyon (North Ossetia) and others [1].

Possibilities of river bed closure with side earth flows are little studied. The Baksan river closure with the right-bank earth flow in 2000 resulted in Tyrnyauz town flooding can serve as the example. This problem has special actuality for the Olympic facilities in the Mzymta river basin so long as only for the last years the river was repeatedly blocked with side earth flows from waterways of Koltsenko and Sumashchedshaya rivers and with PC-6 waterless valley. Earth flows descend on the combined railway along GK-1 brook bed blocking water pass openings under the road and railway [2]. In August
17-18, 2013, on the left bank of the Mzymta river, on 7 brooks from the mouth of the Sulimovsky brook to the Psukh river, mud and stone earth flows of anthropogenic character with removal volume of earth flow mass of 31710 cbm descended. The federal road «Adler – Krasnaya Polyana» was significantly damaged.

According to the data of the North Caucasus Rosgidromet, about 1800 earth flows descended in the south of Russia for the last 30 years. At the same time various authors mention more than 100 earth flow beds where situations of emergency threatening engineering infrastructure facilities and the population are possible [3].

Lack of adequate models capable of giving reliable predictions on a possibility of earth flow descents and their consequences, results in situations of emergency for the railway transport. As an example, one can give the earth flow descend at Shepsi-Tuapse railway section on the 2nd of July, 2013. At this railway area (1887th km) four mud and stone earth flows descended. As a result, one of the locomotive sections of the passenger train that ran into an obstruction came of the rails, the schedule of movement for 22 trains was disturbed, delay of movement was more that 7 hours and errors in the movement schedule were kept the following day.

2. Materials and methods

The development and realization of detail designs in the last decades of the 20th century and the first decades of the 21st century are accompanied by propounding new fundamental tasks to determine resource, viability and safety of unique projects. The peculiarity of these tasks is connected with the fact that in new projects, the unique ones, in particular, it is necessary to take into account the possibilities of beginnings and development of catastrophic situations. It concerns the traditional, atomic and thermal energetics, rocket and cosmic complexes of near-the earth and deep space, aviation, shipbuilding, high-speed and heavily-loaded railway transport, oil and gas chemistry, developments of an offshore area.

As home and foreign experience shows, objects of technosphere from mass objects of technical control and dangerous production projects and critically and strategically important projects of civil and defence sphere have to meet both traditional (strength, resource, wear resistance, cold resistance, seismic stability) and new integrated requirements (viability, safety and protection from disasters, using risk criteria) [4].

A solid-state model of stressed and strained state of the most dangerous part of the Divgorsky canyon landfall dam in the Urukh river basin, as well as Adagum-Atakaï, was built. Cading of source information was being realized in the terms of the increment method taking into account fragmental representation of the landfall dam as volume elements (3-D) [5, 6].

Computation was carried out by the software complex SCAD office, operation of which is based on the method of finite elements and superelements. Stressed and strained state of finite elements under bending, torsion, compression and tension, as well as under their different combination, is considered. Coding of source information was being realized in the terms of the increment method taking into account fragmental representation of elements as objects of a simple geometric form. In the statement of numerical computation, the task was set to determine adequacy of the solid state model of stressed and strained state under the maximum water head with the existing tests on location under different boundary conditions, with changes in the climate and seismic conditions of landfall dam operation, taken into account. In the course of reliability evaluation, numerical simulation was carried out, criteria of physical wear for single elements were received. A model of landfall dam with different combinations of changes in the climatic and seismic conditions of operation both with loadings and different damages was developed.

Processing of the simulation data received showed availability of movements both by the horizontal and by the vertical along the landfall dam that confirmed availability of significant safety margin [7].

In figure 1, a diagram of total movements is presented where availability of the biggest total movements is shown, namely at the points of forming insignificant deflection of the landfall dam.
Comparisons of diagrams for movements by the vertical, by the horizontal far and wide bearing elements revealed insignificant inner changes. The most interesting one is a diagram of movements along the horizontal (figure 1, b), in which a change in element location because of the landfall dam is shown. These results testify to availability of significant safety margin.

![Graph showing movements](image)

**Figure 1.** Diagram of total movements on von Mises: a – entire land fall dam considered; b – the most dangerous area between pickets 2 and 3.

In the course of simulation for canyon forming in downstream of the landfall dam, isofields of stresses were received (figure 2, a), spring water will cut the landfall dam downstream. For instance, in the Usoisky blockage, springs broke out a canyon with about 2 km length and 30-35 m depth. Fears arose that the further growth of the canyon could result in a catastrophe. To check this information, in 1926 the Middle Asia Economic Council organized the expedition to the Sarezskoe lake under the leadership of professor Lange O.K. [8].

Height and energy of water billow that will arise in the lake depends on landslide volume and velocity of its movement. To simulate this process, to computate the height of waves and volume of overflow, one needs to know both parameters. But the velocity can be approximately taken equal to the velocity of landslides what have already happened. Therefore, to determine landslide volume is an immediate task determining scale of supposed catastrophe. The volume of the landslide having been already descended can be evaluated by dimensions of its recess and comparison of topographic maps for the period before and after its descent. To determine the volume of an supposed landslide, it is necessary to know its vertical power, dimensions view in plan and the structure. If on one slope, a series of landslides of the same structure is developing, then by the results of comparison one can approximately evaluate the volume of the expected landslide [9].

By the diagrams of stresses received (figure 2), it is possible to classify technical state of each supposed landslide under different both insignificant defects and dangerous damages of a landfall dam. [9].
A situation of possible seismic impact on a landfall dam (figure 3) was also simulated. The task was set to determine volume of a supposed landslide determining a scale of supposed catastrophe [10]. Two types of observation systems for seismic survey are well known. The first type includes longitudinal observations when geophones and excitation sources of elastic vibrations are located at one profile (figure 3, a). The second type includes unlongitudinal observations when geophones are located at one profile, but sources of elastic vibrations are located at the other one, perpendicular to the first profile (figure 3, b).

To process unlongitudinal observations, availability of control data about the depth up to the refraction boundary is necessary [11]. Longitudinal observations allowed one to receive values of both mean velocities and depths up to refraction boundaries, but they revealed details of native bed, which is rather worse. Therefore, only combination of both types of observations makes it possible to carry out seismic research for studying high-altitude valleys and slopes.
3. Conclusion

The first seismic measurements showed that downstream surface depositions were strongly destroyed and characterized with low values of longitudinal wave velocities. Deep-water gravitation strains caused by valley deepening take place, but they are not determinative for the development of landslide processes. Mapping of tectonic breakdowns, revealing young intrusions, seismologic studies are the priority task for engineering and geological explorations.

Processing with the help of modern computer technologies and generalizing makes it possible to increase, quickly and without significant expenditures, information scope for stressed and strained state and, above all, to work out well-founded plans and competent designs of further explorations that are to be conducted at the modern scientific and technical level.

References

[1] Bock T, Krapivin D, Aleksyuk S, Pritchin S 2002 Monitoring of the boring trajectory in underground channel *19th International Symposium on Automation and Robotics in Construction* 3 519-522

[2] Krapivin D, Aleksyuk S, Pritchin S 2002 Dynamic monitoring of the boring trajectory in underground channel for driving communications *Advances in building technology proceedings of the international conference on advances in building technology* 1 335-338

[3] Yurchenko I F 2016 Information systems of water management meliorative complex management *Bulletin of the Russian Agricultural Science* 1 12-15

[4] Volosukhin V A, Bandurin M A 2012 Features of application of modelling of emergency bridge crossings through water-spending channels at carrying out of operational monitoring *News of Higher Educational Institutions of North Caucasus region* 5 80-83

[5] Gaydzhurov P P, Al-Dzhabobi S F, Al-Khadzh M A 2017 Finite element modeling of force transmission the tension of the steel tendon on the concrete *News of Higher Educational Institutions of North Caucasus region* 2 73-78

[6] Gaydzhurov P P, Kravchenko G M, Savelieva N A 2014 Finite element modeling of elastic plastic bending of steel beams with use of rod end elements *Construction mechanics and design of structures.* 2 17-22

[7] Vakulyuk A, Glebov N 2016 A laser system of remote control and controlling complex for the construction of mini tunnels *Scientific Reports on Resource Issues* 1 134-139.

[8] Volosukhin V A, Bandurin M A 2017 Implementation monitoring multi-factor examination in the context of the growing deficit of safety of hydraulic structures *News of Higher Educational Institutions of North Caucasus region* 1 76-79

[9] Volosukhin V A, Bandurin M A 2013 Questions of numerical simulation of long-term operated bridge removal through water-conducting channels *Science and security* 1 16-26

[10] Travush V, Emelianov S, Kolchunov V 2016 Mechanical safety and surviva-bility of buildings and building structures under different loading types and impacts *Proceedings of the Creative Construction Conference* 1 13-18

[11] Yurchenko I F 2017 Methodological foundations for the creation of an information management system for water use in irrigation *Bulletin of Russian Agricultural Science* 1 13-17