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(Research Article)

Comparative analysis of time dependent temperature profiles of hydrating mass concretes of different mix ratios

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Abstract

In mass concrete, heat due to cement hydration in most cases is not easily released and is otherwise confined within its core. Consequently, mass concrete may exhibit quite remarkable increase in temperatures internally depending on majorly the vicinity temperature and the proportion of cement in mixture ratio. When the surface tensile stresses resulting from temperature difference between its core and surface exceeds the strength of the concrete, cracks could develop at the surface. Two mass concrete blocks of dimensions 1.10 m × 1.10 m × 1.10 m each and mixes of 1: 2: 4 and 1: 3: 6 with constant water cement ratio (w/c) of 0.60 were used in the study. Type-K thermocouples were used to monitor the temperature variance in mass concretes. BK Precision 710 temperature meter dual input was used to determine the temperature readings at time intervals. Thermometer was used to measure the environment temperatures within the vicinity of the mass concretes. Generally, the trends of the temperature profiles exhibit an initial uniform temperature which rises to peak values at 24 hours of concrete placement and then declined to constant temperature at mostly 120 hours and beyond. The sole source of heat in hydrating concrete is the cement paste, and higher cement content leads to higher quantity of heat release. Therefore, the mass concrete block of mix ratio 1:2:4 exhibited higher quantity of heat release than that of 1:3:6 especially at the core.

Keywords: Temperature; Time; Mass Concretes; Hydration and Mix Ratios

1. Introduction

Internal restraint occurs when heat is lost to the immediate vicinity from the surface of concrete, leading to temperature gradients between the hotter center (core) and the cooler concrete's surface. As a corollary, uneven thermal expansivity between the core and the surface will be experienced. Restraint to free expansion will lead to stresses, compressive at the core and tensile on the surface. Whenever the tensile stress at the surface of the mass concrete which is a result of expansion at the center (core), becomes greater than the tensile strength of the concrete, surface cracks will ensue. Concrete members whose dimensions are such that their behaviour when exposed to heat could lead to cracks unless appropriate preventive measures are devised are called mass concretes [1, 2]. Cracks occurrence could lead to durability concerns and defects on the life-cycle performance requirements of such mass concrete members [3]. Cracks may lead to rust due to the chance of chloride ions from highly saline waters percolating into the reinforcement steel through the cracks [4, 5]. When cracking in concretes exceed a limiting critical crack width value, it becomes a worry since the durability, serviceability and appearance of the structure become impaired [6].

In cases whereby the mass concretes exhibit temperatures in excess of 55^{0}C to 70^{0}C, the durability and service life requirement of such concretes could be significantly impaired [7-9]. The major objective of temperature control shall be to achieve a batching temperature such that in relation to vicinity temperatures may not lead to excessive rise in the quantity of heat released by the mass concrete. The hydration of cement blended with cementitious materials results

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to endogenous heat, and the temperature array of mass concretes reduces when the amount of cement is lowered by replacing with supplementary cementitious materials namely, fly ash, slag or silica fume [10, 11]. System of pipes could be embedded, pre-cooling of the ingredients of concrete and the use of low-heat Portland cement are also measures to control the temperature during hydration. The core objective of the paper is to conduct a comparative analysis of the temperature profiles of mass concretes at time intervals with varying mix ratios.

2. Materials and Methods

Two mass concrete blocks of dimensions 1.10m × 1.10m × 1.10m each and mixes of 1: 2: 4 and 1: 3: 6 with constant water cement ratio (w/c) of 0.60 were used in the study. All concrete mixes consist of ordinary Portland cement (Unicem Brand) as the only cementitious material. Type-K thermocouples were used to monitor the temperature variance in mass concretes. BK Precision 710 temperature meter dual input was used to determine the temperature readings at time intervals. Thermometer was used to measure the environment temperatures within the vicinity of the mass concretes. The thermocouples were placed in mass concretes to monitor the temperature variance as shown in Figure 1. For purposes of the study, the temperature readings from the thermocouple locations TC1, TC4, TC7 and TC10 were employed.

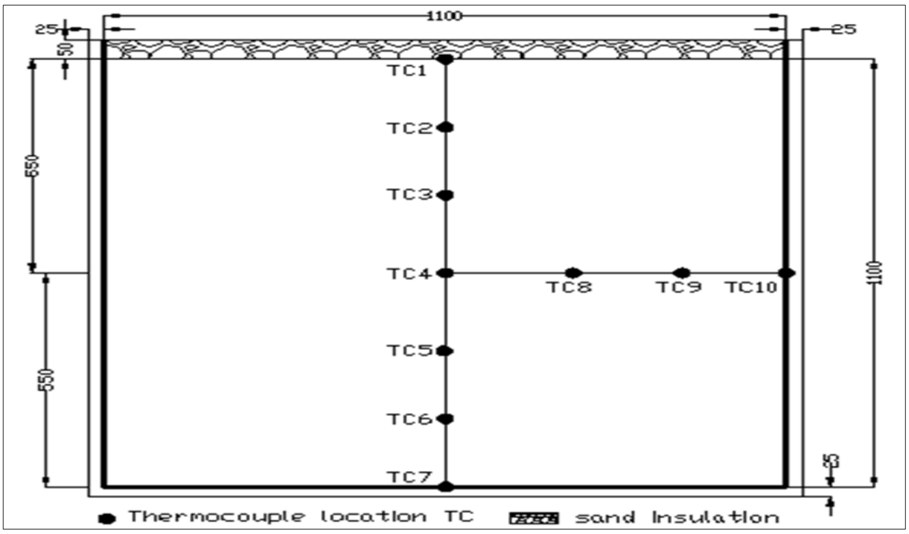

Figure 1 Thermocouples locations (dimensions in mm)

Type-K thermocouples and digital thermometer as shown in Figure 2 were used to monitor the temperatures in mass concretes at time intervals. The cast mass concretes with the embedded thermocouples placed centrally for the two mixes of 1:2:4 and 1:3:6 is as shown in Figures 3 and 4.

Figure 2 Thermometer and Type-K thermocouple.

Figure 3 Cast concrete block with the thermocouples (mix 1:2:4).

Figure 4 Cast concrete block with the thermocouples (mix 1:3:6).

3. Results

The temperature distribution of the mass concrete blocks with respect to time at the various thermocouple locations are as shown in Figures 5 to 8. The zero-hour temperature signifies the temperature in mass concretes after placing which was found to be uniform throughout the various thermocouple positions at 28^0C. TC1 and TC7 signifies the thermocouples located at the top and bottom surfaces, TC10 is located at the side surface and TC4 is located at the center (core) of the mass concrete blocks. Generally, the trends of the temperature profiles exhibit an initial uniform temperature which rises to peak values at 24 hours of concrete placement and then declined to constant temperature of 32^0C at mostly 120 hours and beyond.

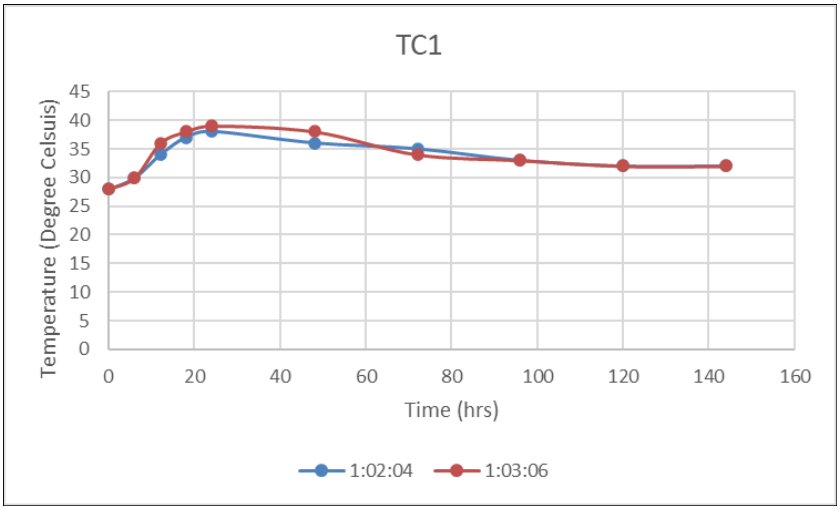

Figure 5 Temperature-time graphs at the top surface

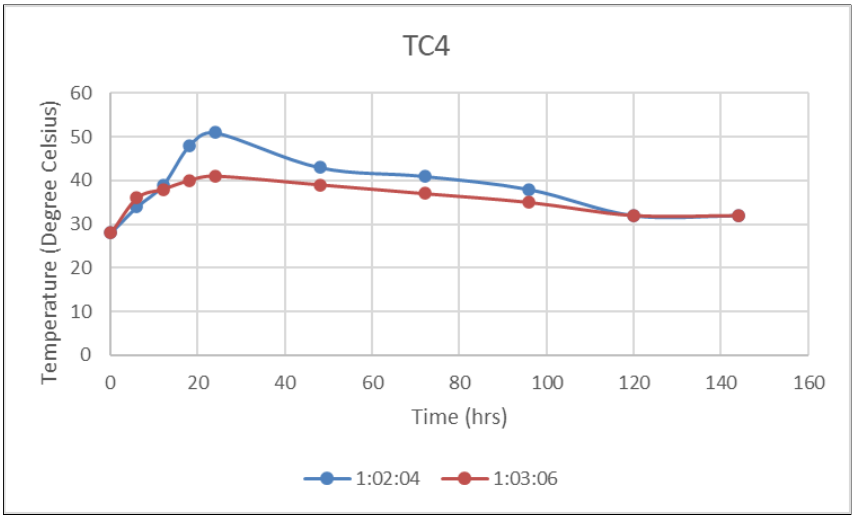

Figure 6 Temperature-time graphs at the center (core)

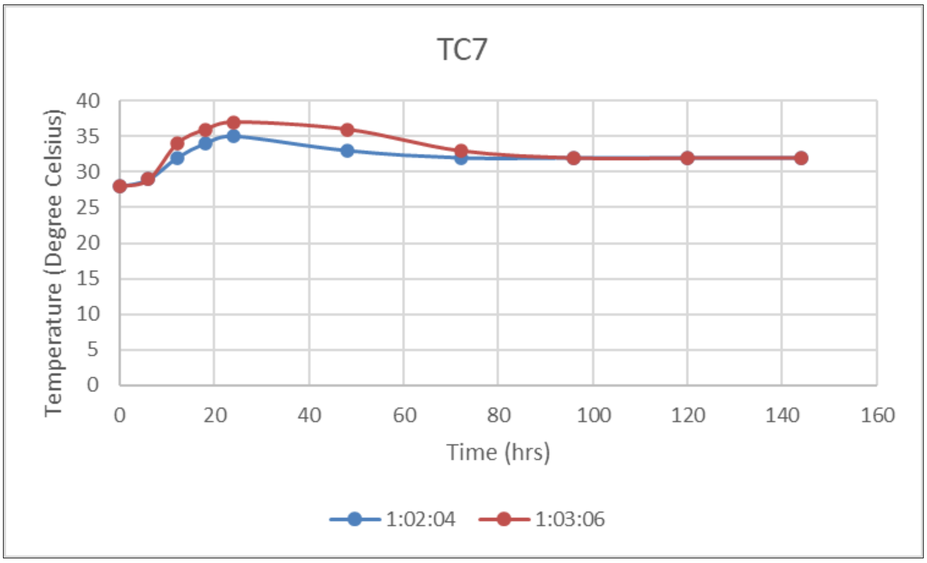

Figure 7 Temperature-time graphs at the bottom surface

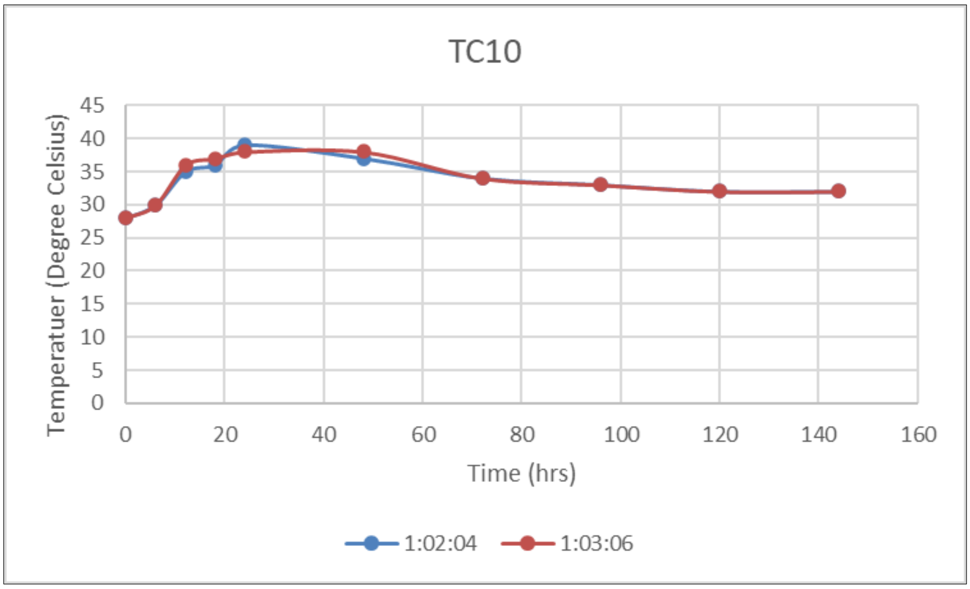

Figure 8 Temperature-time graphs at the side surface

At the top surface, the mass concrete blocks had fairly uniform temperature values at most of the time intervals. However, the bock of mix ratio 1:3:6 had higher temperature values at 12 hours up till 48 hours of concrete placement. At the center (core), the mass concrete block of mix ratio 1:2:4 generally had higher temperature values at 12 hours up till 96 hours of concrete placement. At the bottom surface, the mass concrete block of mix ratio 1:3:6 had higher temperature values at 12 hours up till 72 hours of concrete placement. At the side surface, both mass concrete blocks had fairly uniform temperatures at the various time intervals.

4. Conclusion

Generally, the surface of the mass concrete block cast with mix ratio 1:3:6 had relatively higher temperature values than that of 1:2:4 even though the latter had higher proportion of cement. This could be attributable to the complex nature of heat conduction both between the core and the surface and also between the surface and the ambient environment. The sole source of heat in hydrating concrete is the cement paste, and higher cement content leads to higher quantity of heat release. Therefore, the mass concrete block of mix ratio 1:2:4 would naturally exhibit higher quantity of heat release than that of 1:3:6 especially at the center (core). The core of the mass concrete generally had highest temperatures than the rest of the thermocouple locations with the highest temperature occurring at 24 hours after concrete placement.

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