Verification of Material Parameters of Earthen Dams at Diamond Valley Lake Using Geodetic Measurements

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Key words: Deformation modelling, earth dam, geotechnical parameters.

ABSTRACT

Safety of earth dams depends on the proper design, construction, and monitoring of actual behaviour during the construction and during the operation of the structure. Deformation monitoring of large dams and their surroundings supplies information on the behaviour of the structure and its interaction with the bedrock. Monitoring results may also be used in verifying design parameters where the geotechnical parameters are of the highest importance. The determination of geotechnical parameters may be done in situ or in the laboratory. In laboratory testing, the selected samples may differ from one location to another, they may be disturbed during the collection, or the laboratory loading conditions may differ from natural conditions. Therefore, the comparison of the monitored data with the predicted data, obtained during the design, may give important information concerning the quality of the accepted geotechnical parameters. This paper presents a method, using finite element analysis, for modeling effects of saturation of the dam materials in order to determine expected displacements during the reservoir filling.

Two large earthen dams of the recently built Diamond Valley Lake (DVL), the largest water storage reservoir in South California, have been used as an example in verifying geotechnical parameters through a comparison of modelled and observed displacements. The DVL reservoir, constructed by Metropolitan Water District (MWD) of Southern California, is located about 160 km south-east of Los Angeles. It has been created by enclosing the Domenigoni/Diamond valleys by three large earth/rock filled dams.
This largest in the United States earthfill dam project consists of:
•West Dam, about 85 m high and 2.7 km long, volume 49.7 10^6 m^3,
•East Dam, about 55 m high and 3.2 km long, volume 32.9 $10^6 m^3$, and
•Saddle Dam, about 40 m high and 0.7 km long, volume 1.9 10^6 m^3.
Construction of the dams was finished in 1999 and filling of the reservoir started in December 1999. At the time of writing this paper (January 2002) the reservoir, of a capacity of almost one billion cubic metres, has been 67% filled. It is estimated that filling will be completed in 2-3 more years

In October 2000 a fully automated system with a capability of the continuous monitoring of the behaviour of the dams was implemented. The automated system consists of 8 robotic total stations (Leica TCA1800S) with the automatic target recognition and electronic measurements of angles and distances. In addition, 5 continuously working GPS receivers, have been permanently installed on the crests of the dams to provide a warning system that

will "wake up" the robotic total stations in case of abnormally large displacements. The monitoring data is automatically collected at preselected time intervals and is controlled by an office computer located about 100 km away. All the data collection and automatic data processing are controlled by DIMONS software developed at the University of New Brunswick.

The main objective of the presented study has been to verify whether the behaviour of the West Dam and East Dam during the filling of the reservoir follows a pattern derived from a numerical model using the finite element analysis. In the analysis, the main two effects were considered at the stage of filling the reservoir: pressure of water and effect of wetting. During the process of wetting, the values of geotechnical material parameters and the derived values of Young modulus (E) decrease. Young modulus of the wet material in the submerged sections of the structure becomes smaller and buoyancy force is developed producing dam deformation.

The determination of deformation of the dams due to wetting was performed assuming the behaviour of earth dam and the bedrock as linear elastic materials. Values of the Young modulus in the investigated cross-sections of the dams were obtained from the non-linear analysis in dry conditions (Szostak-Chrzanowski et al. 2000). The determined values shown a large variation of the Young modulus through the structure. In the analysis in wet conditions, the values of Young modulus were decreased according to known empirical formulae and averaged over selected zones.

In the presented example, modeling of the dam deformation due to wetting shows that the predicted displacements, at the crest and at the downstream face, are of the magnitude that can easily be detected by the automated geodetic monitoring system at DVL project. A very good agreement has been obtained between the calculated (modelled) displacements and geodetic monitoring data on the crests of the dams in the process of filing the reservoir. This agreement confirms that the geotechnical parameters and the values of Young modulus, as used in the FEM analysis, as well as the presented method of modelling the dam behaviour, are correct. This is an important conclusion for a possible use of the verified parameters in future analyses of possible effects of additional loads arising, for example, from tectonic movements.

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