

Effect of elevated temperatures on mechanical performance of cement mortar with nanoclay

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Abstract. In this research, the effect of nanoclay addition on mechanical strengths of cement mortars subjected to elevated temperatures was investigated. Mortars with three different replacement dose of montmorillonite nanoclay (0, 1 and 2% of cement weight) were prepared and then subjected to 200 °C, 400 °C, and 600 °C for 2 hrs. Compressive and flexural strengths of the heated and unheated specimens were obtained. The results showed that nanoclay addition to cement mortar caused marginal enhancement in its compressive and flexural strengths at room temperature. But, the efficiency of nanoclay to enhance the flexural strength of cement mortar increased at higher temperatures. The maximum relative improvement in flexural strength due to 2% nanoclay addition was achieved at 400°C.

1 Introduction

Elevated temperatures usually cause severe deterioration to concrete elements and affect their durability due to the different thermal properties of concrete constituents. Elevated temperature may affect the concrete's strengths and modulus of elasticity [1-3]. To minimize the harmful effects of elevated temperatures on concrete, suitable supplementary cementing materials (SCM) can be used. Various literatures showed that adding fly ash, slag, or silica fume significantly affect the performance of concrete and enhance its thermal properties [4-8]. On the other hand, the small size and tremendous properties of nanomaterials make them a good choice to be used as an additive to enhance the behaviour of cement mortar and concrete. Previous work showed that adding nanoclay into cement mortar enhanced its mechanical strengths, chloride penetration resistance, and reduced its permeability [9-12]. Chang et al. [13] showed that adding small percentages of nanoclay (montmorillonite) into cement paste enhanced its compressive strength and decrease its permeability. The optimum compressive strength and permeability were achieved by adding 0.6 and 0.4% nanoclay, respectively. They also reported that adding nanoclay caused higher rate of C-S-H production in samples containing nanoclay. Morsy et al. [14] reported that adding 8% nanoclay (metakaolin) enhanced the compressive and tensile strengths of cement mortar by 7% and 49%, respectively. Morsy et al. [15] investigated the

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effect of using CNT and nanoclay on the mechanical properties of cement mortar. They reported that adding 6% nanoclay and 0.02% CNT improved the compressive strength of the cement mortar by 29%. Farzadnia et al. [16] studied the mechanical strengths and flowability of cement mortar with halloysite nanoclay. Their results showed that adding 3% and 2% nanoclay enhanced the compressive strength and gas permeability of cement mortar by 24% and 56%, respectively. A. Hakamy et al. [17] studied the influence of nanoclay and calcined nanoclay on the properties of cement paste. Their results showed that adding 1% nanoclay into cement paste decreased its porosity and water absorption by 31% and 34%, respectively, but increased its density by 10%. They also found that adding the addition of 1% nanoclay into cement paste enhanced its compressive strength, flexural strength, and impact strength by 40%, 43% and 34%, respectively. In this work, mechanical strength degradation of cement mortar with montmorillonite nanoclay due to high temperatures was investigated.

2 Experimental program

The cement mortar was prepared using Portland cement (Type II), silica sand, nanoclay and water. The properties of silica are shown in Table1. Montmorillonite nanoclay was used as received from Nanocor® Inc., USA. Three mixes of cement mortar were prepared, one control (NC0) and two with nanoclay (NC1 and NC2). The nanoclay was first dispersed in water then used to mix the mortar. Water to cement ratio of 0.55 and cement to sand ratio of 1:3 were used. 50 mm cubic molds were used to cast the compressive strength specimens, whereas prisms of 40mm*40mm*160mm were used to cast the flexural strength specimens as shown in Figure 1. After casting, the specimens were cured for 28 days. Then, the specimens were subjected to temperatures of 200°C, 400°C, and 600°C for two hours. Finally, three specimens of each mix were tested using the ASTM standards.

Table 1. Silica sand properties.

Property	Value
Maximum particle size	1.18 mm
Absorption	1.5 %
Fineness modulus	1.72
Specific gravity	2.6

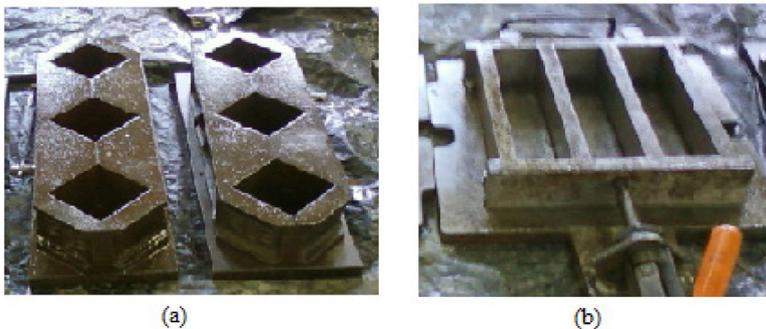


Fig. 1. Steel molds used to cast mortar samples for (a) compressive test (b) flexural test.

3 Results and discussions

Compressive strengths of all tested specimens are shown in Figure 2. The compressive strength of unheated specimen without nanoclay was equal to 37.5 MPa. Heated the cement mortar at 200°C increased its compressive strength by 45%. Elevated the temperature to 400°C reduced the strength compared to specimens heated at 200°C. At 600°C, huge reduction in the compressive strength was noticed. On the other hand, adding nanoclay increased the compressive strength of all test specimens (heated or unheated). The maximum enhancement was noticed in the case of specimen with 2% nanoclay heated at 200°C. The enhancement in the compressive strength in the presence of nanoclay may be attributed to the higher rate of production of C–S–H and more consumption of CH in samples containing nanoclay [14]. More over, the nanoclay with their small size may fill the voids and made the microstructure of the mortar denser.

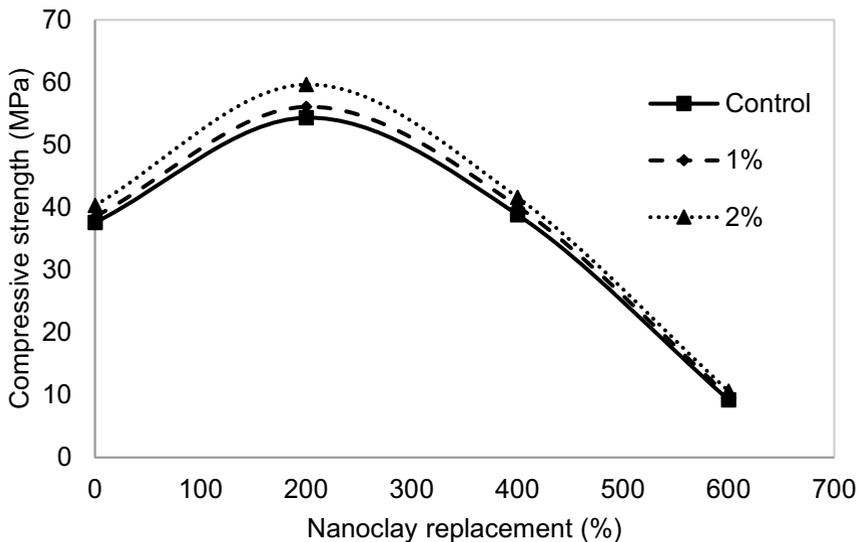


Fig. 2. Compressive strength of cement mortar exposed to elevated temperatures.

On the other hand, the flexural strengths of all specimens are shown in Figure 3. It is clear that adding nanoclay to cement mortars and test them at room temperature insignificantly enhance their flexural strengths. When exposing to elevated temperatures, control specimens and those with nanoclay own same performance. The flexural strength of all specimens increased when exposed to 200°C, then decrease when the temperatures elevated to 400 °C and 600°C. Moreover, maximum enhancement in flexural strength due to nanoclay addition was noticed when the specimens heated at 400°C as shown in Figure 3. The enhancement could be attributed to the fact that the consumption of CH and the extra formation of C–S–H in presence of nanoclay could fill up pores and led to denser microstructure of cement mortars [15].

In general, the enhancement in compressive and flexural strength of cement mortar when heated at 200°C could be attributed to the activation of the hydration process due to heating. When the temperature increased to 400 °C and 600 °C, increasing of internal vapor pressure and degradation of hydration products could be happened caused reduction in the strengths.

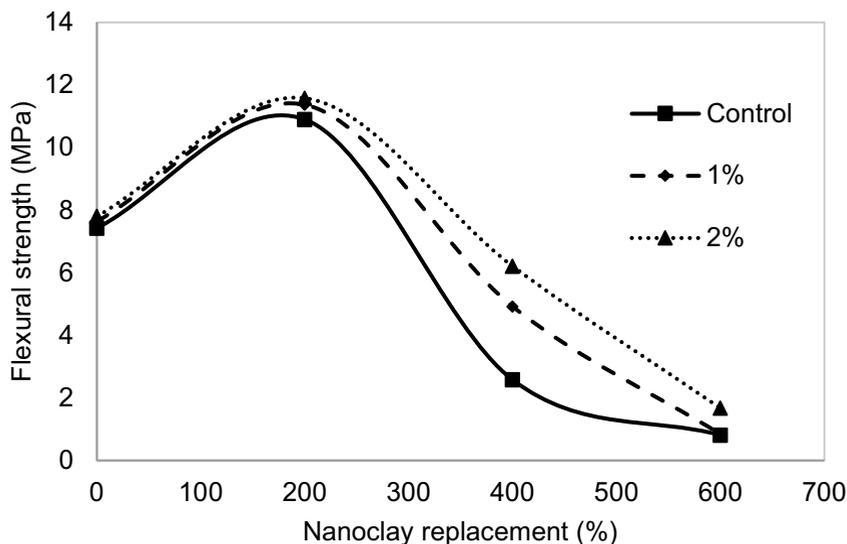


Fig. 3. Flexural strength of cement mortar exposed to elevated temperatures.

4 Conclusions

The following conclusions can be drawn:

1. Exposing cement mortar specimens to elevated temperature of 200°C increased their compressive and flexural strength. Elevated the temperature to 400°C and 600°C decreased the strengths.
2. Adding 1% and 2% of nanoclay to cement mortar enhanced their compressive and flexural strength.
3. Maximum enhancement in compressive strength was achieved in the case of heated cement mortar with 2% nanoclay at 200 °C.
4. Maximum enhancement in flexural strength was achieved in the case of heated cement mortar with 2% nanoclay at 400 °C..

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