International Journal of Engineering & Technology, 7 (2.23) (2018) 99-102

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Determination of Bending and Axial Compression Young's Modulus of Cellular Mortar Exposed to High Temperatures

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Abstract

This paper focuses on laboratory investigation to scrutinize and portray the Young's modulus of cellular mortar exposed to high temperatures. Two densities of cellular mortar of 600 and 900 kg/m^3 density were cast and tested under axial compression and 3-point bending. The tests were performed at room temperature, 105°C, 205°C, 305°C, 405°C, 505°C, and 605°C. The results of this study consistently indicated that the loss in toughness for cement based material like cellular mortar exposed to high temperatures happens principally after 105°C, irrespective of density of cellular mortar. This specifies that the principal contrivance instigating stiffness deprivation is micro cracking in the cement matrix, which happens as water magnifies and disappears from the porous body. As projected, decreasing the density of cellular mortar diminishes its compressive strength and bending strength. Though, for cellular mortar of different densities, the normalized strength-temperature and Young's modulus-temperature relationships are comparable.

Keywords: *Bending; Cellular concrete; Compression; Elevated temperatures; Young's modulus*

1. Introduction

With speedy economic and construction sector, it leads to extraordinary mind-boggling demand on concrete base materials like cellular mortar in Malaysia [1]. These days, the cellular mortar had been mainly utilized for certain purposes like sound barrier component, semi-structural building components such as blocks, insulation element for the roof tiles, infill material for road backfill and others [2]. Figure 1 shows cellular mortar insulation screed was utilized to offer thermal guard for a multi-storey building in Mauritius.

Fig. 1: Cellular mortar insulation screed for a multi-storey building in Mauritius

Cellular mortar actually can be used in almost every parts of building from superstructure right down to the substructure, including wall panel and roofing [3]. Apart of being relatively lighter than conventional concrete with a dry density of 450 kg/m^3 to 1850 kg/m^3 in which giving superfluous potentials such as nailability, tapering the dead weight of the material itself, diminishes the foundation size, labor, transportation and operating costs [4]. Basically, the strength of cellular highly depends on the porous of structure of the concrete [5]. Figure 2 demonstrates cellular mortar being poured to produce blocks in steel molds.

Fig. 2: Cellular mortar being poured to make blocks in steel molds

Upon exposure to high temperatures, the cellular mortar will experience chemical changes and also mechanical properties degradation holistically [6]. At a temperature of approximately 108°C, the hydration reaction will take place which will release the calcium silicate hydrate (CSH) [7]. This CSH is the main product of the hydration of the Portland cement material [8]. CSH also delivers main connection and load bearing expansion in the hydrated cement matrix [9]. At a temperature of around 360°C, the CSH gel will lead to internal stresses and straight away micro cracks in the matrix will occur [10]. This situation will also reduce the stiffness of the cellular mortar [11]. Then, at a temperature of 450°C, the component of calcium hydroxide detached from the cement matrix in which will give serious effect to the shrinkage property of the material [12]. At this temperature the compressive strength and flexural strength of cellular mortar dropped dramatically [13]. Hence, the goal of this laboratory work is to experimentally inspect and illustrate the Young's modulus of cellular mortar which will be uncovered to very high temperatures exposure. Tests were conducted using a electric kiln in which the samples were exposed to diverse temperatures up to 605°C. Widespread axial compressive strength and also 3-point bending strength tests were accomplished for the cellular mortar of densities of 600 and 900 kg/m^3.

2. Preparation of Cellular Mortar Mixes

2.1 Ordinary Portland cement (OPC)

The Ordinary Portland Cement (OPC) utilized in this research was supplied by a company known by YTL Cement Bhd. This cement utilized conformed to Type I Portland Cement in accordance to BS 12 Standard [14]. The cement was prepared before mixing and covered it with plastic to avoid hydration process on it. The chemical arrangement of this cement is summarised in Table 1.

Table 1: Chemical compositions of Portland cement

Chemical compound	Portland cement
Mgo	1.50
Al2O3	3.60
SiO2	16.00
SO3	3.10
K2O	0.34
CaO	72.00
Fe2O3	2.90
Na2O	n/d

2.2 Sand

Fine aggregates river sand was used. The sand was dried and sieved through sieve 2.36 mm and treated in accordance with BS 882 to increase the cellular mortar flow features and constancy as in BS12620 [15].

2.3 Water

The water used for this study was potable tap water, free from any dissolved metal or ions that might constrain the setting and hydration process of the cellular mortar mixes [16]. The water was also used to insipid the foaming agent for aeration process.

2.4 Surfactants

In this laboratory exploration, protein based surfactant was utilised as the foaming agent as it is more stable compared to the others available in the market. Based on researcher experiences, protein based surfactant formed tiny bubble size, which can offer more stable and stronger closed bubble structure in the mix [17]. The bubbles were created by the foam making machine with the aid of air compressor by using a surfactant and water at a ratio of 1 to 33. For this research project, the foam density ranged between 58 kg/m^3 and 63 kg/m^3 was used for the production of cellular mortar. It was used to mix with fresh mortar therefore the wet density of the mortar can be controlled via rate of air bubbles generated in the cement paste mix [18]

3. Experimental

The axial compressive strength tests were conducted up to the age of 28 days. Compressive strength is tested using cube specimens of 100mm x 100mm x 100mm according to BS EN 12390-3:2009 [19] as per shown in Figure 3. Flexural test is also conducted up to the same age of 28 days. The flexural strength is done using prism specimens of 100mm x 100mm x 500mm according to BS ISO 1920-8:2009 [20]. Figure 4 shows the prism specimens prepared in this research.

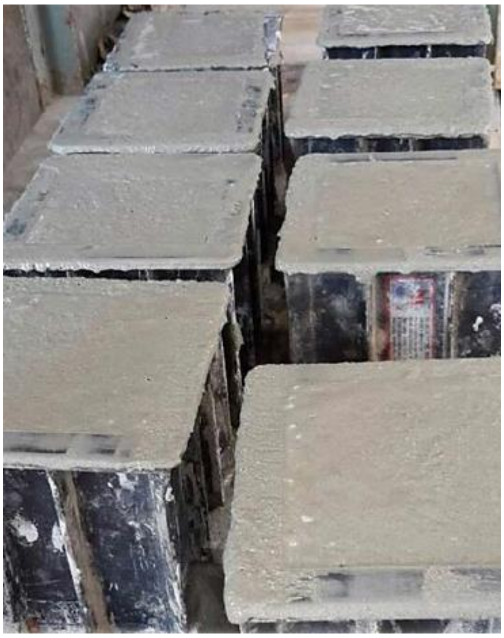

Fig. 3: Cube specimens of 100mm x 100mm x 100mm

Fig. 4: Prism specimens of 100mm x 100mm x 500mm

4. Results and Discussions

4.1 Effect of high temperature on modulus of elasticity of cellular mortar in compression

Figures 5 and 6 exhibit the variations in Young's modulus of cellular mortar under axial compression at various temperature exposure. The Young's modulus was calculated by taking into account the modulus of secant at the dot in which the cellular mortar transformed from elastic behaviour to plastic mode [21, 22]. Compared to the drop in cellular mortar strength, the fall in Young's modulus is larger. Both figures display that the loss in Young's modulus instigated instantaneously upon heating when the specimens started to dry. The Young's modulus at 205°C, 305°C, 405°C 505°C and 605°C was correspondingly about 80%, 65%, 50%, 35% and 20% of room temperature strength.

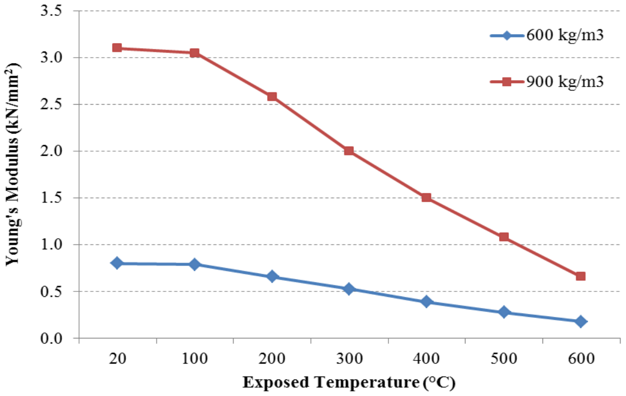

Figure 5: Young's Modulus under axial compression as a function of temperature

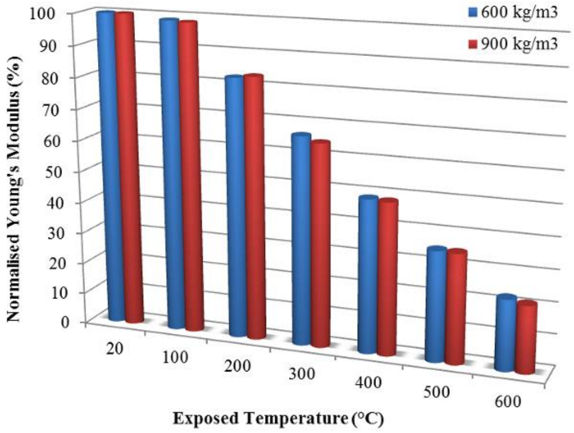

Fig. 6: Normalized Young's modulus under compression as a function of temperature

4.2 Effect of high temperature on modulus of elasticity of cellular mortar in bending

Figures 7 and 8 exemplify the deviations in flexural Young's modulus of cellular mortar as a function of temperature and compare the flexural Young's modulus with the compressive Young's modulus attained from the cylinder tests. Even though there are some variances, the compressive Young's modulus and flexural Young's modulus values are comparable for both densities and at different temperatures. The modulus of elasticity at 205°C, 305°C, 405°C 505°C and 605°C was around 80%, 65%, 50%, 35% and 20% correspondingly compared to the strength at room temperature.

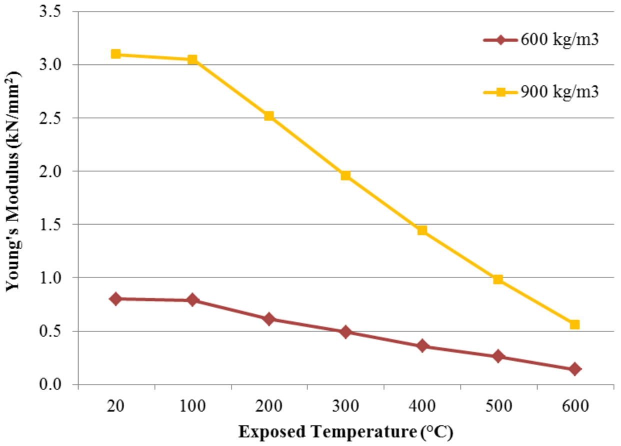

Figure 7: Young's Modulus under bending as a function of temperature

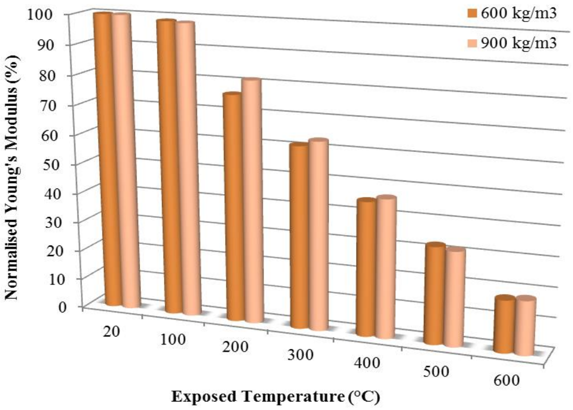

Fig. 8: Normalized Young's modulus under bending as a function of temperature

5. Conclusion

The laboratory results had confirmed that the loss in Young's modulus of cellular mortar at very high temperatures happens mainly after about 105°C, irrespective of density. This specifies that the principal mechanism instigating Young's modulus deprivation is cracking in the cement matrix of the cellular mortar, which transpires as water enlarges and disperses from the permeable body of the material. Unsurprisingly, by decreasing the cellular mortar density, it reduces the strength mechanism and stiffness properties. However, for cellular mortar of dissimilar dry densities, the normalized strength and stiffness properties almost similar.

Acknowledgement

The authors are grateful for the financial assistance of this research granted by Ministry of Higher Education Malaysia under FRGS Grant (Ref. No. 203/PPBGN/6711514)

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