Construction and Building Materials 23 (2009) 1240–1248

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Effect of high temperature and cooling conditions on aerated concrete properties

Leyla Tanaçan [a,*], Halit Yaşa Ersoy [b], Ümit Arpacıoğlu [b]

[a] Istanbul Technical University, Faculty of Architecture, Taskisla, Taksim 34437, Istanbul-TR, Turkey
[b] Mimar Sinan University of Fine Arts, Faculty of Architecture, Fındıklı 80040, Istanbul-TR, Turkey

ARTICLE INFO

Article history:
Received 19 July 2007
Received in revised form 2 August 2008
Accepted 4 August 2008
Available online 18 September 2008

Keywords:
Aerated concrete
High temperature
Fire
Young's modulus of elasticity
Compressive strength
Splitting strength

ABSTRACT

In this study, effect of elevated temperatures and various cooling regimes on the properties of aerated concrete is investigated. Air cooled materials are tested at room temperature and in hot condition right after the fire. Water quenching effect is determined by testing the material in wet condition right after the quenching and in dry condition at room temperature. Unstressed strength of the material tested hot is relatively higher than air cooled unstressed residual strength up to 600 °C. On the other hand, water quenching decreases the percentage of the strength particularly when the material is wet right after the quenching; strength is lost gradually as the temperature rises. As a result, if the quenching effect is disregarded, temperature rise does not have a considerable effect on the strength of the aerated concrete approximately up to 700–800 °C. It is able to maintain its volumetric stability as well. However, more care needs to be taken in terms of its use above 800 °C for fire safety.

© 2008 Elsevier Ltd. All rights reserved.

1. Introduction

Concrete is an inorganic material and high temperature and its duration decrease the concrete strength and its durability. Fire resistance of concrete is primarily affected by factors like the temperature, duration and condition (multiple or one-way effect-direct flame contact-hot gas or radiation) of the fire. The type of aggregate and cement used in its composition, the porosity and moisture content of concrete, its thermal properties, and sizes of structure members and their construction type are the other factors that determine the level of fire resistivity of the material. An increase in the size of structural members increases fire resistance. As a two phase composite material, the behavior of the cement matrix in fire is more important than its dispersed phase. Fire resistance of aggregates is generally high.

To determine the resistance of concrete samples exposed to high temperature, there are three test methods available for finding the residual compressive strength of concrete at elevated temperatures: stressed test, unstressed test, and unstressed residual strength test. The first two types of the tests are suitable for accessing the strength of concrete during high temperatures, while the later is excellent for finding the residual properties after the high temperature. In the stressed test, specimens are restrained by a preload prior to and throughout the heating process. In the unstressed test, the specimens are heated without restraint. Both stressed and unstressed specimens are loaded to failure under uniaxial compression when the steady-state temperature is reached at the target temperature. The unstressed residual property test method is designed to provide property data of concrete at room temperature after exposure to elevated temperatures [1,2]. It was found that the last method gives the lowest strength and is therefore more suitable for getting the limiting values [3].

On the other hand, the type of cooling (in air and water) affects the residual compressive and flexural strength, the effect being more pronounced as the temperature increases [2]. According to Peng et al. the behavior of concrete under high temperature conditions more or less different from the standard fire condition. Residual mechanical properties reported in most previous literature might be overestimated, where natural cooling was usually employed. And proper evaluation of fire resistance of concrete needs more experimental data obtained under various cooling regimes such as water spraying or water quenching where they cause different stresses in reinforced concrete members at high temperature and the structural member can lose load bearing capacity [4].

The effect of high temperatures on the mechanical properties and durability of lightweight, normal, or high strength concrete have been investigated by many researchers in order achieve fire resistant material since the 1940s [3,5–7]. However, very few researches related to the fire resistance of cellular concrete have been carried out [8,9]. Aerated concrete in which air-voids are entrapped in the mortar matrix by means of a suitable aerating agent is produced from cement or lime, silica sand and sometimes pozzolanic materials and classified as lightweight concrete. Based on the method of pore-formation it is classified into three groups:

* Corresponding author. Tel.: +90 212 2931300x2211; fax: +90 212 2514895.
E-mail address: tanacan@itu.edu.tr (L. Tanaçan).

0950-0618/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.conbuildmat.2008.08.007

air-entraining method (gas concrete), foaming method (foamed concrete) and combined method. Aerated concrete can be non-autoclaved (NAAC) or autoclaved (AAC) based on the method of curing. The compressive strength, drying shrinkage, absorption properties etc. directly depend on the method and duration of curing. Once it is cured enough, the concrete foam is stripped from its mold, sliced into blocks or slabs of the required size. A wide range of densities (300–1800 kg/m^3) can be obtained thereby offering flexibility in manufacturing products for specific applications (structural, partition and insulation grades). Heat transfer through porous materials is affected by conduction, and at high temperatures, by radiation. The good fire resisting property of aerated concrete is where its closed pore structure pays rich dividends, as heat transfer through radiation is an inverse function of the number of air–solid interfaces traversed. The homogeneous character of the material and its low thermal conductivity and diffusivity suggest that cellular concretes might possess excellent fire resistance properties and hence its use does not involve any risk of spread of flames. In practice, fire resistance properties markedly superior to those of ordinary dense concrete where the presence of coarse aggregate leads to differential rates of expansion, cracking and disintegration [8,10].

However, although the material has lower thermal conductivity and thermal expansion coefficient than structural lightweight concrete which delays the effective temperature of the fire to reach it's core, under various cooling conditions this may cause big temperature differences in the section of the material and may destroy the material due to the diverse thermal expansions. The previous study conducted by the authors tested only the unstressed residual strength of the cellular concrete where natural cooling was applied [9].

Thus, the main objective of this research is to examine the unstressed residual and unstressed strength of the aerated concrete at elevated temperatures by considering the effect of various cooling regimes. In the tests, temperatures of 21, 100, 200, 400, 600, 800, and 965 °C were chosen for ease of observation of the test results. All series were exposed to same temperatures. Compressive and splitting strengths of the cellular concrete which were exposed to high temperatures and cooled differently (in air and in water) were compared with each other and then compared with the samples which were not heated.

2. Experimental study

Aerated concrete tested in the experimental study was provided directly by the manufacturer. The commercial name of the product is called G4. The material properties are given in Table 1 [11].

Tests were planned under two different cooling conditions: air cooled and water quenched. All the specimens were kept at room temperature (20–21 °C) and constant humidity (60 ± 0.05%R.H) until they reached equilibrium moisture and weight previous to heating. Then, they were placed into the oven without preload and were submitted to the selected heating regime up to reach a maximum of six temperatures until a thermal steady state was achieved: 100, 200, 400, 600, 800 and 965 °C. Oven was heated according to the time–temperature schedule of ASTM E 119-00 [12]. Afterwards, all the specimens were maintained in the oven for slow cooling down for 30 min. Before testing, G#1 series were allowed to cool in the desiccators to room temperature to avoid contact with the atmosphere and further up take of humidity. In G#2 series, load was applied to the hot specimen at a prescribed rate until failure occurs. G#3 and G#4 series were quenched in water at 22–23 °C for 30 s. In G#3 series load was applied right after the quenching when the material was wet. After the prescribed quenching time in water, G#4 series were kept in the etuve at 60 ± 5 °C for 24 h and later they were replaced into the desiccator until the equilibrium moisture content is reached prior to testing.

Table 1
Properties of the material used in the experimental study

G4 type aerated concrete		Physical properties	
Mechanical properties		Specific density (g/cm^3)	2.60
Modulus of elasticity (MoE) (kN/mm^2)	1.950–2.0	Unit weight (g/cm^3)	0.6
Compressive strength (N/mm^2)	~4	Pore Proportion (%)	75
Tensile strength (N/mm^2)	~0.5	Pore size (mm)	0.5–1.5
Flexural strength (MoR) (N/mm^2)	~0.7	Thermal conductivity (W/m K)	0.14
Shear strength (N/mm^2)	~1.1	Thermal expansion coefficient (m/m °C)	0.8×10^{-5}

The dimensions of the specimens were 50 × 50 × 50 mm and 40 × 40 × 160 mm. Each data point reflects the three test results. The weights of the specimens were measured by the scale of electronic PRECISA 4000C, which has a 10 kg capacity and 0.01 gr. precision. Ultrasound pulse velocity was determined by the CNS Electronic Ltd. PUNDIT non-destructive ultrasound equipment. The mechanical tests were done by the Amsler Type 6DB7F120 Hydraulic test equipment with capacity of 6–60 kN and by the Losenhausenwerk Hydraulic test equipment with capacity of 20–200 kN. NUVE MF100 oven was used to obtain high temperatures with the maximum capacity of 1000 °C and 1 °C precision and Hereaus etuve was used for drying water-quenched specimens with maximum capacity of 300 °C and ±5 °C precision.

The detailed sample compositions were coded using the format (# # # – *X* – *X*). The first coding group indicates the effective temperature (°C) the specimen submitted. The second letter shows the cooling type of the specimen which is (A) for air-cooled (G#1, G#2) samples and (W) for water quenched (G#3, G#4) samples. The third letter shows the condition of the sample when the load was applied. It is coded as (R), (H), (W) and (D) to indicate room temperature, hot, wet and dry conditions respectively. As an example, 400-A-R indicates the code of a specimen fired at 400 °C, air cooled and tested at room temperature.

While, volume, unit weight, ultrasound velocity, Young's Modulus of Elasticity (MoE) tests were done only on G#1 series; compressive and splitting strength tests were applied to all the series from G#1 to G#4. Splitting test results of G3 series were found not applicable to evaluate.

3. Results and discussion

The test results of the volume, unit weight, ultrasound velocity, and MoE of G#1 series before and after heating are given in Table 2 and the average compressive and splitting strength test results of G#1, G#2, G#3 and G#4 series are given in Table 3.

3.1. Effect of high temperatures on volume and unit weight

Relative changes observed in volume, length, weight and unit weight of the material as function of applied temperature is given in Fig. 1. The linear thermal expansion coefficient of aerated concrete is $\alpha = 8 \times 10^{-6}$ m/m °C. Accordingly, material expands initially, but shrinks relatively more than its original size depending on the applied temperature. The trend of the relational line is adjacent to the calculated theoretical values of linear and volumetric thermal expansion of the material until 200 °C which are also shown in the same figure. Dimensional changes directly affect the volume of the material. It gradually decreases between

Download English Version:

https://daneshyari.com/en/article/260284

Download Persian Version:

https://daneshyari.com/article/260284

Daneshyari.com