Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Concrete Hydration Heat Analysis for RCB Basemat Considering Solar Radiation

Seong-Cheol Lee [a*], Yong-Ki Son [a], Seong-Cheol Choi [b]
[a]*KEPCO International Nuclear Graduate School, 658-91 Heamaji-ro, Seosaeng-myeon, Ulju-gun, Ulsan 689-882, Korea*
[b]*Chung-Ang University, 84 Heukseok-ro, Dongjak-gu, Seoul 156-756, Korea*
[*]*Corresponding author: sclee@kings.ac.kr*

1. Introduction

The NPP especially puts an emphasis on concrete durability for structural integrity. It has led to higher cementitious material contents, lower water-cementitious-material ratios, and deeper cover depth over reinforcing steel. These requirements have resulted in more concrete placements that are subject to high internal temperatures. The problem with high internal temperatures is the increase in the potential for thermal cracking that can decrease concrete's long-term durability and ultimate strength. Thermal cracking negates the benefits of less permeable concrete and deeper cover by providing a direct path for corrosion-causing agents to reach the reinforcing steel.

The purpose of this study is to develop how to analyze and estimate accurately concrete hydration heat of the real-scale massive concrete with wide large plane. An analysis method considering concrete placement sequence was studied and solar radiation effects on the real-scale massive concrete with wide large plane were reviewed through the analytical method.

2. Subject structure in APR1400 and Analysis Modeling

2.1 RCB basemat in APR1400

One of the basement blocks in the APR1400 Nuclear Power Plant was used as an analysis model in order to study how to accurately analysis the concrete hydration heat and thermal stress in APR1400 Nuclear Power Plant considering the environmental conditions and working conditions of construction site.

As shown in **Fig. 1**, the most vulnerable structure for the concrete hydration heat is the basemat of Reactor Containment Building (RCB) because of its huge thickness, 33ft (10m), and its large dimensions. At the construction site of APR1400, the concrete placements of the basemat are divided by 3 layers which have thicknesses of 10ft (3.05m), 11ft (3.35m) and 12ft (3.66m) for constructability.

Fig. 2 shows the sequence of the concrete placement at the construction site. The concrete placement intervals among the each layer have not been less than 1 month. It means that the thermal impacts from the hydration heat of previous concrete layer would be negligible. And the surfaces which meet the other concrete blocks at the same layers such as S001 & S002 are relatively so small compared to its top surface. So it was assumed that there are not any thermal impacts on the interface of concrete placements.

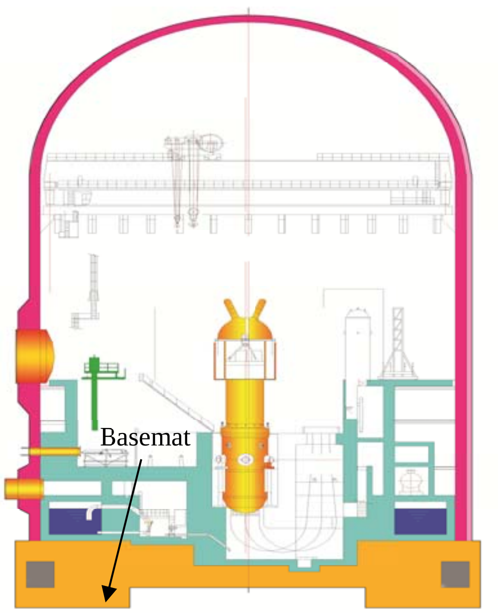

Fig. 1. RCB in APR1400

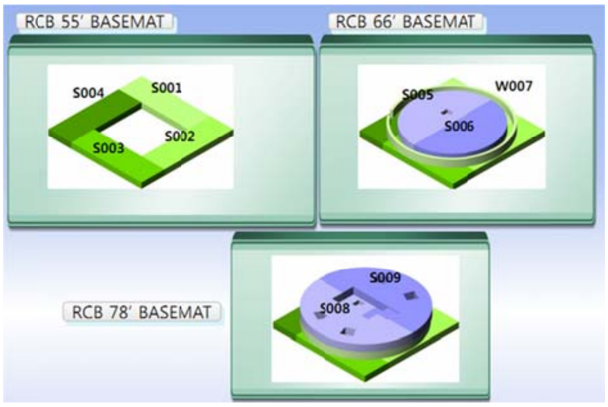

Fig. 2. Concrete placement sequence of APR 1400 RCB basemat

2.2 Concrete material properties

The concrete strength and mix proportions are presented in **Table I**. The adiabatic curve for concrete hydration is presented in **Fig. 3**.

Table I: Concrete mix proportions

Compressive strength (psi)		W/B (%)		S/A (%)	
5000		40		51	
Unit weight of material (kg/m^3)					
Water	Binder			Sand	Gravel
	Type I cement	GGBS	Silica fume		
149	112	242	19	952	923

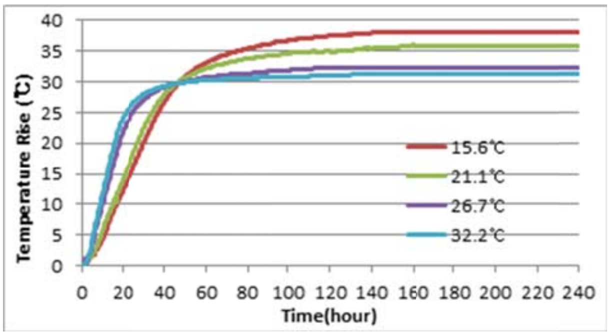

Fig. 3. Adiabatic curve for concrete hydration

2.3 Modeling of APR1400 RCB basemat

To study more simply about the thermal cracking, the concrete block S001was selected. The concrete block S001 is the reinforced concrete structure which is target structure of 1st concrete pouring activity. It is a key milestone of APR1400 construction schedule.

When modeling works for analysis were conducted, it was considered that the hardened concrete with 5m thickness is right below the concrete block S001 as a constraint boundary condition. It was assumed that the hardened concrete has same thermal properties with the concrete block S001. The size dimensions of the S001 block are 38.25 (length)×12.65 (width)×3.05 (height) m. Considering axis-symmetric conditions, 1/4 modeling concrete block was applied to the DIANA FEM Analysis program as the following figure.

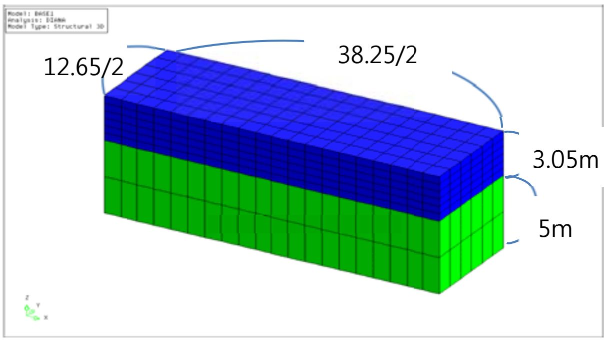

Fig. 4. 1/4 modeling for S001 in RCB basemat

2.4 Ambient temperature and solar radiation

The following ambient temperature variation and solar radiation have been considered in the analysis. It is noted that solar radiation absorptivity is 50% because of shadow effects due to workers, equipment, and structures.

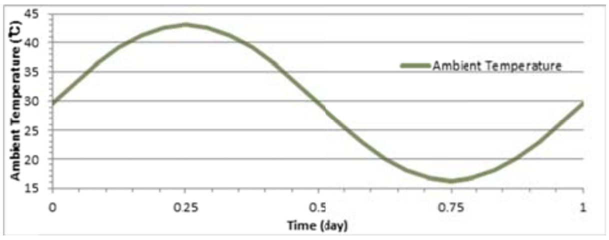

Fig. 5. Ambient temperature variation

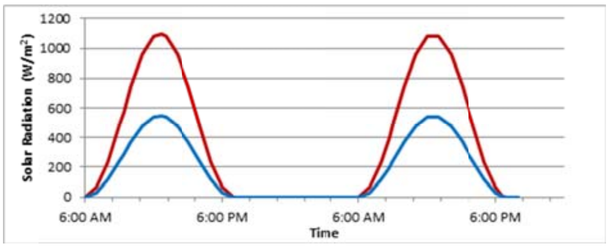

Fig. 6. Solar radiation considering absorptivity

3. Concrete hydration heat analysis results

3.1 Concrete hydration heat analysis results

As a result of the analysis considering concrete placement duration and solar radiation effect, the peak temperature at the top of concrete is 57.8^{o}C at the day 3.66 and the maximum gap of temperature is 18.2^{o}C at the day 8.66. The measured temperature and analysis temperature have very similar pattern and are very closed on temperature curve as shown at figure 5.20. The gap of maximum temperatures at the center of concrete between analysis and measured temperature is 0.7^{o}C and temperature rise curves of analysis results have also very similar trend comparing to the one of measured temperature at the center of concrete. These are why the solar radiation effects are applied to the concrete hydration heat analysis properly.

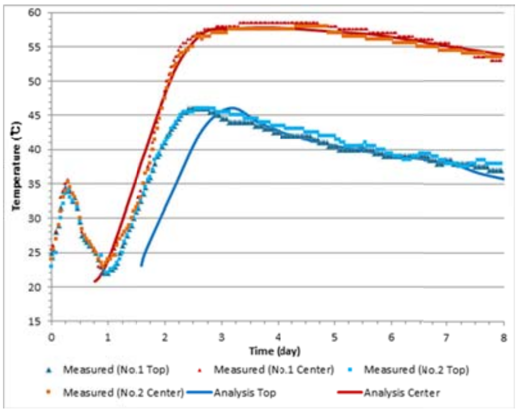

Fig. 7. Hydration heat analysis results

3.2 Thermal stress analysis results

The thermal stress analysis results considering concrete placement duration and solar radiation effect are shown in **Fig. 8 and 9**. Generally, if the concrete hydration heat analysis curve is fit very well with the measured one, it can be said that the analysis results of thermal stress reflect very well the thermal stress that real-scale structure undergoes since thermal stress analysis is induced from the concrete hydration heat analysis. Therefore, the accurate analysis results of thermal stress for research subject structure were obtained with the consideration of concrete placement duration and solar radiation effect.

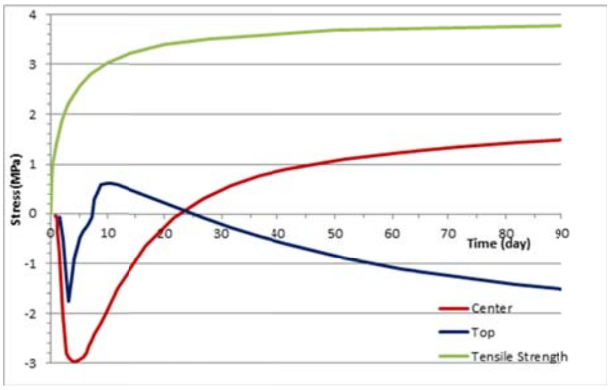

Fig. 8. Thermal stress variation

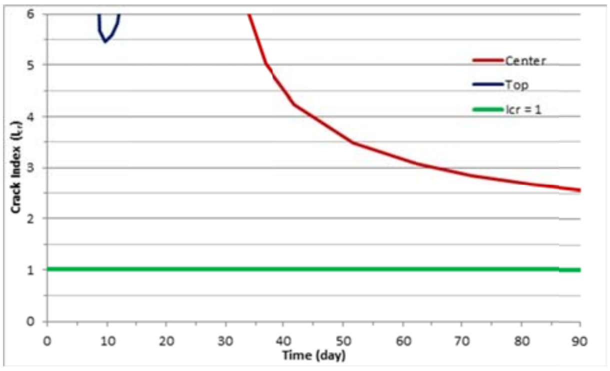

Fig. 9. Crack index variation

4. Conclusion

In this study, the measured temperatures at the real scale structure and the analysis results of concrete hydration heat were compared. And thermal stress analysis was conducted. Through the analysis, it was found that concrete placement duration, sequence and solar radiation effects should be considered to get the accurate concrete peak temperature, maximum temperature differences and crack index.

REFERENCES

[1] S.W. Cha, Modeling of Hydration Process and Analysis of Thermal and Hygral Stresses in Hardening Concrete. Ph.D dissertation, Seoul National University, Seoul, Korea, 1999.

[2] Se-Jin Jeon, Advanced Assessment of Cracking due to Heat of Hydration and Internal Restraint. ACI Materials Journal, July-August, p. 325-333, 2008.