Concrete Gravity Dams: Coupled Thermal-Stress Numerical Analysis

Rana A. EMBABY
MSc Student, Ain Shams University, & Structural Engineer, Dar Alhandasah, Shair and Parteners, Egypt
rana.embaby@dargroup.com

Rana Embaby, born 19--, received her BSc degree from Ain Shams University, Egypt

Amr A. ABDELRAHMAN
Professor, Ain Shams University, Cairo, Egypt
amr@aace-eg.com

Amr Abdelrahman, born 1964, received his BSc and MSc from Ain Shams University, Egypt and his PhD from the University of Winnipeg, Manitoba, Canada.

Ezzeldin Y. SAYED-AHMED
Professor, Ain Shams University (*on leave*), Visiting Professor, the American University in Cairo, Egypt
eysahmed@aucegypt.edu

Ezzeldin Sayed-Ahmed, born 1963, received his BSc and MSc from Ain Shams University, Egypt and his PhD from the University of Calgary, Canada.

Summary

During the process of setting-out and hardening in concrete, the temperature profile shows a gradual nonlinear distribution due to the development of heat of hydration of cement. At early ages of concrete structures, this non-linear distribution can have an influence on crack evolution, especially in mass concrete such as that used in concrete gravity dams. It is thus important to study the factors affecting the amount of heat generated in the hydration process and minimize it as much as possible in order to prevent the generation of undesired cracks through the dam's body. Coupled thermal-stress finite element analysis has been performed on a full-scale concrete gravity dam to determine the impact of changing the time intervals in concrete placing schedule on the thermal/stress response of the dam. The significance of time, material and environmental factors has been scrutinized in this numerical investigation. The investigated parameters are the construction schedule of casting concrete, the cement content and the ambient temperature. The investigation also numerically explored the effect of water pipe cooling of mass concrete on the generated temperature and induced stress in concrete which ends up with recommending the most effective strategy for pipe cooling.

Keywords: adiabatic temperature, construction schedule, gravity dams, hydration heat, pipe cooling, tensile stresses.

1. Introduction

The objective of any thermal investigation of concrete dams is to optimize the spacing between the contraction joints through the dam and the maximum allowable concrete placing temperature. In general, the higher the concrete placing temperature, the closer together will have to be the contraction joints. The optimization of the contraction joint spacing and the maximum placing temperature depends upon a considerable number of factors and ideally should not be treated in isolation. These factors include, but not limited to, the construction method, concrete placement schedule, environmental (ambient) conditions at the site, components/mix properties, maximum concrete placing temperature, adiabatic temperature and the dam's geometry.

Generally, the temperature of concrete arising from the hydration of cement coupled with the low conductivity of concrete induces undesired tensile stresses that eventually lead to a reduction of dam's durability and performance with time. The objective of current coupled thermal-stress study of concrete dams is to optimize both the spacing between the contraction joints through the dam and the maximum allowable concrete placing temperature. ACI 207.1R-05 [1] suggests variety of options to minimize thermal stresses which includes: limiting the placing of concrete to the time of year when cool weather is expected, lowering the placement temperature, placing at night and jointing. It common to limit the generated temperature of concrete below 60^{o}C through dam's aging and consequently, keeping the internal concrete tensile stress below the concrete tensile strength which is normally in the order of 2.5 MPa.

Many researchers [e.g. 2-7] have performed numerical analysis using different approaches to predict temperature and stress distribution in mass concrete. Here, another numerical analyses based

https://doi.org/10.2749/222137814814028052
Distributed by structurae