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Test study on hydration temperature of compound concrete made of demolished concrete lumps and fresh concrete

一Bo Wu[a], DaoZhong Wu[a]

[a]State Key Laboratory of Subtropical Building Science, South China Univ. of Technology, Guangzhou 510640, P. R. of China

Abstract

Twelve 300 mm cubes and four 1000 mm cubes made of demolished concrete lumps (DCLs) and fresh self-compacting concrete (FSCC) were manufactured, and hydration temperatures of these cubes were measured during the first seven days after casting. The influence of replacement ratio of DCLs (0, 20%, 25%, and 30%) on hydration temperature of the compound concrete containing DCLs is examined. It is found that the using of DCLs is an effective way to reduce the hydration temperature in concrete mix, and such temperature decreases gradually with the increasing of the replacement ratio; the maximum hydration temperature of the 1000 mm cube with a replacement ratio of 30% is only 84.5% of that of the 1000 mm cube made of FSCC alone.

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Keywords: demolished concrete lumps (DCLs); hydration temperature; replacement ratio of DCLs

1. Introduction

Recycling and reusing of waste concrete has been a global focus of research in recent years, and is motivated by the increasing severity of environmental degradation and resource depletion. Nowadays, landfill is the main way to deal with large amount of waste concrete, which causes some negative influences on the environment. Recycled aggregate concrete is another effective way to cope with waste concrete, but energy- and time-consumption in the

* Corresponding author. Tel.: +86-130-0204-5156
E-mail address: bowu@scut.edu.cn

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production of recycled aggregates are great, meanwhile the amount of fresh cement employed in recycled aggregate concrete cannot be reduced, as compared with natural aggregate concrete. Different from the aforementioned practices, demolished concrete lumps (DCLs) with distinctly larger size (e.g., 60 mm~300 mm) than recycled aggregates have been directly employed in structural members by the authors [1-3], and mechanical properties of the compound concrete made of DCLs and fresh concrete have been experimentally investigated in the past several years [4-6]. Obviously, manufacturing process of DCLs is simpler than that of coarse and fine recycled aggregates, resulting in less energy and time consumption. On the other hand, a great deal of old cement in DCLs can be reused in the compound concrete.

Hydration of mass concrete usually generates a lot of heat, which causes concrete cracking seriously. Because reusing of DCLs not only reduces the amount of fresh cement in the compound concrete, but also absorbs some hydration heat, it is possible to reduce the hydration temperature in mass concrete by using of DCLs. The purpose of this study is to experimentally verify this issue.

2. Experiment program

2.1 Preparation of specimens

Nine 300 mm cubes and three 1000 mm cubes made of DCLs and fresh self-compacting concrete (FSCC) were prepared, meanwhile three 300 mm cubes and one 1000 mm cube made of FSCC alone were cast as reference specimens. Three values (20%, 25%, and 30%) are considered for the replacement ratio of DCLs (i.e., a ratio of the weight of DCLs to the total weight of specimen). Details of the specimens are listed in Table 1.

Table 1 Parameters of specimens

Notation	Length of cube / mm	Replacement ratio of DCLs (η)	Number of specimens
CU300	300	0	3
CU300-0.2	300	20%	3
CU300-0.25	300	25%	3
CU300-0.3	300	30%	3
CU1000	1000	0	1
CU1000-0.2	1000	20%	1
CU1000-0.25	1000	25%	1
CU1000-0.3	1000	30%	1

DCLs with a characteristic size of 100 mm~120 mm (Fig. 1) were made by breaking two waste support beams, which were obtained from a demolition site in Guangzhou city, into lumps. Cylinders with a diameter of 80 mm and a height of 80 mm were drilled from the waste beams, and were axially loaded to obtain the compressive strength of the waste concrete. The equivalent 150 mm cubic compressive strength of DCLs was 41.0 MPa. FSCC was from a same batch of commercial self-compacting concrete, and its mix proportion is shown in Table 2.

Fig. 1 Demolished concrete lumps (DCLs)

Table 2 Mix proportion of fresh self-compacting concrete (FSCC)

Material / (kg·m^{-3})					
Water	Cement	Sand	Coarse aggregate	Fly ash	Water reducer
173	355	685	1027	110	6.04

All the DCLs were fully wetted by using tap water just before concrete pouring. During casting of the specimens, DCLs and FSCC were placed into the mold alternately. Meanwhile, a pocket vibrator was used to guarantee the compactness of the concrete mixture (Fig. 2).

300 mm cubic specimen 1000 mm cubic specimen

Fig. 2 Casting of specimens

2.2 Measuring devices

Two thermocouples were installed in each 300 mm cube (Fig. 3) to measure the hydration temperature during the first seven curing days. To this end, the wood mold of each specimen was insulated by using polystyrene insulating layer with a thickness of about 100 mm, as soon as concrete casting was over[7-10] (Fig. 4 & Fig. 5).

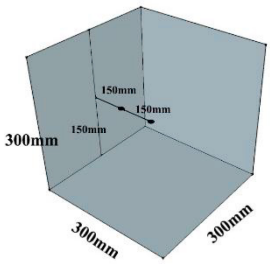


Fig. 3 Locations of thermal couples in 300 mm cube

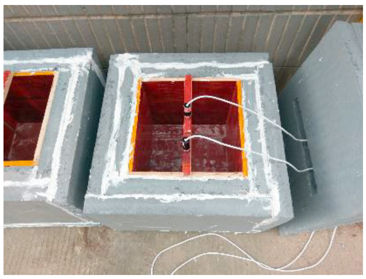
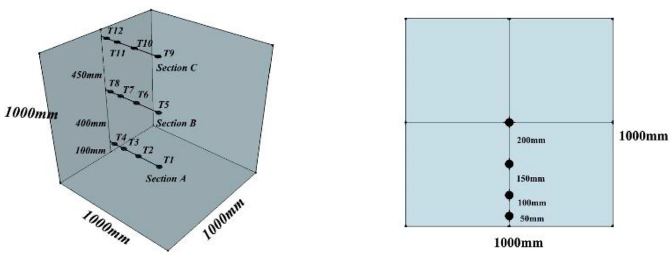


Fig. 4 Polystyrene insulating layer

Fig. 5 Insulated 300 mm cube

Twelve thermocouples were installed in each 1000 mm cube (Fig. 6) to measure the hydration temperature of mass compound concrete during the first seven days after casting[11].



(a) 3-dimensional diagram (b) Locations on Sections A, B and C

Fig. 6 Locations of thermal couples in 1000 mm cube

3. Test results and discussions

3.1 Temperature-time curves related to 300 mm cubes

Fig. 7 shows the measured temperature-time curves at the center of the insulated 300 mm cubes. In this figure, the temperature is a mean value of the recorded temperatures of three specimens with the same replacement ratio of DCLs. It can be seen that the maximum temperature of the cube made of FSCC alone is 55.5℃, and the maximum temperatures of the cubes with the replacement ratios of 20%, 25% and 30% are, respectively, 51.5℃, 49.5℃ and 47.9℃. The maximum temperature of the cube with a replacement ratio of 30% is only 86.3% of that of the cube made of FSCC alone. Obviously, the using of DCLs reduces the hydration temperature in concrete mix, and such temperature decreases gradually with the increasing of the replacement ratio. This is attributed to less amount of fresh cement being employed in the specimens made of DCLs and FSCC, as compared with the specimens made of FSCC alone, and to the larger the replacement ratio, the less the fresh cement content in the cubes. On the other hand, the cool DCLs can absorb some hydration heat, this further resulting in lower maximum temperature.

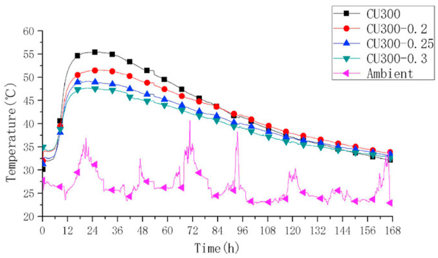


Fig. 7 Measured temperature-time curves pertaining to insulated 300 mm cubes

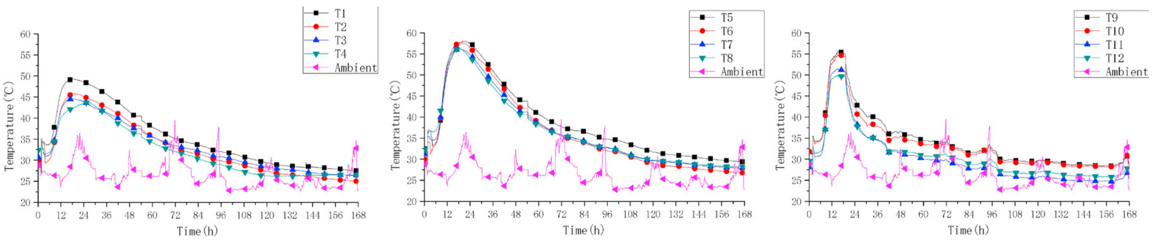
3.2 Temperature-time curves related to 1000 mm cubes

The measured temperature-time curves related to four 1000 mm cubes are shown in Figs. 8~11. It is found that:

(a) For any given specimen, the maximum temperature always occurs at the center of Section B (i.e., the center of the cube);

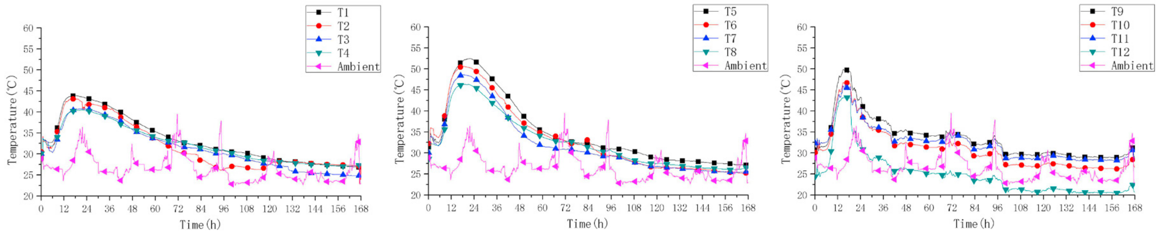
(b) The influence of environmental temperature on the measured temperatures of Section C is more obvious, as compared with Section A and Section B, due to the distance between Section C and the surface of the cube being the smallest (i.e., 50 mm); and

(c) The maximum temperatures of the four specimens with the replacement ratios of 0, 20%, 25% and 30% are, respectively, 58.0℃, 52.6℃, 50.9℃ and 49.0℃. Again it can be concluded that the using of DCLs reduces the hydration temperature greatly, and such temperature decreases gradually as the replacement ratio of DCLs increases. The maximum temperature of the cube with a replacement ratio of 30% is only 84.5% of the maximum temperature of the cube made of FSCC alone. This is attributed to both the heat absorbing effect of DCLs and less amount of fresh cement being used in the compound concrete.



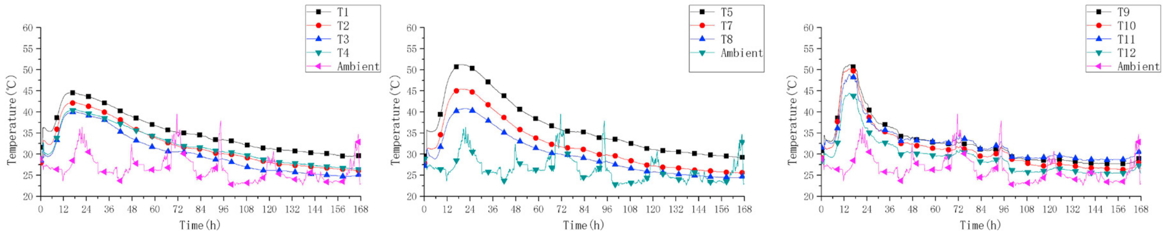
Section A Section B Section C

Fig. 8 Measured temperature-time curves pertaining to 1000 mm cube made of FSCC alone



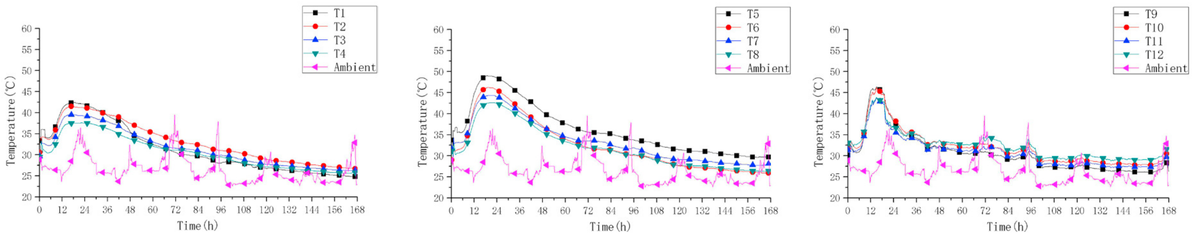
Section A Section B Section C

Fig. 9 Measured temperature-time curves pertaining to 1000 mm cube with a replacement ratio of 20%



Section A Section B Section C

Fig. 10 Measured temperature-time curves pertaining to 1000 mm cube with a replacement ratio of 25%



Section A Section B Section C

Fig. 11 Measured temperature-time curves pertaining to 1000 mm cube with a replacement ratio of 30%

4. Conclusions

Based on the experimental study conducted in this paper, the following conclusions can be drawn:

(1) For mass concrete which is seriously cracked due to excessive hydration heat, the using of DCLs is an effective way to reduce the hydration temperature in concrete, and such temperature decreases gradually with the increasing of the replacement ratio;

(2) When the replacement ratio of DCLs is 30%, the maximum hydration temperature of the 1000 mm compound concrete cube is only 84.5% of the maximum temperature of the 1000 mm cube made of FSCC alone; and

(3) The influence of environmental temperature on the hydration temperatures of a cross section close to the cube's surface is relatively obvious.

Acknowledgements

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