SYNOPSIS

The sustainability of the cement and concrete industries is imperative to the wellbeing of our planet and human development. The production of Portland cement, an essential constituent of concrete, releases about one tone of carbon dioxide (CO_2) into the atmosphere per tone of cement. On the other hand, coal based thermal power stations produce a huge amount of fly ash, of which about 35% used in construction of landfills, embankments, production blended cement etc. and remaining as an industrial hazards. Alkali activated geopolymer mortar/concrete are being introduced to reduce the rapid utilization of Portland cement mortar/concrete throughout the world. In the last few decades, the application of geopolymer concrete using mainly fly ashhas becomes an important area of research.

Geopolymer is an inorganic alumino-silicate polymer synthesized from alkaline activation of various alumino-silicate materials of geological origin or by product materials like fly ash, metakaolin, blast furnace slag etc. Geo-polymeric reaction generally depends on the activation with alkali solutions and heat activation at different temperature to obtain better strength and durability compared to normal concrete. A lot of research work already have been reported on the development of strength and durability of geopolymer mortar/concrete at different molar concentrations cured at different temperature and period. It was recognized in the previous studies that at higher concentration of sodium hydroxide (NaOH) solution and higher ratio of sodium silicate (Na_2SiO_3) tosodium hydroxide ratio (by mass)the fly ashbased geopolymer concrete results in higher compressive strength. However, heat activation was the much needed property for geopolymer mortar/concrete to develop early strength. With the increase in curing temperature (for heat activation) in the range of 30°C to 90°C, the compressive strength of fly ash-based geopolymer mortar/concrete also increases. Geopolymer concrete without heat activation showed poor strength and durability due to slow polymerization process. Thus, the use of geopolymer mortar/concrete is presently limited to the pre-cast member due to requirement of heat activation after casting.

This thesis reports the details of development of low calcium fly ash-based geopolymer mortar/concrete cured at ambient temperature. There are limited literatures

available on geopolymer mortar/concrete cured at ambient temperature. This study narrates two new different techniques to develop low calcium fly ash based geopolymer mortar/concrete without heat activation - (1) **the addition of nano silica in geopolymer mortar/concrete mix** and (2) **the geopolymeric process modification**. Also due to the lack of knowledge on structural behaviors of fly ash based geopolymer concrete with/without heat activation, the structural behaviors of the above two geopolymer concrete has been also incorporated.Low calcium fly ash was chosen as the basic material to be activated by geopolymerization process in presence of alkali activator solution of sodium hydroxide and sodium silicate throughout the study. Nano silica has been in partial replacement of fly ash.

Addition of colloidal nano silica in geopolymer mortar cured at ambient temperature shows an appreciable improvement in mechanical strength (compressive, split tensile and flexural strength) and durability (Rapid Chloride Ion Penetration Test, water absorption and sulphate test). Geopolymer mortar (cured at ambient temperature) with the addition of different percentages colloidal nano silica (w/w) of fly ash with the activator fluid ($NaOH+Na_2SiO_3+H_2O$) at different molar concentrations (8M, 10M, 12M) were investigated and compared with heat activated conventional geopolymer mortar (without nano silica) and control cement mortar. The experimental results of this study clearly elucidates that with the addition of nano silica of 6% of fly ash at 12 molar NaOH solution, geopolymer mortar cured at ambient temperature shows better mechanical strength and durability performance than conventional heat cured geopolymer mortar and control cement mortar.

Based on the preeminent results of nano silica modified geopolymer mortar and to establish structural behavior of geopolymer concrete with nano silica, a series of tests of the compressive strength, split tensile strength, modulus of elasticity and bond strength were investigated and also compared with conventional heat cured geopolymer concrete without nano silica and OPC based control cement concrete. Flexural behavior of reinforced nano silica modified geopolymer concrete beam at different percentages of tension, compression and shear reinforcement were investigated. This experimental study reveals that the compressive strength, bond strength, split tensile strength of nano silica modified geopolymer concrete is higher than heat activated geopolymer concrete without nano silica and OPC concrete. Field Emission Scanning Microscope (FESM) images show that the geopolymer matrix with 6% nano silica seemed to consist of more amount of crystalline compound transformed from amorphous compound than that of geopolymer mortar without nano silica. Also the X-ray Diffraction (XRD) analysis shows the wide diffraction hump identified around 25 – 30° 2theta that confirms the presence of crystalline phases in nano silica modified geopolymer matrix.

Beside the mechanical strength and durability the mechanistic anti-bacterial activity of the silver-silica nano composite modified geopolymer mortar were investigated and compared to nano silica modified geopolymer mortar and control cement mortar. The result shows that silver-silica nano composite modified geopolymer mortar cured at room temperature shows almost similar strength and durability with respect to nano silica modified geopolymer mortar but better anti-bacterial property.

The work also includes to develop a modified geopolymer process (Process – I) in which heat activation of fly ash and activator fluid mixture had been made before casting. The duration of such heat activation is substantially reduced to 45 minutes compared to 48 hours and more. The mechanical strength and durability behavior of this modified geopolymer mortar (Process – I) had been compared to that of conventional heat activated geopolymer mortar (Process – II) in which the heat activation has been made after casting for 48 hours. Geopolymer mortar made by Process – Ishows better strength and durability than Processes – IIgeopolymer mortar at different fluid to fly ash ratio. In Process – Igeopolymer mortar, fly ash has been more uniformly polymerized within the whole matrix than Process – IIgeopolymer mortar as per FESEM analysis. Energy Dispersive X-Ray (EDS) and XRD analysis also confirm the presence more crystalline compound in Process – I geopolymer mortar than Process – IIgeopolymer mortar. Finally, an economical benefit for the Process-I in terms of energy savings and practical applicability had been presented.

Based on the performance of process modified geopolymer mortar, the study has been further extended on geopolymer concrete. The structural behavior (compressive, split tensile, flexural strength, bond strength and modulus of elasticity) of such process modified geopolymer concrete (Process – I) has been studied and compared with conventional heat cured geopolymer concrete (Process – II). The process modified geopolymer concrete (Process – I) shows better structural performance than that of conventional geopolymer concrete (Process – II) due to early age polymerization of fly ash and activator fluid.

Finally two novel techniques to develop the geopolymer concrete without heat activation have been identified. Besides the elimination of heat activation, nano silica modified geopolymer and process modified (Process – I) mortar/concrete show improved mechanical strength and durability. Silver-silica modified geopolymer mortar demonstrates better anti-bacterial property than conventional cement mortar and silica modified geopolymer mortar. Therefore, this innovative technology can be implemented in practical construction in terms of strength, durability, energy savings and substantial reduction of greenhouse gas emissions for sustainable development.