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Effect of nano-silica on strength and durability of fly ash based geopolymer mortar

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HIGHLIGHTS

- Addition of nano SiO_2 in geopolymer mortar improves strength and durability.
- Optimum strength at ambient temperature due to addition of 6% of nano SiO_2.
- Water absorption and RCPT shows appreciable improvement with addition of nano SiO_2.
- Presence of crystalline compound is more in nano SiO_2 modified geopolymer mortar.

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ABSTRACT

In general, the fly ash based geopolymer concrete/mortar needs heat activation for early strength developments depending on the molar concentration of activator. To overcome the above shortcomings, an experimental program has been taken up on low calcium fly ash geopolymer mortar having three molar concentrations (8 M, 10 M and 12 M) of activator liquids along with different percentage of nano silica addition (0%, 4%, 6%, 8% and 10% of fly ash). Geopolymer mortar with the addition of 6% nano silica shows appreciable improvement in compressive, flexural and tensile strength at 28 days under ambient temperature curing. The water absorption and charge passed in RCPT are also seemed to be comparatively less for 6% addition of nano silica modified geopolymer mortar. Such improvement of nano silica modified geopolymer mortar is due to transformation of amorphous compound to crystalline compound as noted in the XRD and FESEM analysis.

1. Introduction

Worldwide production of coal combustion products in the form of fly ash was approximately 780 Mt tones in the year of 2011–2012. Although effective utilisation of fly ash was limited to 415 Mt or 53% of total production and widely varies within countries [1]. The power requirements throughout the world are rapidly increasing with the growth of the industrial sectors particularly in India and China. Recently, the application of alkali activated geopolymer concrete using fly ash (without cement) becomes an important area of research [2–6].

Most of the research works on fly ash based geopolymer are on the mix proportion and strength variation of geopolymer concrete cured at different temperature range of 45–80 °C for about 2–3 h [7–13]. It is noted that the strength of such geopolymer mortar is more at 60 °C compared to 80 °C for a given molar concentration [14,15]. It also provides poor strength at ambient temperature of about 27 ± 2 °C curing due to slow polymerisation process. There are limited literatures on available on geopolymer to eliminate the shortcomings of ambient temperature curing [16–18]. However, incorporating nano silica in conventional cement concrete or high volume fly ash concrete had showed better results in terms of strength and durability [19–23]. Use of nano silica and nano aluminium oxide in geopolymer paste for high calcium based fly ash is also reported for a particular molar concentration [24]. The early strength is also achieved in geopolymer mortar (fly ash + rice husk ash) having different percentage of nano silica and nano aluminium oxide with heat activation for 2, 4 and 8 h at different temperatures [25]. The improvement of strength for addition of nano silica on slag based geopolymer is also reported at 38 °C [26].

This paper investigates the effect of different percentage of nano silica addition in low calcium based fly ash geopolymer mortar of different molar concentrations and cured at the ambient

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Table 1
Chemical analysis report of fly ash.

Material	Chemical composition (in percentage)								
Fly Ash	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_4	LOI
	64.97	26.64	5.69	0.33	0.85	0.49	0.25	0.33	0.45

temperature. The mechanical strength of such geopolymer mortar was analyzed by compressive strength, flexural strength and splitting tensile strength. Also, durability property based on rapid chloride ion permeability test and water absorption test was incorporated. The micro structural property of nano silica modified geopolymer mortar was assessed via Field Emission Scanning Electron Microscope (FESEM) and X-ray Diffraction test (XRD).

Table 2
Physical analysis report of fly ash.

Material	Particle size distribution						
Fly ash	>500μ	300–500μ	150–300μ	150–90μ	90–45μ	<45μ	Specific gravity
	NIL	0.05	6.02	33.32	53.40	6.21	2.05

Table 3
Basic properties of colloidal nano silica.

Colloidal nano silica type	Average particle size (nm)	Solid content (wt%)	Viscosity (Pa S)	pH	Solid density (g/cm^3)
CemSynXLP	4–16 nm	30%	8.5	9.0–9.6	2.37

Table 4
Mix proportion varying molar concentration, percentage of nano silica and curing condition.

Sample mark	Fly ash: sand	Molar concentration	% of Nano silica w.r.t fly ash	Curing conditions
Control	1:3	–	0.0	Water curing
8M0	1:3	8 (M)	0.0	Heat cured at 60 °C for 48 h
8M4	1:3	8 (M)	4.0	Ambient temperature(27 ± 2 °C) curing
8M6	1:3	8 (M)	6.0	Ambient temperature(27 ± 2 °C) curing
8M8	1:3	8 (M)	8.0	Ambient temperature(27 ± 2 °C) curing
8M10	1:3	8 (M)	10.0	Ambient temperature (27 ± 2 °C) curing
10M4	1:3	10 (M)	4.0	Ambient temperature(27 ± 2 °C) curing
10M6	1:3	10 (M)	6.0	Ambient temperature(27 ± 2 °C) curing
10M8	1:3	10 (M)	8.0	Ambient temperature(27 ± 2 °C) curing
10M10	1:3	10 (M)	10.0	Ambient temperature(27 ± 2 °C) curing
12M0	1:3	12 (M)	0.0	Heat cured at 60 °C for 48 h
12M4	1:3	12 (M)	4.0	Ambient temperature(27 ± 2 °C) curing
12M6	1:3	12 (M)	6.0	Ambient temperature(27 ± 2 °C) curing
12M8	1:3	12 (M)	8.0	Ambient temperature (27 ± 2 °C) curing
12M10	1:3	12 (M)	10.0	Ambient temperature (27 ± 2 °C) curing

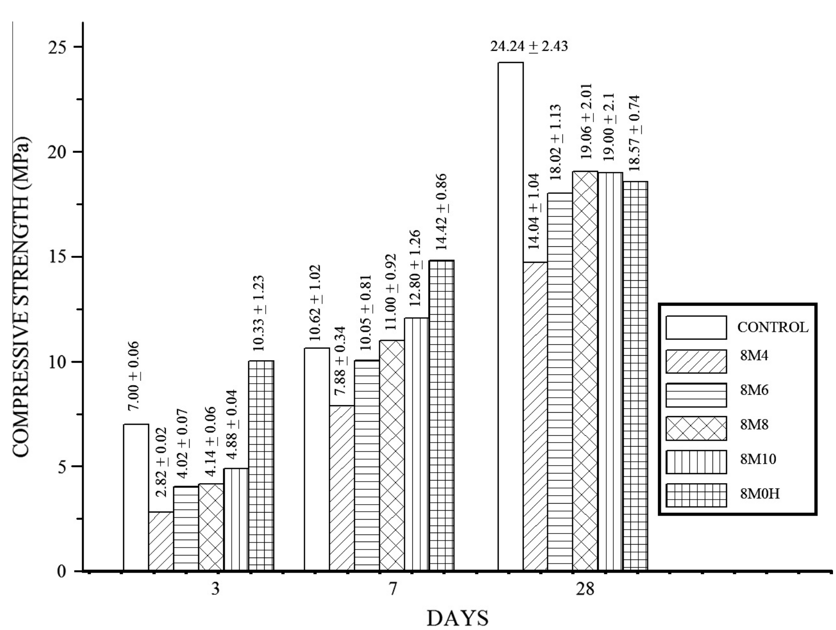

Fig. 1A. Compressive strength of fly ash based geopolymer mortar (with or without nano silica) having molar concentration of 8 (M) and cement mortar samples.