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STUDY OF HEAT OF HYDRATION AND ITS EFFECTS IN RCC STRUCTURAL MEMBERS

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Abstract

This paper presents the review on experimental and analytical studies on the performance of concrete when exposed to strength of RCC members. Hydration heat is one of the most important factors because it is used as source of heat in concrete structures We use calorimeter (UTCM-0347 HEAT OF HYDRATION CALORIMETER) to calculate the heat of hydration of samples of different grade of concrete Though much attention has been bestowed over the performance of concrete under room temperature conditions, the study on behavior of RCC subjected to elevated strength is gaining momentum The objective is to do the study of heat of hydration released in different grade of concrete and which grade of concrete is suitable to use in different atmospheric conditions to increase the serviceability and durability of the structure. 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

Key Words: *Strength, UTM, RCC, Hydration, and Cement etc…*

1. INTRODUCTION

The chemical reaction takes place between the active components of cement and water is known as hydration of cement. The active components of cement are Bogue's compounds i.e., C3S, C2S, C3A and C4AF. These reactions are exothermic reactions. Heat is evolved during hydration of cement. The evolution of heat causes an increase in temperature of the concrete, being greatest in mass concreting. The study of that heat of hydration is to be done by us.

1.1 Aim of the Study

In this topic we will study about:

1. The comprehensive process of hydration occurs in making the concrete hardened and gaining strength and what reaction takes place.
2. We will get to know the results of heat of hydration released in different types of grade of concrete used in variety of structures.
3. What is the result of using different percentage of Bogue's compound with different percentage of water.
4. Effects of variation of heat of hydration in different grade of concrete.
5. Effect of using different water/cement ratio.

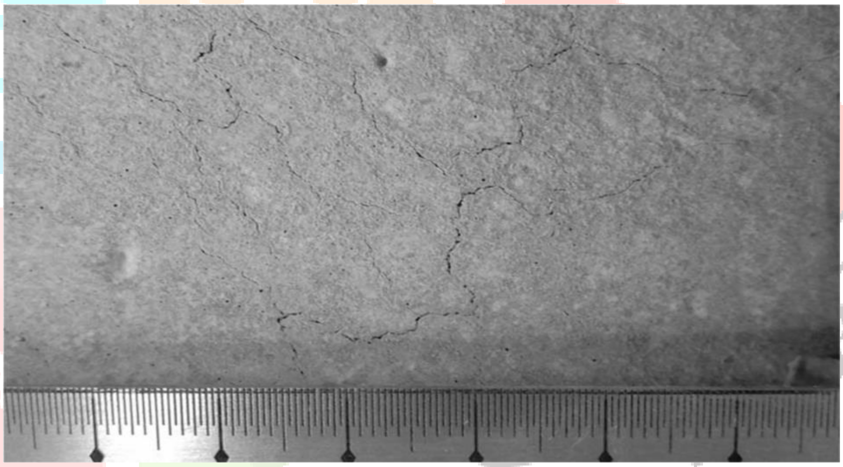
1.2 Literature Review

Most applications of foamed concrete are in large-volume concrete construction projects. The heat generated by the hydration affects the temperature field in the structure, resulting in three problems. First, the increase and decrease of the hydration heat lead to the expansion and contraction of the foamed concrete structures, which affects the structure itself and adjacent buildings.
The maximum temperature is used as an indicator of this problem. Second, a temperature difference exists between the external and internal portions of the structure and the temperature stress results in cracks in the structure's surface.

This reduces the strength of the structure and affects its integrity and durability. Third, as studies on the impact of the hydration heat on the strength of concrete have shown a lot of heat is produced by the hydration of foamed concrete, which may affect the strength of the material. Because the coefficient of thermal conductivity for this material is low, high temperatures are maintained for very long periods in the structure. Regarding these problems, Jones stated that the heat evolution in foamed concrete is affected by a greater number of parameters than that in normal-weight concrete. Tarasov studied the influence of the density and the volume of the castings and of fine aggregates on the temperature profiles in foamed concrete. However, the effect of hydration heat on the strength development of foamed concrete was not considered, and the experiments were carried out in the laboratory without considering external influencing factors.

Fly ash is a pozzolanic material and has been widely used as an admixture in concrete to address the problem of the hydration heat. Its application in concrete has been studied widely, but its application time in concrete is short. Most studies on the addition of fly ash to concrete have focused on the mechanical properties and durability. If fly ash can be used satisfactorily in concrete, it can be used to replace part of the cement. This lowers the construction costs and increases the performance of the concrete and its application potential. The low-carbon economy is an important goal in China; therefore, the application of fly ash has a far-reaching significance.

The main goal of this study is to investigate the relationship between the hydration heat and the strength development of foamed concrete. First, six groups of indoor model tests with different casting densities and different fly ash dosages were conducted to study the effects of the casting density and fly ash content on the temperature profiles of the concrete. Second, compression tests under two curing conditions (standard curing, temperature matched curing) were conducted to study the effects of the curing conditions on strength development. Finally, the changes in the temperatures of the foamed concrete were analyzed in four field tests.



2. MATERIAL USED

The foamed concrete was comprised of ordinary Portland cement, water, and bubbles. The cement was Type I Portland cement conforming to GB 175-2007, the fly ash was Class F Type I conforming to GB/T 1596-2005, and the water was tap water. The bubbles were created using a synthetic foaming agent, which was highly eco-friendly, and its air bubbles were strong

3. METHODOLOGY

We use calorimeter (UTCM-0347 HEAT OF HYDRATION CALORIMETER) to calculate the heat of hydration of samples of different grade of concrete.

Firstly we collect the different grades of concrete samples from construction site. Now we perform the calorimeter test on samples that has been collected.

The UTCM-0347 Heat of Hydration Calorimeter is used for determining the heat of hydration of low heat Portland and hydraulic cement. The apparatus consists of a Dewar flask housed in an insulated box, an electric stirrer, a filler funnel and a high resolution battery operated electronic thermometer. It displays, saves and prints ΔT, Min., and Max and Mean Values. Its resolution is 0.001°C and Accuracy 0.05°C.

To find the heat of hydration, firstly we have to measure the heat released from the unhydrated cement using a calorimeter.

Then we have to measure the heat of hydration from hydrated cement

For that take 60 grams of cement and add 24 ml of water.

Then fill this mixture in three glasses and seal them with wax to avoid the entry of air.

The standard temperature should be 27 degrees celsius.

Then measure the heat of the solution using a calorimeter.

Heat of hydration = Heat released from hydrated cement – Heat released from unhydrated cement

For low heat cement, the heat of hydration for 7 days should not be greater than 66 cal/g and for 28 days should not be greater than 75 cal/gm.

From this apparatus we get the results from which we conclude the things suitable for each temperature conditions.

3.1 Testing Method

3.1.2. Indoor Model Test

The layout of the Pt-100 thermal resistance thermometers in the indoor model test, which was conducted to determine the heat of hydration of the concrete, is shown in Figure 3. The size of the model was 500 mm long × 500 mm wide × 500 mm high. The bottom and the periphery of the model were covered with double-layer insulating foam boards. In order to simulate the conditions at a construction site, the top surface was covered with a thin film to simulate the semi adiabatic boundary conditions after the casting of the concrete. The construction time interval of each layer was about 24 h in construction projects, and the temperatures were acquired for 36 h after the casting. The tests were conducted at a room temperature of 20°C.

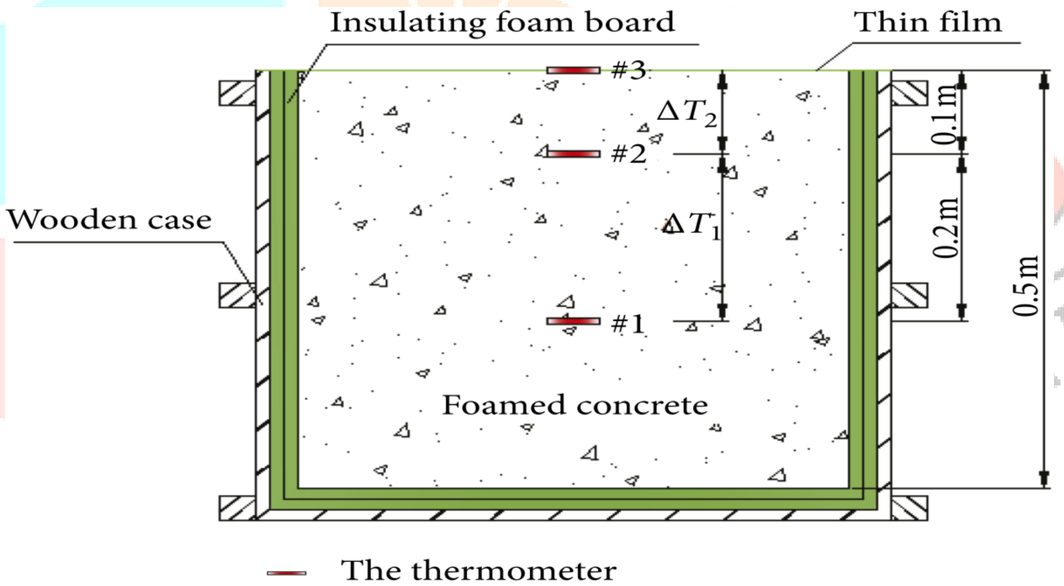


Fig -2: Profile model of the test

3.1.2. Adiabatic Temperature Rise Test:

Water-cement ratio (w/c) has a great influence on the hydration degree, and the same hydration degree can be achieved when w/c is close to 0.48. It has been proved by Mill too. So two concrete specimens (named as C1 and C2) with w/c of 0.5 and 0.45 were prepared. .e specific mix proportion of concrete in the test is indicated.

Experimental Schemes: The adiabatic temperature rise chamber, provided by the Yangtze River Scientific Research Institute of China, was used to carry out the adiabatic tests of fly ash concrete. .e specimen was a concrete cylinder with a diameter of 380 mm and a height of 360 mm. In order to describe the temperatures of different positions in the concrete specimen, 13 testing points (T0, T1, T2…… T12 in C1 and T13, T14, T15……T25 in C2) were evenly arranged into 5 layers along the height direction of the concrete specimen (Figure 1). Micro K thermocouple detectors were adopted to provide quick and accurate temperature measurement, and a multichannel temperature measuring device was used to record the data according to the set intervals automatically.

TABLE 1: Chemical composition and physical properties of the cementing materials.

Material	CaO (%)	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	SO_3 (%)	Loss of ignition (%)	Density (kg/m^3)	The specific area (m^2/kg)
Cement	57.72	35.48	0.87	1.20	3.49	2.42	1.26	3200	385
Fly ash	1.28	53.88	25.41	7.65	3.19	0.73	3.35	2600	414

TABLE 2: Mixture proportion of concrete.

Mix number	w/c	S/a	Unit weight (kg/m^3)				
			Water	Cement	Fly ash	Sand	Gravel
C1	0.5	0.34	100	100	100	731	1419
C2	0.45	0.34	90	100	100	731	1419

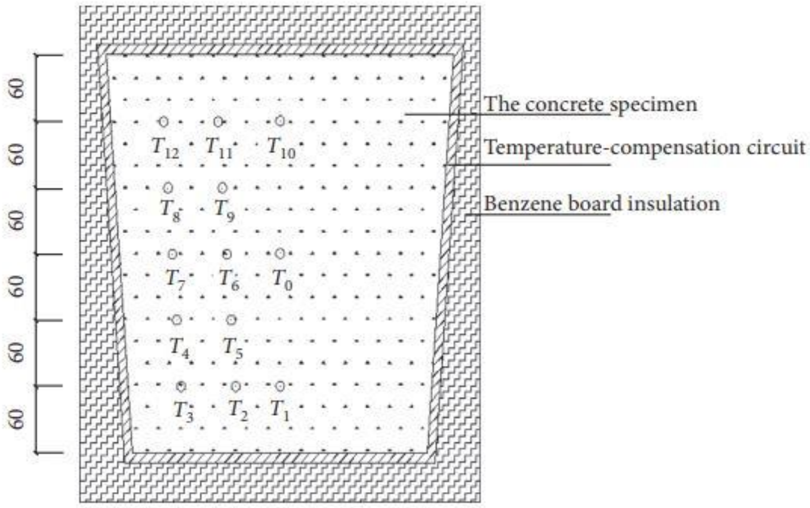


FIGURE 1: The location of sensors of adiabatic test (unit: mm).

The temperature sensors fixed on a welded iron frame were wrapped with the epoxy resin asphalt to prevent damage during the concreting process and were put into the cylinder container as soon as the asphalt dried. e concrete was carefully poured through a funnel to ensure that the positions of sensors were not shifted, and at the same time, the concrete specimen was vibrated on the platform vibrator, and then the specimen was put into the outer cylinder after the surface was flattened. e whole experimentation was carried out under the room temperature of 25°C, and the temperatures of the laboratory were adjusted timely according to the concrete specimen by air conditioner in order to ensure that the ambient temperatures are in accordance with the test temperatures during the adiabatic test. Figure 2 shows the concrete pouring, the insulation measures of the adiabatic chamber, and the temperature acquisition system in turn.

Experimental Results: The Temperature of Specimen with Different Water Cement Ratios. In each of the two specimens, three testing points were selected as representatives, and the historic curves of adiabatic temperature rise were plotted in order to give out the changes of temperature over time. Figure 3 presents the temperatures of the testing points in the two specimens which have taken account into the heat loss of the adiabatic chamber. It can be seen from Figure 3 that the temperatures of the both specimens are increasing with the increase of curing age, and the concrete is rapidly hydrated in the rest few hours to reach a higher temperature, after which the rate of hydration becomes slow and the rate of temperature rise diminishes significantly. Meanwhile, we can also acquire from Figure 3 that the temperatures of C2 are lower than those of C1 in the whole process on account of the lower w/c. Moreover, the rising rates of C1 and C2 are slightly different; the temperature rising of C1 is faster than that of C2 at the beginning, and the increasing rates of the both are opposite at the later stage. e w/c of C1 is relatively large which can provide adequate conditions for the hydration of cement leading to a faster hydration rate at the beginning while the w/c of C2 is smaller, and the cement cannot contact with water fully and the hydration rate is slow accordingly. With the curing ages increasing, the hydration of C1 is completed basically, while, by contrast, the internal temperature of C2 increases with the cement hydration, which is an important factor that promotes the hydration rate of cement, so the rate of C2 is slightly larger than that of C1 at a later period.

The Temperature at Different Positions of Specimen: Table 3 shows the temperatures at the testing points in the specimens C1 and C2 at different ages, and the spatial distribution of temperature is non uniform obviously. e data of the testing points T0, T6, and T7 and T25, T18, and T19 indicate that the temperature near concrete core is higher while it slightly decreases along the radius at the same curing ages, and this is mainly because that the heat loss compensation of the equipment is not sufficient. Figure 4 shows the temperatures along the height section of 1 d, 3 d, 7 d, 14 d, and 28 d after pouring, taking C1 as an example. Both of them manifest that the temperatures of the testing points vary a lot in the first curing days. The temperature of testing points near concrete core is highest among the points at the same moment because more heat is dissipated through the top and bottom of the adiabatic chamber. It is just due to the fact that the top of the concrete in the pouring process is exposed to the air and the ambient temperature is higher, which improves the temperature of the top because of the heat transfer and leads to a faster hydration. As a result, the temperature of the top is higher at the early stage than later. After pouring, the external conditions of the top and the bottom are the same while the heat insulation effect of the bottom is better than that of the top during the hydration process. From Figure 4, it also can be shown that all the temperature changes have a similar trend, and the difference of the temperatures of the testing points becomes small from the third curing day.

3.1.3. Compression Test

For this test, thirty identical samples (100 mm long × 100 mm wide × 100 mm high) were cast for each mix proportion. After the casting, half of the samples were cured under standard curing conditions, and the others were cured under temperature matched curing conditions. For the standard curing condition, the samples were cured in a standard curing room after they were unmolded until the test time. For the temperature matched curing conditions, the samples in the molds were placed in a constant temperature and humidity box. After the samples were unmolded, they were wrapped in bags cured in the constant temperature and humidity box. The temperatures for the different densities were collected in the same manner as for the indoor model test. The humidity value remained at 100%.

Fig -3: The constant temperature and humidity box

4. CONCLUSIONS

As we perform calorimeter test in lab on collected concrete samples of different grades. We observe the amount of heat it releases and perhaps we conclude all the results and will show in tabular and graphical form. And now we are able to reach to the result that is which grade of concrete is suitable to be used in each of type of temperature variation and atmospheric conditions.

The following conclusions can be drawn based on the experimental and comparative results.

(1) For the concrete without an admixture, the strength increases significantly during the early stage and decreases during the later stage under temperature matched curing conditions. The strengths are improved for all curing times when the fly ash is added, and the effect increases with the increase in the fly ash content.

(2) The space-time evolution characteristics of fly ash concrete are revealed in this paper. The space distribution of temperatures is uneven, and the higher temperature near concrete core and lower temperature near concrete surface are found in the adiabatic temperature rise test. The temperature keeps increasing in the curing process, and the temperature rise rate in the 3 days is faster while the rate at the later stage is slower.

(3) Standard curing conditions and temperature matched conditions have an effect on the structure of composite cementitious materials mixed with fly ash at the later stage. The structure of concrete hole wall is more compact under temperature matched conditions, increasing its compressive strength.

(4) Due to external factors occurring in the field tests, the maximum temperature increments are lower in the field tests than in the indoor model test for the same casting density. Reasonable cooling measures and the addition of the fly ash decrease the maximum temperature increments.

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