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AAR and Solar Radiation Effects on Long Term Structural Performance of Concrete Arch Dams

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Abstract

In this paper, effects of solar radiation along with the deteriorative effect, Alkali-Aggregate Reaction (AAR) are considered on the structural behavior of concrete arch dams. Modelling the real boundary conditions, first of all two transient thermal analyses are conducted for attaining the internal nodal temperatures. Solar radiation effect is included in one of the mentioned analyses. A numerical computer program is developed for simulating AAR during the structural analyses based on Finite Element Method. Attaining the first and second order structural responses for a generic high concrete arch dam, it is inferred that AAR and solar radiation, both can severely affect the structural responses of the considered dam during its long life. Although the effects of AAR is more intensive especially when stresses are assessed over the dam body.

Keywords: Alkali-Aggregate-Reaction, Concrete Arch Dams, Finite Element Method, Solar radiation effects, Transient Analysis.

1. INTRODUCTION

Alkali-Aggregate Reaction, AAR, is a cause of deterioration in the concrete structures. Wet structures or those located in hot and wet climate are more damageable to this phenomenon. Based on the natural characteristics of this reaction, it is significantly affected by both of thermal and structural status of the damaged case. On the other side, solar radiation may be an effective parameter on the thermal and consequently structural performance of the thin structures with broad outer surfaces. Concrete arch dams are examples of such structures. In these infrastructures, solar radiation changes the boundary conditions, increases the body mean temperature, and alters the internal temperature distribution. This may finally change the structural responses due to making changes in the thermal loads. Each of the three aforementioned factors, may affect initiation, propagation and growth of AAR over the body of any AAR-affected concrete dam. Therefore simultaneous evaluation of AAR and solar radiation may be an interesting subject for study.

Several researches were presented with especial concentration on each of these phenomena. P. Leger et al. proposed a numerical approach for computing temperature variations in two-dimensional models of concrete gravity dams. They showed that temperature gradient generates tensile stresses at the surface that may lead to cracking. They neglected the effects of solar radiation and deteriorative factors such as AAR [1]. T. Meyer and L. Mouvet investigated thermal behavior of a concrete gravity dam in Switzerland utilizing Finite Element method (FEM). Results showed that air temperature is not singly a good criterion for estimation of internal temperature but solar radiation increases the whole dam temperature up to 4°C [2]. J. L. Castellanos and E. M. Marin studied the effects of various parameters on thermal behavior of concrete arch and gravity dams using a three-dimensional FE model [3]. M. Malla and M. Wieland modeled a rather small arch-gravity dam in both linear and nonlinear conditions. In their research, AAR was modeled and lack of an accurate simulation, solar radiation was accounted for by adding corrective values to the downstream temperatures (sunny side). Furthermore, they modeled the AAR volumetric expansion using the equivalent temperature method and was taken uniform over the whole dam body [4]. J. Noorzaei et al. analysed a RCC dam using Finite Element approach. They considered the solar radiation effect by adding 1°C to ambient environment temperature [5]. F. Sheibani and M. Ghaemian developed a detailed three-dimensional FE model of a concrete arch dam that was immune from AAR. They found that probable cracks occur in very narrow regions of downstream face, which is mainly due to thermal loads [6]. Introducing a new phenomenological model for AAR, V. Saouma and L. Perotti developed a numerical computer program for