Three-dimensional Imaging of Dam Structure and its Application

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Abstract

With many high-hazard potential dams and long river embankments in China, the task of reinforcement of hydraulic projects needs tremendous efforts. Thus, it is of great significance to carry out effective structure quality control and hidden hazard detection. Based on GSR-3D imaging system and dam engineering practice in China, three-dimensional imaging system for dam structure with China’s national conditions was created through secondary development. The system had already been applied in several reservoirs. And the application results show that the system can well realize real-time presenting in all material partition shape of dam and has a high imaging ability. Therefore, the three-dimensional imaging of dam structure provides complete real-time analysis and imaging tools for the internal structure and the orientation of hidden trouble of dams and embankments, which can be used for detecting construction quality and safety hazard, for experts to determine the security state of engineering and for leadership to make decisions by providing the scientific basis.

Keywords: dam structure; three-dimensional imaging; detecting

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1. Introduction

As the end of 2009, China has built 87,151 reservoirs and 291,400 km embankments [1]. Because of social, economic and technical conditions of the period, most of reservoirs and embankments built from the 1950s to the 1970s have problems of inherent shortages, disrepair, serious danger. These reservoirs

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not only have difficulty to play efficiency on flood control and disaster mitigation, but also themselves have become vulnerability of flood security. The formation of dangerous reservoir certainly has its inherent reasons, and there are potential dangers caused by extreme conditions. For instance, Wenchuan Earthquake caused a total of 2380 dams’ hidden danger. After a long run of hydraulic structures, underwater structure condition is a frequently problem in engineering safety assessment process. It is essential to provide new methods for danger location and quality inspection of dangerous dams.

2. Research at home and abroad

Dam safety inspection abroad began in the 1980s. In early 1990s, the Italian Institute of structural model proposed for a system of dam inspection, which was based on acoustic chromatography testing, if necessary, together with the sonic logging and density logging [2], they had already carried out regular inspection in the dam. Recently, other countries also carried out work and made great progress in this area. Association of State Dam Safety Officials in USA holds the annual conference, and there are 4 conference papers relating to the instrument literature that is all about safety inspection instrument [3].

China began hidden danger detection in the 1980s. In 1974, Shandong Hydraulic Research Institute used electric method to assess dam grouting, and established an integrated detection system in 1985. In 1992, Yuanbao LENG assumed study in shallow seismic reflection, ground penetrating radar, electric sounding, power profile, high-density DC resistivity, transient electromagnetic, natural electromagnetic frequency selection, transient Rayleigh wave [3]. In 1996, QingYun DI used high-density DC resistivity to detect Zhuhai embankment. In 1997, Xiangan WU studied detecting dam feasibility by ground-penetrating radar. The State Flood Control and Drought Relief Headquarters held on-site speed evaluation which showed domestic danger detection technology rapidly developed and various methods were more obvious advanced. However software needs to be further strengthened, particularly in real-time [4,5].

Although great many achievements on hidden danger detection technology we already have nearly 20 years, current hidden dangers detection and location methods at home for locating rapidly and analyzing risk is not enough [6]. If have three-dimensional imaging system it would be able to quickly and accurately determine the orientation of hidden trouble and provide a scientific basis for reconstruction of damaged dams caused by Wenchuan Earthquake.

GSR-3D system was explored by Geostructural Seismic Research. The system used refraction imaging algorithm based on Huygens principle to produce 3D models in order to assist engineers extract additional information from geophysical datas [7]. It is mainly used for field geological exploration, as well as civil traffic engineering structural imaging analysis. The original English system integrates many functions, which is an difficult to distinguish for Chinese beginners. Based on dams practice in China, secondary development of system based on introduction, digestion, absorption by C language makes various functional modules systematic, specific, and increases display and data output functions of parts of the image. The system interfaces after secondary development are shown in Fig.1 to Fig.2.

Fig.1. (a) the interface of database modeling subsystem; (b) the interface of analytic software
3 Engineering application and analysis

3.1. Imaging analysis of dam cross-section

One reservoir dam in Zhejiang province is a clay dam with inclined soil wall, the maximum dam height of 16.82m, crest length 600m and top width of 5.5m. The first stage of the upstream slope is 1:2.8 and the second is 1:3.0; the first class of the downstream slope is 1:2.2 and the second is 1:2.5. The 0 +160.00 m dam section design is shown in Fig.3 (a).

Three-dimensional imaging results of dam upstream slope shown in Fig.3 (b), and different velocities represent different materials. By comparing Fig.3 (a) and Fig.3 (b), the upstream slope of dam to detect the filling quality of upstream slope and the existence of security risks.

3.2. Imaging analysis of cut-off wall

One reservoir in Nanjing is a small reservoir with the main objective of flood control and irrigation. The anti-seepage treatments of homogeneous earth dam are composed of multiple small-diameter cement mixing piles, with single-row layout, the wall thickness of 0.3m, pile foundation design deep in weathered sandstone not less than 0.5m. Cut-off wall design drawing is shown in Fig.4(a).

From the three-dimensional imaging results of the cut-off wall in Fig.4 (b), the construction effect of the cut-off wall is good and the thickness basically reached design requirements without obvious structural damage situation such as cut-off wall fracture. Through the three-dimensional imaging system of dam structure, non-destructive detection of cut-off wall structure can achieve real-time rapid detection and especially makes significant sense to the safety of flood of dangerous reservoirs.
4. Conclusion

The paper created three-dimensional imaging system for dam structure adapted to China's national conditions. The system can intuitively understand the status of the dam structure and identify quickly and efficiently the location and severity of hidden danger of dam structure, which is used to detect construction quality and safety hazard. Due to some of the high dam and the complex dam material composition, the system needs to be improved on image effects in the deep parts of dam structure. Increasing the dam analysis system and building the intelligent detection system of dam will become significant aspects of the development of three-dimensional imaging of dam.

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