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HEAT OF HYDRATION ANALYSIS IN CONCRETE STRUCTURES FOR TECHNICAL FLOOR

Nguyen Thi Thu Nga
PhD., Technical Basic Department, University of Transport Technology,
No 54 Trieu Khuc street, Thanh Xuan Distr, Hanoi, Vietnam

Nguyen Anh Tuan
PhD., Civil Engineering Department, University of Transport Technology,
No 54 Trieu Khuc street, Thanh Xuan Distr, Hanoi

ABSTRACT

Hydration heat is one of the most important factors because it is used as source of heat in concrete structures. Development of compressive strength of concrete for technical floor may be delayed due to using large amount of fly ash to control the heat of hydration. However, long-term development of compressive strength of concrete is expected after 28 days due to the pozzolanic reaction of cement (binder) hydrates. Thus, we suggest the extension of specified strength control age from 28 days to 90 days. Based on the results of finite element analysis of hydration heat for technical floor, we suggest curing methods and periods as follows in order to restrict thermal cracks. This paper presents the results of mix design of concrete grade 50MPa and finite element analysis of heat of hydration on the technical floor. The concrete mix proportion, considering member size and work condition, for technical floor of grade 50MPa is designed.

Key words: strength, hydration, crack.

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1. INTRODUCTION

The risk of fire in the commercial floor is very high, if the incident, the ability of fire prevention system timely solving the fire is possible. Then, the emergence of a technical floor between the residential and commercial floors would significantly contribute to limiting the possibility of widespread fire from commercial to residential areas. Because of the role of the technical floor, the requirements for concrete designed for this floor are highly demanded. Concrete is not only guaranteed in terms of strength but also to control the temperature of the hydration process in the concrete to avoid cracking and shrinkage that affects the strength and durability of the concrete.

In this paper, the authors show 50MPa concrete for the technical floor of the building from 36 to 40 floors and also determines heat of hydration of concrete by finite element method. On that basis, measures are taken to limit the thermal cracking of concrete.

2. MIX DESIGN OF GRADE 50MPA HIGH STRENGTH CONCRETE

2.1. Requirements

Table 1 summarizes the requirements for the grade 50MPa high strength concrete for technical floor which has congested rebar and massive section.

Table 1 Requirements for grade 50MPa high strength concrete for technical floor

Member	Compressive strength	Slump flow	Required properties
Transfer girder	50MPa	Over 500mm	Low heat development High consistency Resistance against segregation Compact-ability

2.2. Materials used

Table 2 shows the physical properties of materials used in this mix design.

Table 2. Physical properties of materials

Cement	Sand	Gravel	Super-plasticizer
But Son, Ha Nam (Specific gravity 3.10)	Song Lo (Specific gravity : 2.60, FM : 2.85)	Ha Nam (Specific gravity : 2.76)	Poly-carboxylate acid based (Silk road SR3000F, SR3000S)

2.3. Concrete Mixture

Table 3 shows the mix proportion of grade 50MPa high strength concrete. In order to restrict the heat of hydration development, unit cement (binder) content was designed below 500kg/m^3.

Table 3. Mix proportion

W/B[1)] (%)	S/a (%)[2)]	Unit weight (kg/m^3)				SP dosage (kg/m^3)	
		Water	Binder[3)]	Sand	Gravel	SP1[4)]	SP2[5)]
32.0	48.0	160	500	832	935	4.20	1.55

1) Ratio of water and binder

2) Sand and Aggregate ratio could be changed to cope with the change of material quality and work conditions.

3) Ordinary Portland cement (binder)

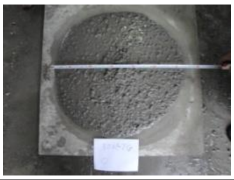
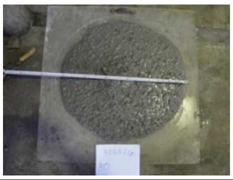
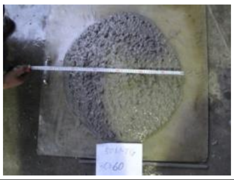
4) SP 1: Poly-carboxylate acid based super-plasticizer which has dispersing property of cementitious materials.

5) SP 2: Poly-carboxylate acid based super-plasticizer which has sustaining property of consistency.

2.4. Fresh Concrete Property

Consistency of fresh concrete was estimated by slump flow test, ASTM C 1611 [1] Standard test method for slump flow of self-consolidating concrete, 0, 30, 60, and 90minutes after mixing. Table 4 shows the slump flow retention according to the time elapsed.

Table 4. Test results of slump flow

After mix	30min.	60min.	90min.
			
635mm	625mm	600mm	520mm

2.5. Compressive Strength

Table 5 shows the compressive strength results of six specimens at 2, 3, 7, 14, and 28days.

The mixture developed the designed compressive strength, 50MPa, within 14days and increased with the day passed. However, the compressive strength of this mixture could be increased continuously due to the pozzolanic reaction of cement (binder) hydrates. Thus, it is strongly recommended that the specified compressive strength control age extend from 28days to 90days from the hydration heat reducing point of view.

Table 5. Test results of compressive strength [2]

	2days	**3days**	**7days**	**14days**	**28days**
No.1	33.7	38.4	45.4	52.7	57.7
No.2	32.4	38.0	44.8	51.2	55.6
No.3	30.8	37.9	44.2	51.6	56.8
No.4	34.8	38.0	44.6	51.4	56.4
No.5	32.9	38.4	44.1	50.3	53.9
No.6	30.6	37.2	43.8	49.3	54.2
Average	32.5	38.0	44.5	51.1	55.8
STDV	1.637	0.440	0.574	1.165	1.495

3. FINITE ELEMENT ANALYSIS (FEA) OF HEAT OF HYDRATION

3.1. Summary of Heat of Hydration Analysis

After portland cement is mixed with water, heat is generated by the result of the chemical reaction between cement and water. This heat is called hydration heat. In general, adiabatic temperature rise test has been used to calculate hydration heat.

Finite element method helps to evaluate the crack risk based on the time dependent material properties such as tensile strength development and tensile stress due to the thermal difference. For this purpose, MIDAS GEN [3] finite element method program was used. The process consists of 6 steps, described in block diagram in Figure 1.

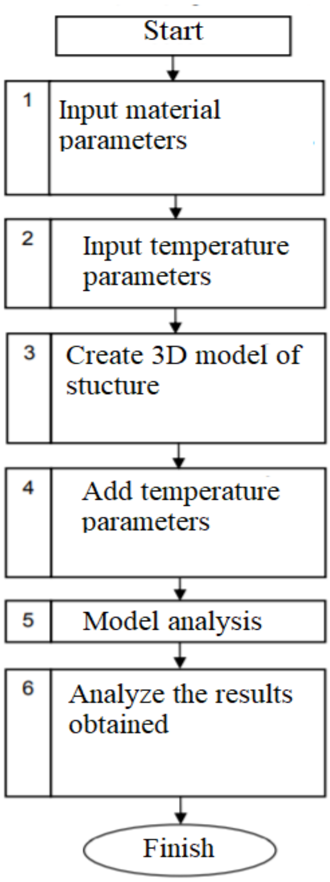


Figure 1 Analytical process

3.2. Analysis Conditions

3.2.1. Modeling

Figure 2 shows the plan of technical floor which has 2400×2200mm sized transfer girder. Heat of hydration analysis was performed on some part of the transfer girder 8. Figure 2 shows the mesh model of columns (1100×1100×4300mm), transfer girders and beams(13600×6400×2200mm). As a construction stage, after 50MPa column was cast and cured a week, transfer girders and beams were cast one shot pouring.

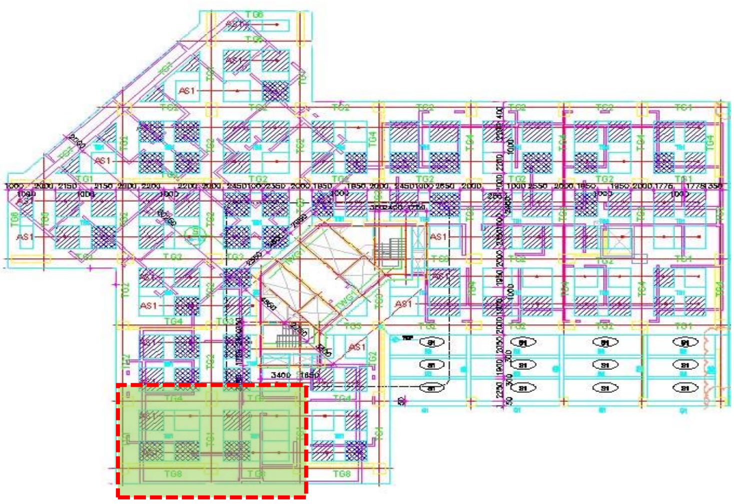
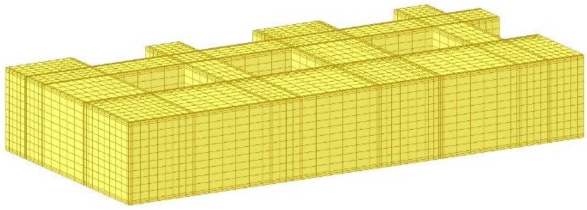


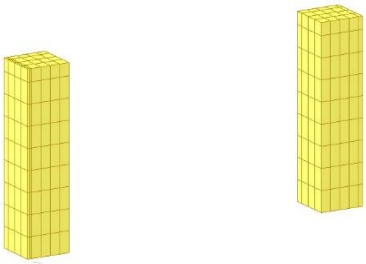
Figure 2 Plan of technical floor and FEM analysis member

3.2.2. Input Variables

Input variables for FEM analysis of heat of hydration are shown in Table 6. Adiabatic temperature development curve is shown in Figure 4 which shows the maximum temperature rise up to 45.1℃. Ambient temperature was adopted from the weather statistic data as 17℃ in March, 24℃ in April, and 27℃ in May (Figure 5). Fresh concrete temperature assumed as 25℃ considering ambient temperature and using chilled water as mixing water.



(a) Transfer girder and Transfer beam (13600×6400×2200mm)



(b) Column (1100×1100×4300mm)

Figure 3. Model for heat of hydration analysis considering construction stages

Table 6. Input data of 50MPa concrete

Specific heat	Density	Heat conductivity	Thermal expansion coefficient	Poisson ratio
0.245kcal/kg·℃	2400kg/m^3	2.3kcal/m·hr.·℃	1.0×10^{-5}/℃	0.167

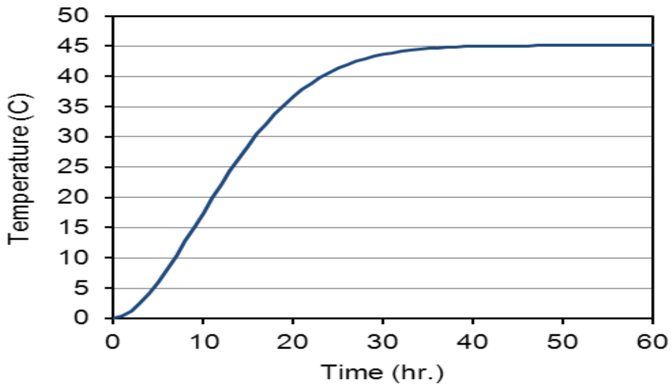
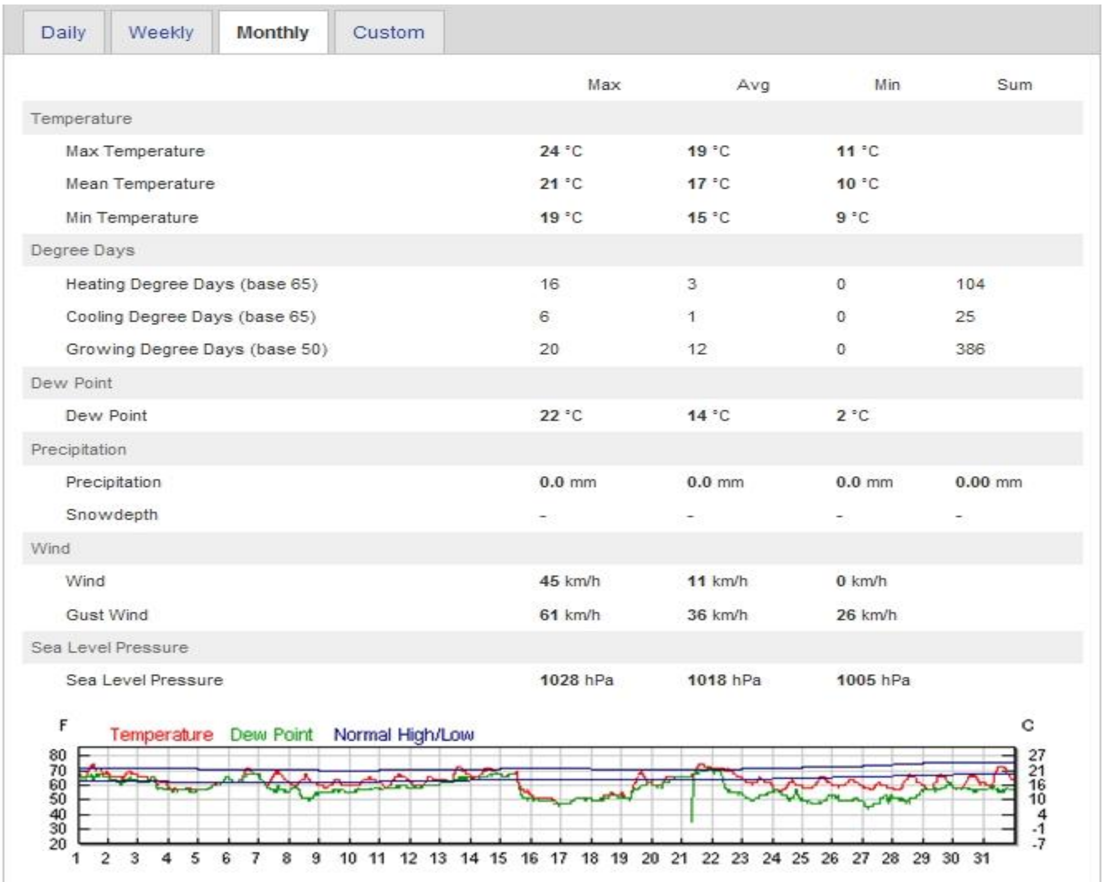


Figure 4 Adiabatic temperature developing curve of 50MPa concrete



Daily | Weekly | Monthly | Custom

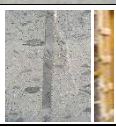
	Max	Avg	Min	Sum
Temperature				
Max Temperature	24 °C	19 °C	11 °C	
Mean Temperature	21 °C	17 °C	10 °C	
Min Temperature	19 °C	15 °C	9 °C	
Degree Days				
Heating Degree Days (base 65)	16	3	0	104
Cooling Degree Days (base 65)	6	1	0	25
Growing Degree Days (base 50)	20	12	0	386
Dew Point				
Dew Point	22 °C	14 °C	2 °C	
Precipitation				
Precipitation	0.0 mm	0.0 mm	0.0 mm	0.00 mm
Snowdepth	-	-	-	-
Wind				
Wind	45 km/h	11 km/h	0 km/h	
Gust Wind	61 km/h	36 km/h	26 km/h	
Sea Level Pressure				
Sea Level Pressure	1028 hPa	1018 hPa	1005 hPa	

Figure 5 Weather statistic data of Hanoi city

3.2.3. Curing Methods

Convection coefficient of each material was shown in Table 7. On the concreting surface, three types of curing method were analyzed. The convection coefficient of euro form/ plywood will be used for the side form, applied 6.87.

Table 7. Convection coefficient according to the curing methods

Curing method	**Schematic**	**Convection coefficient (kcal/m·hr.·°C)**
None / exposed curing		12.00
Plastic sheet		7.00
Fabric sheet		4.00
Euro form/ Plywood		6.87

4. RESULT AND DICUSSION

Heat of hydration analysis results considering ambient condition during concreting and construction stages are summarized in Table 8.

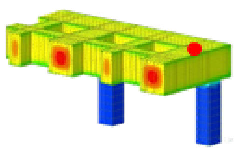
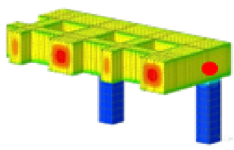
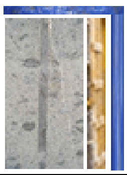
Table 8. Heat of hydration analysis results

	Curing condition	Removal time	Position	Max. temperature			Max. difference			Crack index	
				Tem. (°C)	Hr.	Dif. (°C)	Tem. (°C)	Hr.	Dif. (°C)	Value	Hr.
Upper	None	-	Center	65.7	34	28.3	63.7	44	29.7	0.70	30
			Surface	37.4			34.0				
	Plastic S.	4days	Center	65.7	34	21.9	61.9	51	23.8	0.81	34
			Surface	43.8			38.1				
	Fabric S.+ Plastic S.	(4+2)days	Center	66.2	34	15.6	51.0	100	19.5	1.04	39
			Surface	50.6			31.5				
Side	Euro form/ Plywood	4days	Center	65.7	34	21.0	61.8	51	24.1	0.83	30
			Surface	44.7			37.7				
	Euro form /Plywood+ Plastic S.	4days	Center	66.2	34	15.2	51.0	100	20.3	1.01	20
			Surface	50.9			30.7				

To minimize the thermal cracking considering construction progress, curing materials and periods are suggested as Table 9

Table 9 Suggestion of curing method

Concrete — Plastic sheet — Fabric sheet — Euroform/Plywood

Position	Schematic	Curing methods and removal time						
		1 day	2 days	3 days	4 days	5 days	6 days	7 days
Upper								
		Covering start after surface drying				Removal of plastic sheet		Removal of fabric sheet
Side								
		Vertical form and sheet curing				Removal of vertical form and sheet		

5. CONCLUSIONS

From the testing results in this study, the conclusions and recommendations can be drawn:

- Super-plasticizers should be used to increase workability and improve the strength of concrete.
- There should be reasonable curing methods, as suggested in table 9, the coating layers have a specific use time.

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[2] ASTM C39 (2003), "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens".

[3] Midas Gen is one of famous programs of Midas Software, that is integrated solution system for building and general structures.

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