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Utilizing Fly Ash Cenosphere and Aerogel for Lightweight Thermal Insulating Cement-Based Composites

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Abstract : Thermal insulating composites help to reduce the total power consumption in a building by creating a barrier between external and internal environment. Such composites can be used in the roofing tiles or wall panels for exterior surfaces. This study purposes to develop lightweight cement-based composites for thermal insulating applications. Waste materials like silica fume (an industrial by-product) and fly ash cenosphere (FAC) (hollow micro-spherical shells obtained as a waste residue from coal fired power plants) were used as partial replacement of cement and lightweight filler, respectively. Moreover, aerogel, a nano-porous material made of silica, was also used in different dosages for improved thermal insulating behavior, while poly vinyl alcohol (PVA) fibers were added for enhanced toughness. The raw materials including binders and fillers were characterized by X-Ray Diffraction (XRD), X-Ray Fluorescence spectroscopy (XRF), and Brunauer–Emmett–Teller (BET) analysis techniques in which various physical and chemical properties of the raw materials were evaluated like specific surface area, chemical composition (oxide form), and pore size distribution (if any). Ultra-lightweight cementitious composites were developed by varying the amounts of FAC and aerogel with 28-day unit weight ranging from 1551.28 kg/m³to 1027.85 kg/m³. Excellent mechanical and thermal insulating properties of the resulting composites were obtained ranging from 53.62 MPa to 8.66 MPa compressive strength, 9.77 MPa to 3.98 MPa flexural strength, and 0.3025 W/m-K to 0.2009 W/m-K as thermal conductivity coefficient (QTM-500). The composites were also tested for peak temperature difference between outer and inner surfaces when subjected to heating (in a specially designed experimental set-up) by a 275W infrared lamp. The temperature difference up to 16.78 ^oC was achieved, which indicated outstanding properties of the developed composites to act as a thermal barrier for building envelopes. Microstructural studies were carried out by Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS) for characterizing the inner structure of the composite specimen. Also, the hydration products were quantified using the surface area mapping and line scale technique in EDS. The microstructural analyses indicated excellent bonding of FAC and aerogel in the cementitious system. Also, selective reactivity of FAC was ascertained from the SEM imagery where the partially consumed FAC shells were observed. All in all, the lightweight fillers, FAC, and aerogel helped to produce the lightweight composites due to their physical characteristics, while exceptional mechanical properties, owing to FAC partial reactivity, were achieved.

Keywords : aerogel, cement-based, composite, fly ash cenosphere, lightweight, sustainable development, thermal conductivity
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