Research Article

Study on the Heat of Hydration and Strength Development of Cast-In-Situ Foamed Concrete

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This study aims to investigate the relationship between the heat of hydration and the strength development of cast-in-situ foamed concrete. First, indoor model tests are conducted to determine the effects of the casting density and the fly ash content on the hydration heat of foamed concrete in semiadiabatic conditions. Second, compression tests are carried out to evaluate the development of the compressive strength with the curing time under standard curing conditions and temperature matched curing conditions. Third, the hydration heat development of the foamed concrete is tested in four projects. The results showed that the peak temperature, the maximum temperature change rate, and the maximum temperature difference increased with the increase in the casting density at different positions in the foamed concrete. For the same casting density of the foamed concrete, the peak temperature, the maximum temperature change rate, and the maximum temperature difference decreased with the increase in the fly ash content. For the foamed concrete without the admixture, the early strength was significantly higher under temperature matched curing conditions than under standard curing conditions, but the temperature matched curing conditions had a clear inhibitory effect on the strength of the foamed concrete. The strengths during the early stage and the later stage were both improved under temperature matched curing conditions after adding the fly ash, and the greater the fly ash content, the larger the effect. The maximum temperature increments were higher in the indoor model test than in the field tests for the same casting density. Reasonable cooling measures and the addition of fly ash decreased the maximum temperature increments and increased the corresponding casting times.

1. Introduction

Cast-in-situ foamed concrete is composed of cement, an admixture, and a proportion of stable tiny bubbles, and it is cast, molded, and cured at the construction site [1–3]. This type of concrete is a new type of geotechnical material developed in recent years and possesses the advantages of low weight, stable performance, convenient construction, and so forth. [4–7]. The applications of cast-in-situ foamed concrete have expanded considerably in civil engineering as a result of scientific and technical advances in its production. According to the statistical results of the China Concrete and Cement Products Association (CCPA), the annual market size of foamed concrete was over 40 million m³ in China during 2017, more than 80% of which was cast-in-situ foamed concrete. Due to construction growth in civil

engineering, the applications of foamed concrete will also increase [8, 9].

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 (Figure 1) [10, 11]. Third, as studies on the impact of the hydration heat on the strength of concrete have shown [12–14] a lot of heat

FIGURE 1: Damage to foamed concrete structures caused by hydration 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 [11] stated that the heat evolution in foamed concrete is affected by a greater number of parameters than that in normal-weight concrete. Tarasov [15] 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 foamed concrete is short. Most studies on the addition of fly ash to foamed concrete have focused on the mechanical properties and durability [16–19]. If fly ash can be used satisfactorily in foamed concrete, it can be used to replace part of the cement. This lowers the construction costs and increases the performance of the foamed 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 [20, 21].

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 foamed 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. Materials and Methods

2.1. Materials. 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 [22, 23].

2.2. Mix Design Procedure. Table 1 shows the mix proportions and major parameters of the foamed concrete used in the indoor test. A prefoaming method was used to produce the foamed concrete. First, bubbles with a density of $35 \pm 5 \text{ kg/m}^3$ were prepared [24]. Second, the cement and water were weighed and mixed to produce the cement slurry. Finally, the prepared bubbles were incorporated into the cement slurry to create the foamed concrete slurry, which was then cast (Figure 2). In order to meet the requirements of the fluidity of the foamed concrete during construction, its flow value should be maintained between 160 mm and 180 mm according to the Specifications for the Design of Highway Subgrades (JTG D30-2015).

2.3. Testing Method

2.3.1. 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 foamed concrete, is shown in Figure 3. The size of the model was 500 mm long $\times$ 500 mm wide $\times$ 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 semiadiabatic boundary conditions after the casting of the foamed 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.

2.4. Compression Test. For this test, thirty identical samples (100 mm long $\times$ 100 mm wide $\times$ 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

TABLE 1: Mix proportions and major parameters of the foamed concrete.

	Theoretical casting density (kg/m^3)	Water/binder	Water (kg/m^3)	Cement (kg/m^3)	Fly ash (kg/m^3)	Fly ash/ (cement + fly ash)	Air bubbles (l/m^3)	Measured casting density (kg/m^3)	Flow value (mm)
1	400	0.75	169	225	0	0	763	406.7	165.4
2	700	0.62	267	430	0	0	612	708.4	168.8
3	1000	0.54	346	640	0	0	448	1004.7	171.9
4	700	0.62	267	386	43	10%	609	707.3	172.3
5	700	0.62	267	301	129	30%	604	705.1	175.7
6	700	0.62	267	215	215	50%	598	707.9	179.1

(a)

(b)

(c)

FIGURE 2: Preparation of the foamed concrete slurry [25].

FIGURE 3: Profile model of the test.

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 (Figure 4). The temperatures for the different densities were collected in the same manner as for the indoor model test. The humidity value remained at 100%.

3. Results and Discussion

3.1. Effect of Casting Density on the Heat of Hydration

3.1.1. Changes in the Temperature for Different Casting times.

Figure 5 shows the relationship between the temperatures and the casting time for three casting densities in different

FIGURE 4: The constant temperature and humidity box.

positions. The results show that the temperatures first increase and then decrease with the increase in the casting time for all positions, and all three densities of the foamed concrete and peaks are observed for each curve. For the foamed concrete with the casting densities of 400 kg/m^3 , 700 kg/m^3 , and 1000 kg/m^3 , the peak temperatures in position 1 are at 62.33°C , 81.03°C , and 94.27°C , respectively, and the corresponding times are 16 h, 15 h, and 16 h, respectively. For position 2, the peak temperatures are 59.74°C , 71.68°C , and 82.33°C , respectively and the corresponding times are 12 h, 14 h, and 15 h, respectively. For position 3, the peak temperatures are 35.59°C , 41.30°C , and 49.09°C and the

FIGURE 5: Relationship between temperatures and casting time (pure cement). Note: 400-1 denotes the value of the test with a casting density of 400 kg/m³ in position 1.

corresponding time is 14 h for the three densities. For the same position, the peak temperature increases with the increase in the casting density of the foamed concrete. For the same casting density, the peak temperature is highest for position 1 followed by position 2 and position 3, and the corresponding times are different. This indicates that there is a heat exchange between the surface of the foamed concrete and the surrounding air.

3.1.2. Temperature Change Rate as a Function of the Casting Time. The relationship between the temperatures change rate and the casting time for the three casting densities in position 1 is shown in Figure 6. For the foamed concrete with a casting density of 400 kg/m³, the temperature change rate reaches the maximum value of 7.5°C/h at a casting time of 10.5 h. For the casting densities of 700 kg/m³ and 1000 kg/m³, the maximum values of the temperature change rate are 11.7°C/h and 14.3°C/h, respectively, at a casting time of 9.5 h. The maximum value of the temperature change rate increases, and the corresponding casting time decreases with the increase in the casting density. For the three casting densities of foamed concrete, the values of the temperature change rates are below 0 at casting times longer than 15-16 h, and the values remain stable when the casting time exceeds 20 h. The temperature change rate is highest for the casting density of 400 kg/m³, followed by the casting densities of 700 kg/m³ and 1000 kg/m³; therefore, the temperature attenuation increases with the increase in the casting density. In general, the temperature change rate increases before reaching the peak and the rate of temperature attenuation after the temperature peak increases with the increase in the casting density.

3.1.3. Relationship between the Temperature Difference and the Casting Time. The relationship between the temperature difference and the casting time for the three casting densities

FIGURE 6: Relationship between the temperature change rate and the casting time (pure cement; #1).

is shown in Figure 7. For the foamed concrete with the casting densities of 400 kg/m³, 700 kg/m³, and 1000 kg/m³, the maximum temperature differences ΔT_1 are 8.05°C, 10.65°C, and 12.46°C and the corresponding casting times are 21 h, 20 h, and 17 h. The temperature differences ΔT_1 first decrease and then increase to the maximum value for all the densities. After that, the values decrease slowly. For the temperature difference ΔT_2 at the casting densities of 400 kg/m³, 700 kg/m³, and 1000 kg/m³, the maximum values are 27.53°C, 33.50°C, and 39.21°C and the corresponding casting times are 11 h, 17 h, and 20 h. This indicates that for the temperature difference ΔT_2 , the maximum values of the temperature difference increase, and the corresponding casting times increase with the increase in the casting density.

3.2. Effect of Fly Ash Content on the Heat of Hydration

3.2.1. Changes in the Temperature for Different Casting Times. Figure 8 shows the relationship between the temperature and the casting time of the foamed concrete with different fly ash contents. The relationship is similar for the same casting density with different fly ash contents in the same position. For the foamed concrete with the casting density of 700 kg/m³ in position 1, at a fly ash content of 0%, 10%, 30%, and 50%, the peak temperatures are 81.03°C, 74.28°C, 63.11°C, and 53.24°C and the corresponding casting times are 15 h, 17 h, 20 h, and 24 h, respectively. For position 2, at a fly ash content of 0%, 10%, 30%, and 50%, the peak temperatures are 71.68°C, 66.75°C, 58.18°C, and 45.97°C and the corresponding casting times are 14 h, 16 h, 18 h, and 27 h, respectively. For position 3, at a fly ash content of 0%, 10%, 30%, and 50%, the peak temperatures are 41.30°C, 38.70°C, 35.07°C, and 33.77°C and the corresponding casting times are 14 h, 14 h, 29 h, and 28 h, respectively. The results show that the peak temperature decreases, and the corresponding casting time increases with the increase in the fly ash content for the same casting density in the same position.

FIGURE 7: Relationship between the temperature difference and the casting time (pure cement).

FIGURE 8: Relationship between temperature and casting time (containing fly ash). Note: 0%-1 denotes the value when the fly ash content is 0% in position 1.

3.2.2. Temperature Change Rate as a Function of the Casting Time. The relationship between the temperature change rate and the casting time of the foamed concrete with different fly ash contents in position 1 is shown in Figure 9. At fly ash contents of 0%, 10%, 30%, and 50%, the maximum values of the temperature change rate are 11.68°C/h, 9.09°C/h, 5.97°C/h, and 4.12°C/h and the corresponding casting times are 9.3 h, 10.5 h, 13.5 h, and 14.5 h. The maximum value of the temperature change rate increases, and the corresponding time increases with the increase in the fly ash content. When the value of the temperature change rate is stable, the value increases with the increase in the fly ash content, indicating that the temperature attenuates slowly for the foamed concrete with high fly ash content.

3.2.3. Relationship between the Temperature Difference and the Casting Time. Figure 10 shows the relationship between

FIGURE 9: Relationship between temperature change rate and casting time (containing fly ash; #1).

FIGURE 10: Relationship between the temperature difference and the casting time (containing fly ash).

the temperature difference and the casting time with different fly ash contents. At fly ash contents of 0%, 10%, 30%, and 50%, the maximum temperature differences $\Delta T1$ are 10.65°C, 10.91°C, 9.35°C, and 7.79°C and the corresponding casting times are 20 h, 22 h, 25 h, and 32 h. After reaching the maximum temperature difference, the values decrease more slowly with the increase in the fly ash content. At fly ash contents of 0%, 10%, 30%, and 50%, the maximum temperature differences $\Delta T2$ are 33.50°C, 30.38°C, 25.19°C, and 18.17°C and the corresponding casting times are 17 h, 16 h, 18 h, and 17 h. In conclusion, the maximum temperature difference increases for the same position for the same casting density with the increase in the fly ash content.

3.3. Effect of Curing Conditions on the Strength Development. Figure 11 shows the relationship between the compressive strength and the curing time for three casting densities. For the foamed concrete with the casting densities of 400 kg/m³,

FIGURE 11: Relationship between compressive strength and curing time (pure cement). Note: 400 s denotes the value with the casting density of 400 kg/m³ under standard curing conditions. 400 m denotes the value with the casting density of 400 kg/m³ under temperature matched curing conditions.

700 kg/m³, and 1000 kg/m³ under standard curing conditions, the compressive strength values are 0.065 MPa, 0.248 MPa, and 0.912 MPa, respectively, for a curing time of 1 d and the compressive strength values are 0.513 MPa, 1.552 MPa, and 3.981 MPa, respectively, when the curing time is 7 d. Under temperature matched curing conditions, the compressive strength values are 0.216 MPa, 0.855 MPa, and 2.157 MPa, respectively, for a curing time of 1 d and 0.509 MPa, 1.883 MPa, and 4.279 MPa, respectively, for a curing time of 7 d. The comparative analysis shows that the early strength of the foamed concrete is higher under temperature matched curing conditions for the same casting density, and the improvement decreases with the increase in the curing time. For the foamed concrete with casting densities of 400 kg/m³, 700 kg/m³, and 1000 kg/m³ and a curing time of 28 d, the compressive strength values are 0.654 MPa, 2.359 MPa, and 5.357 MPa, respectively, under standard curing conditions and 0.535 MPa, 1.959 MPa, and 4.495 MPa, respectively, under temperature matched conditions; the compressive strength values under temperature matched conditions are 81.8%, 83.0%, and 83.9%, respectively, of the values under standard curing conditions. Therefore, when the foamed concrete is mixed without the admixture, there is a promoting effect of the temperature matched conditions on the strength development in the early stage and an inhibition effect in the later stage.

The relationship between the compressive strength and the curing time with different fly ash contents is shown in Figure 12. For the foamed concrete with the casting density of 700 kg/m³ and fly ash contents of 0%, 10%, 30%, and 50% at curing times of 1 d, 3 d, and 7 d, the compressive strength values are larger for the temperature matched curing conditions than the standard curing conditions. For the foamed concrete with a casting density of 700 kg/m³ and fly ash contents of 0%, 10%, 30%, and 50% at a curing time of 28 d, the compressive strength values are 2.359 MPa, 2.250 MPa,

FIGURE 12: Relationship between compressive strength and curing time (containing fly ash). Note: 0% s denotes the value of the test when the fly ash content is 0% under standard curing conditions. 0% m denotes the value of the test when the fly ash content is 0% under temperature matched curing conditions.

1.813 MPa, and 1.648 MPa, respectively, under standard curing conditions and 1.959 MPa, 1.991 MPa, 1.943 MPa, and 1.777 MPa respectively, under temperature matched conditions and the latter values are 83.0%, 88.5%, 107.2%, and 107.8%, respectively, of the compressive strength values under standard curing conditions. The ratio increases with the increase in the fly ash content. The results show that the temperature matched condition has a promoting effect on the strength development in the later stage with the addition of the fly ash, and this effect is not observed for the standard curing condition. The higher the fly ash content, the more obvious the effect.

Studies have shown that there are more hydration products during the early stage and fewer hydration products during the later stage in the temperature matched conditions compared with the standard curing conditions for pure cement [26, 27]. This results in early strength increases and later strength decreases. The main reason is that high temperatures promote the hydration of the cement particles during the early stage, whereas the hydration products cover the surface of the cement particles and inhibit the hydration reaction during the later stage. For the foamed concrete with the fly ash under temperature matched conditions, the hydration reaction of the cement and the pozzolanic reaction of the fly ash are enhanced; the surface of the fly ash particles experience etching, the content of the gelling material increases, and the structure becomes denser (Figure 13).

In summary, when the casting density ranged from 400 kg/m³ to 1000 kg/m³ and no fly ash was used, the difference between the internal and external temperature of the cast-in-situ foamed concrete was significantly higher than 25°C, which does not meet the requirements of the standard for the construction of mass concrete. When the casting density was 700 kg/m³ and the fly ash content was 30%, the temperatures met the

FIGURE 13: The SEM photographs of foamed concrete structures (28 d): (a) standard curing conditions (pure cement), (b) temperature-matched curing conditions (pure cement), (c) standard curing conditions (containing fly ash), and (d) temperature-matched curing conditions (containing fly ash).

requirements of the standard for the construction of mass concrete. Therefore, it is necessary to consider field conditions and add a fly ash admixture or develop a system to contain moisture to meet the requirements.

4. Field Test

4.1. Introduction to Field Tests. The field tests consisted of four projects, and the details of the projects are shown in Table 2. Figure 14 shows an overview of the test sites. For project 3, the water was tap water, and for the other projects, the water was drawn from the rivers using pumps. The casting temperature was adjusted using water. The layouts of the components in the four projects are shown in Figure 15. For project 1, the height was 0.8 m and this distance was divided into two layers of 0.4 m. Because the base was rough, the foamed concrete was cast with a thickness of 0.1 m. For the other projects, the height exceeded 1.5 m. The three bottom layers were tested and each layer was 0.5 m. The bases were identical for projects 2, 3, and 4, and the gravel layer was used for drainage, and a geomembrane was used to separate the water.

4.2. Results of Field Tests. Figure 16 shows the relationships between the temperatures at the eight positions and the casting times for the four projects. For project 1, at a casting temperature of about 13°C, the maximum temperature increments are 48.95°C and 54.77°C for positions 2 and 5, respectively, and the corresponding casting times are 17.5 h

and 17 h. For project 2, at a casting temperature of about 22.5°C, the maximum temperature increments are 41.46°C, 45.00°C, and 47.76°C for the positions 2, 5, and 7, respectively, and the corresponding casting times are 17.5 h, 17 h, and 16 h. For project 3, at a casting temperature of about 21°C, the maximum temperature increments are 43.25°C, 47.14°C, and 50.02°C for the positions 2, 5, and 7, respectively, and the corresponding casting times are 17.1 h, 16.2 h, and 14 h. For project 4, at a casting temperature of about 30°C, the maximum temperature increments are 28.23°C and 29.79°C for positions 2 and 5, respectively, and the corresponding casting times are 17 h and 16.5 h. For position 7, the maximum temperature increment is 31.51°C, and the corresponding casting time is 20.8 h at a casting temperature of about 27°C. It is observed that when the upper layer is cast, the maximum temperature increment increases and the corresponding casting time decrease due to the heat transfer from the lower layer. For the four projects, the temperatures in position 1 at the bottom of the foamed concrete structures first increase with the casting times, reach the maximums, and then decrease slowly and stabilize. This occurs because of the contact with the lower layers. Due to the 0.1 m thickness of the foamed concrete layer, the stable temperature is high for project 1. A comparison of the temperatures at positions 3, 4, and 5 indicates that the temperatures of the second layers of the foamed concrete are affected by the first layers. They absorb heat during the early stage and release heat during the later stage.

Compared with projects 2, 3, and the indoor model tests, the results of project 4 show that reasonable cooling

TABLE 2: Details of the projects.

Project	Design casting density (kg/m ³)	Measured casting density (kg/m ³)	Mix proportions (/m ³)	Construction location	Weather
1	1000	1018.5, 1011.1	C : F : W : A = 640 : 0 : 346 : 448	Zigong city, Sichuan province	Wind speed: 1–3 Humidity: 78–80%
2	650	651.4, 656.7, 654.2	C : F : W : A = 405 : 0 : 223 : 647	Chengdu city, Sichuan province	Wind speed: 1–3 Humidity: 83–86%
3	670	657.8, 663.5, 675.6	C : F : W : A = 420 : 0 : 231 : 634	Huai'an city, Jiangsu province	Wind speed: 1–3 Humidity: 69–71%
4	700	702.1, 721.5, 694.8	C : F : W : A = 308 : 132 : 246 : 602	Guiyang city, Guizhou province	Wind speed: 0–4 Humidity: 61–81%

Note: C : F : W : A = cement (kg) : fly ash (kg) : water (kg) : air bubbles (l).

FIGURE 14: Overview of the test sites: (a) project 1 (fill on the top of the arch bridge), (b) project 2 (backfill behind the wall), (c) project 3 (widening of expressway), and (d) project 4 (backfill of high-speed station).

measures and the addition of fly ash decrease the maximum temperature increments and increase the corresponding casting times. When it rains, the foamed concrete structure is affected because the permeability coefficient of the foamed

concrete is large and water can penetrate into the foamed concrete [25]. However, the upper layer is more affected than the internal portion. A large temperature difference between the internal and external portions of the structure

FIGURE 15: Layout of the components in (a) project 1 and (b) projects 2, 3, and 4.

FIGURE 16: Continued.

FIGURE 16: Relationship between temperatures and casting time: (a) project 1, (b) project 2, (c) project 3, and (d) project 4.

FIGURE 17: Crack fractures caused by the shower in project 4.

may cause numerous crack fractures (Figure 17) and reduces the quality of the project; therefore, rain or sudden cooling should be avoided.

The maximum temperature increments are higher for the indoor model test than the field test for the same casting density (Figure 18), but the corresponding casting times are similar. This is caused by the contact of the upper layer with the air and the heat transfer of the lower layer. The temperature decreases more slowly in the middle layer. Taking into account the results of the compressive strength tests under different curing conditions, this indicates that the strength should be reduced or the mix proportions should be improved. The maximum temperature increment is affected by the casting density, the fly ash content, and external influencing factors (wind speed, casting temperature, etc.). An experimental equation may be put forward in future studies when a larger dataset will be used.

FIGURE 18: Maximum temperature increments of the foamed concrete. Note: 700-10%-i denotes the value with a casting density of 700 kg/m³ with 10% content of fly ash and the indoor model test. 700-10%-f denotes the value with the casting density of 700 kg/m³ with 10% content of fly ash and the field test.

5. Conclusion

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

- (1) For the foamed concrete with the casting densities of 400 kg/m³, 700 kg/m³, and 1000 kg/m³, the peak temperatures are 62.33°C, 81.03°C, and 94.27°C, respectively, and the maximum values of the temperature change rate are 7.5°C/h, 11.7°C/h, and 14.3°C/h in position 1. The peak temperature, the maximum temperature change rate, and the maximum temperature difference increase with an

increase in the casting density at different positions in the foamed concrete.

- (2) For the foamed 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.
- (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 foamed 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.

Data Availability

The data in this article allow researchers to verify the results, replicate the analysis, and conduct secondary analyses.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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