Construction and Building Materials 174 (2018) 741–748

Contents lists available at ScienceDirect

Construction and Building Materials

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

High temperature resistance of polymer-phosphazene concrete for 365 days

Harun TANYILDIZI [a,*], Erol ASİLTÜRK [b]

[a] Department of Civil Engineering, Fırat University Elazig, Turkey
[b] Department of Primary School Education, Fırat University Elazig, Turkey

HIGHLIGHTS

- Polymer-phosphazene concrete were subjected to elevated temperatures in this study.
- This article applied the Taguchi method and Anova analysis.
- The most effective parameters on experiments were found as temperature.
- This study has been shown that the polymer-phosphazene concrete can be used in structures that can be exposed to 400 °C.

ARTICLE INFO

Article history:
Received 15 November 2017
Received in revised form 6 April 2018
Accepted 9 April 2018

Keywords:
Concrete
Polymer
Phosphazene
Elevated temperature
Mechanical properties
SEM
EDX
XRD

ABSTRACT

The performance of the polymer-phosphazene concrete subjected to elevated temperatures was investigated for 365 days in this study. Taguchi L_{25} (5^6) orthogonal array was used to find the parameters that affect compressive strength, ultrasonic pulse velocity and changes in weight by performing smaller number of experiments. Percentage of phosphazene in monomer (0%, 1%, 2%, 3% and 4%), curing period (28, 60, 90, 180 and 365 days), cement dosage (300, 350, 400, 450 and 500 kg/m^3) and high temperature (20, 200, 400, 600 and 800 °C) were selected as experimental parameters. After the experimental design, samples with dimensions of 100 × 100 × 100 mm were produced. The samples were removed from the water and dried at 105 ± 5 °C. Then, the vinyl acetate monomer with phosphazene was impregnated to samples for a 24 h period under atmospheric conditions. The polymerization of samples was performed at 60 °C for 4 h. Finally, these samples were exposed to temperatures of 200 °C, 400 °C, 600 °C and 800 °C. The ultrasonic pulse velocity, changes in weight and compressive strength experiments were applied to the samples. Furthermore, Scanning Electron Microscopy (SEM), Energy Dispersive X-ray (EDX) and X-ray powder diffraction (XRD) analyses of specimens were conducted. The results showed that the best values were obtained from samples exposed to 400 °C. Thus, this study has been shown that the polymer-phosphazene concrete can be used in structures that can be exposed to 400 °C.

1. Introduction

During its lifetime, concrete could be damaged due to physical, chemical and mechanical factors. Such environmental factors could lead to a decrease in performance, thus decrease the durability of concrete. Exposure to high temperatures is one of these physical factors that have an impact on concrete [1]. The material properties of concrete under high temperatures and micro-structural changes are interlinked [2,3]. Several factors come together during heating to influence the strength of the concrete. When the concrete is exposed to different temperatures, the volumetric changes could result in tensile stress and cracks in concrete [4,5]. The changes that occur in concrete during high temperature exposure are presented in Fig. 1.

Destructive and non-destructive on site and laboratory tests should be conducted to decide on the demolition or restoration of a strengthened concrete structure subjected to elevated temperatures due to fire [7]. It was reported that deterioration of the structural integrity of concrete occurs at 800 °C [8]. As the temperature increased, the strength decreased [9–16]. Savva et al. produced the samples using limestone and silica aggregates. Then, these samples were exposed to temperatures of 100, 300, 600 and 750 °C. The results of the study demonstrated that the residual

* Corresponding author.
E-mail address: htanyildizi@firat.edu.tr (H. TANYILDIZI).

https://doi.org/10.1016/j.conbuildmat.2018.04.078
0950-0618/

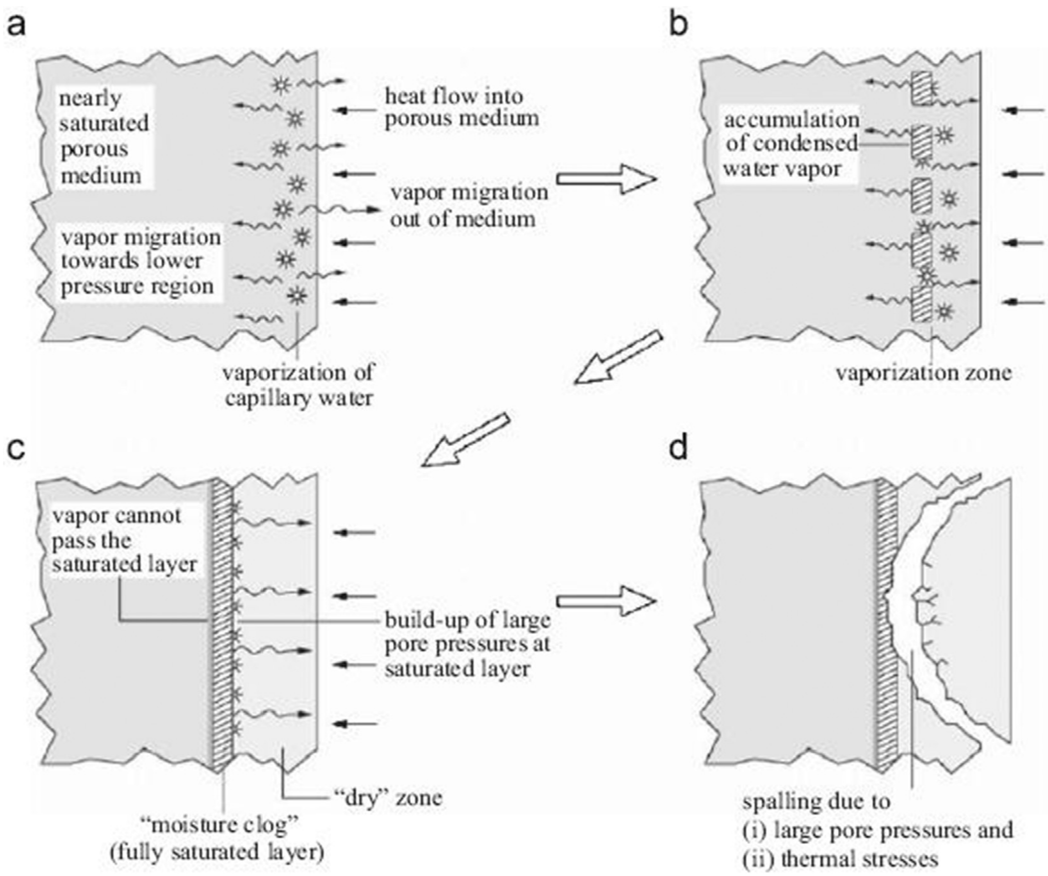

Fig. 1. Working mechanism of the concrete exposed to fire [6].

properties of concrete, which highly correlated with aggregate and binder type. Concrete produced using pozzolanic material at temperatures up to 300° C exhibited better properties than only those produced with Portland cement, but at higher temperatures these concretes were more sensitive. It was reported that there was an increase in all mixtures between 100 °C and 300 °C when compared to the initial strength and this increase was higher in the case of silica aggregated concretes and that the range of 300 °C-750 °C was critical for the loss of strength in concrete [17]. Phosphazenes are phosphorus-nitrogen compounds with a –P=N– structure. There are three important groups of compounds; linear, cyclic and poly. Cyclic and polyphosphazenes are the most studied and well-known types. Among the cyclic phosphazenes, hexachlorocyclotriphosphazene ($N_3P_3Cl_6$) was the most studied [18]. Recent studies, literature and patents on phosphazene derivatives demonstrate that they are also used in advanced technology materials. To provide a few examples, it is known that phosphazene compounds were used in nonflammable fibers, nonlinear optics and glasses with high refractive indices, semiconductors, biocompatible materials, liquid crystal materials, and synthesis of films with various characteristics [19]. Polymers are synthetic materials that have a chain-like structure that formed by chemical units called monomers. These materials could be found in the nature in the form of coal, crude oil, water, air and lime [20]. Artificially produced organic polymeric materials are plastics, elastomers and fibers [21]. It is obvious that the knowledge on the properties of the polymer, which is known to affect the properties of fresh and hardened concrete positively, which would be acquired by the concrete as a result of the addition of the polymer itself or polymer-based plasticizer additives, would result in great innovations in the cement industry [22,23].

A study with the use of phosphazene in concrete did not find in the literature. Furthermore, there is not a study on the use together both polymer and phosphazene in concrete exposed to high temperature. So, this study was conducted. In this study, the polymer-phosphazene concrete subjected to elevated temperatures was investigated experimentally and statistically for 365 days.

2. Experimental details

2.1. Materials

CEM I 42.5 R was used in the experiments. The specific weight of this cement is 3.10 g/cm^3. The properties of the cement are presented in Table 1. The specific surface area of cement is 3430 cm^2/g. Superplasticizer was used in all mixtures.

2.2. Design of experimental and mixing proportions

The Taguchi method uses to find the optimum working conditions of the parameters that affect the experimental results [24–27]. Due to this, the most important stage in the Taguchi experimental design is the determination of the control factors affecting experimental results [28]. Flowchart of the systematic approach to the application of Taguchi methods was given in Fig. 2. In this study,

Table 1
The chemical properties of cement.

Compounds	% (by mass)
SiO_2	21.12
Al_2O_3	5.62
Fe_2O_3	3.24
CaO	62.94
MgO	2.73
SO_3	2.93
LOI	1.42