The 2016 World Congress on
The 2016 Structures Congress (Structures16)
Jeju Island, Korea, August 28-September 1, 2016

Heat Transfer and Stress Analysis of Reactor Containment Building for Various Concrete Mix Proportions in Severe Weather Conditions

*Yun Lee[1)], Sang-Ryul Cha[2)] and Jin-Keun Kim[3)]

[1)] Department of Civil Engineering, Daejeon University, Daejeon 34520, Korea
[2), 3)] Department of Civil Engineering, KAIST, Daejeon 305-600, Korea
[1)] yunis@dju.ac.kr

ABSTRACT

Prediction of concrete cracking due to hydration heat in mass concrete such as reactor containment building (RCB) in nuclear power plant is a crucial issue in construction site. In this study, the numerical analysis for heat transfer and stress development is performed for the containment wall in RCB by considering the various concrete mix proportions. Finally, concrete cracking risk in hot and cold weather is discussed based on analysis results. In analyses considering severe weather conditions, it is found that the through-wall cracking risk in cold weather is high due to the abrupt temperature difference between inside concrete and the ambient air in cold region. In hot weather, temperature differences between inner and outer face is relatively small, and accordingly the relevant cracking risk is relatively low in contrast with cold weather.

Keywords: reactor containment building (RCB), hydration heat, heat transfer, thermal stress, finite element analysis

1. Introduction

Thermal cracking problems due to the heat of hydration of cement in concrete structures were first noted in the many large-sized concrete dams that were constructed in the United States in the 1930s. Since this time, many studies concerning thermal cracking have been performed. In particular, a number of numerical tools using the Finite Element Method (FEM) have been developed. Currently, however, input data related to the thermal properties of the concrete have not been thoroughly investigated. For structures located at coastal regions or areas under the influence of strong winds, however, thermal damage by convective heat transfer may also be prevalent. In order to more accurately evaluate such thermal damage, it is necessary to consider thermal properties such as the convective heat transfer coefficient.

Fundamentally, concrete structures show various behaviors after being placed at construction sites due to the stress-inducing mechanisms of hydration heat, autogenous shrinkage, and drying shrinkage. For the verification and prediction of concrete behavior, numerical schemes such as the finite element method (FEM) and the finite difference method (FDM) are considered powerful tools.

In this paper, the numerical analysis for heat transfer and stress development is performed for the containment wall in RCB by considering the severe weather conditions and construction

---

[1), 3)] Ph.D., professor
[2)] Ph.D. student
Note: Paper to be submitted to "Computers and Concrete, An International Journal" for the purpose of Special Issue.

sequences. From the analysis, the concrete cracking risk in hot and cold weather will be discussed based on thermal stress results.

2. Numerical Analysis

In order to investigate the cracking behavior of a RCB concrete wall, a numerical simulation for a representative portion in RCB concrete wall with a thickness of 1.2 m is carried out. The shape and configuration of the structure are shown in Fig. 1. Additionally, as boundary conditions for the numerical analysis, convection and restraint conditions are imposed by considering the ambient temperature and external constraint conditions.

In the mesh modeling of the structure, concrete is modeled as an eight node isoparametric solid, as shown in Fig. 1. For simplification, only a quarter of the structure is considered in this analysis. Input data for the thermal stress analysis of the concrete wall are shown in Table 1. To simulate the severe temperature conditions as predicted in construction sites, hot and cold temperature based on annual monitoring estimates in UAE and Finland are considered in this analysis, as tabulated in Table 1. Two types of ambient temperature and casting temperature were considered. For the adiabatic temperature rise curve of RCB concrete mix, the equation (i.e., Eq. (1)) of the Korea Concrete Institute (KCI) Code was used.

$$T = K\left[1 - e^{-\alpha(t-t_0)}\right] \quad (1)$$

where T is the adiabatic temperature rise at time(℃), K is the maximum adiabatic temperature rise, α is the temperature increasing velocity and t_0 is the delayed time.

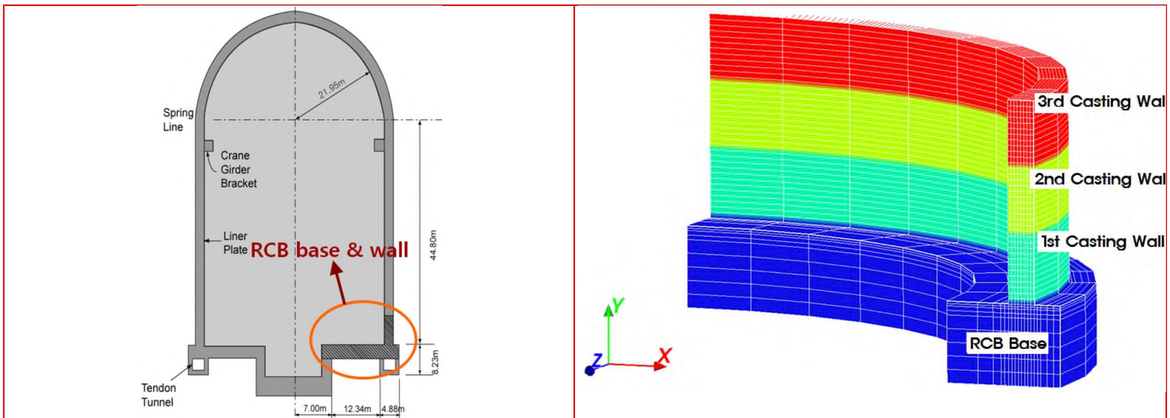

Fig. 1 Mesh Modeling of RCB Base Mat and Containment Concrete Wall

Table 1 Input data for thermal stress analysis of the concrete wall

Parameter		
Casting temperature (℃)	26.7 (UAE)	12.8 (Finland)
Ambient temperature (℃)	32 (UAE)	4.8 (Finland)
Convection heat transfer coefficient (W/(m^2·K))	w/o form	14
	Steel form	14

Note: Paper to be submitted to "Computers and Concrete, An International Journal" for the purpose of Special Issue.