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MONITORING AND ANALYSIS OF CONCRETE DAMS BEHAVIOR OVER TIME CONSIDERING SWELLING EFFECTS. INTEGRATED USE OF FINITE ELEMENT MODELS AND MODELS FOR EFFECTS SEPARATION

Miguel Rodrigues[(*)], Sérgio Oliveira
National Laboratory for Civil Engineering (LNEC), Lisbon, Portugal
[(*)]*Email:* mrodrigues@lnec.pt

ABSTRACT

This work compares the observed results from hybrid separation of effects models (which use information from finite element models) with the results from finite element models, with a particular interest in the swelling effect. Aguieira dam was the case study because it is a structure with swelling problems. It was possible to verify that, with sufficient monitoring data, the hybrid separation of effects models present results near the ones presented by the finite elements models. This proves that the introduction of finite elements results in a separation of effects model increases the robustness of the separation of effects model.

Keywords: concrete dams, finite elem. models, observed behavior over time, swelling effects.

INTRODUCTION

Dams are amongst the most important structures in our society, mainly because of their primary functions, the risk associated to their failure on downstream populated areas, and their initial investment cost. Dams main purposes are: the retainment of fresh water (reservoir), the regularization of storm water flows and the energy production. Additionally, the IPCC reports on Climate Change forecast the increase of extreme weather events, specifically, droughts will be increasingly longer and rainfall will be more intense. This forecast raises dam's importance even to an higher degree. Considering the above, these structures require a careful and rigorous monitoring, continuously in time, in order to study, analyse and prevent eventual accidents/incidents.

This paper presents a contribution for the development of operational concrete dams behaviour analysis methodologies, particularly for concrete dams with diagnosed swelling problems. This objective is achieved with the upgrade of DamSafe3.0 (program that supports dam's observational data analysis) with integrated use of Finite Elements Models (FEM) and Separation of Effects Models (SEM). The SEM program module enables: i) the use of $a_1(e^{h/k_1}-1)+a_2(e^{h/k_1}-1)+...$ exponential functions to simulate water level elastic effect; ii) determination or fixation of SEM parameters based on FEM results, namely for the functions that simulate the water level elastic effect; iii) explicitly separate the creep effect component related to the hydrostatic pressure, resorting to the Bazant and Panula creep law parameters; iv) use of estimations for the self-weight creep effect resorting to the elastic response determined by the FEM and to the concrete dam creep function; and v) consider $c(1-e^{-t^n/\beta})$ exponential functions to simulate the swelling effect.

The FEM program module enables: i) 3D FEM calculus, for geometries discretized with 20 nodes isoparametric “serendipity” elements, for dam-foundation systems, subjected to the following principal load conditions: self-weight and hydrostatic pressure, temperature variation and swelling; ii) calculus at different water levels to obtain influence lines based on the FEM; and iii) calculus of the structural behaviour considering the accumulated swelling value for a determined time period; this swelling field is determined with the resort to observed values in extensometers for the calibration of the swelling process simulation model (Gomes, 2007), taking into account the hygrometric and thermic field evolution (Leitão, 2012) and the quantity of alkali and silica in the concrete components (for the alkali-silica reaction).

RESULTS AND CONCLUSIONS

Aguieira dam is 90 m tall and is composed by 3 arches. The first filling was in 1980. Aguieira dam was used as the case study for this paper. The dam behaviour over time was analysed with the intent to characterize the structural effect of the concrete swelling identified in the last decade. Figure 1 presents observation results in geodesy and plumb line equipment, as well as the results determined by the FEM.

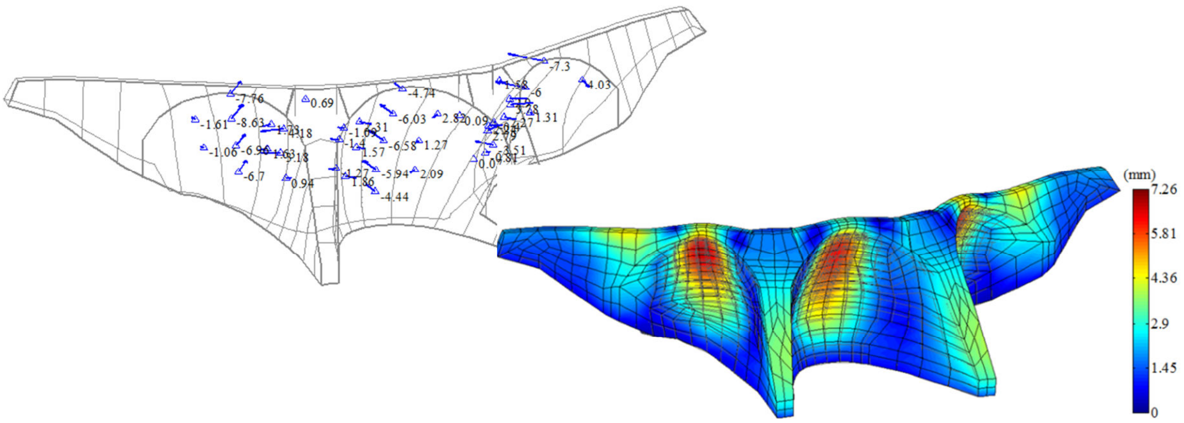

Fig. 1 - Radial displacement associated with swelling: comparison between SEM and FEM.

The results obtained for Aguieira dam enable the following conclusion: a SEM based in a creep function for a concrete affected by a swelling process (creep values approximately doubling the initially predicted, based on tested concrete samples from 1980), obtains a good correlation between observed displacements (analysed through SEM) and numerically calculated displacements (FEM), predominantly in what regards the accumulated swelling between 1980 and 2016, as is possible to observe in Fig. 1. Additionally, the hybrid SEM operating with information extracted from the FEM achieves the expected results from the FEM.

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