Title: Modified Bacteria Incorporated Geopolymer- A Qualitative Approach for an Eco-friendly, Energy- efficient and Self-healing Construction Material.

ABSTRACT

The sustainability of the cement and concrete industries is imperative to the well-being of our planet and human development. The production of Portland cement, an essential constituent of concrete, releases about one tone of carbon dioxide (CO2) into the atmosphere per ton 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 hazard. 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 ash has 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 (Na2SiO3) tosodium hydroxide ratio (by mass) the fly ashbased geopolymer results in higher compressive strength. However, heat activation was the much-needed property for geopolymer mortar 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 also increases. Geopolymer concrete without heat activation showed poor strength and durability due to slow polymerization process. Thus, the use of geopolymer mortar is presently limited to the pre-cast member due to requirement of heat activation after casting. The compressive strength and durability of concrete can be increased substantially (> 30%) by using some specific hot spring bacteria (BKH1 and BKH2) or their extra-cellular protein (e.g. bioremediase, M.W. ~ 28 kDa). Those bacteria possess silica leaching (biosilicification) activity which can be used to develop new phase (Gehlenite) inside the mortar matrices for getting higher strength and more durability in concrete structures). The use of *Bacillus pasteurii* bacteria in concrete is associated with mineral precipitation (calcium carbonate) that helps to fill micropores and cracks, thus reducing its permeability and increasing its strength and durability. However, the highly alkaline pH environment within the concrete matrices restricts the growth of the bacteria. The slow growth rate of the hot spring bacteria may restrict them to use in the concrete industry. The problem has been overcome by transferring the bioremediase gene into E. coli JM 107 and *Bacillus subtilis* bacterial strains and used those transformed bacteria in concrete/mortar mix to increase the strength and durability of the cementitious material in short time period. *Bacillus subtilis* is a spore forming bacterial strain which can remain in dormant form within the concrete/mortar matrices for quite long time and becomes active when water ingresses within the concrete. Development of tiny cracks in concrete reduces it strength. It allows water and various detrimental ions inside the structures which corrodes the steel

reinforcement and decreases the lifetime of the structures. Scientists are showing their interest on the recovery of mechanical properties of damaged concrete structures by self-healing manner to extend its longevity. It occurs due to formation of calcite (calcium carbonate) or gehlenite (calcium-aluminium silicate) crystals inside the matrices. Though self-healing of bacteria in concrete is considered as eco-friendly, still no straight forward experimental evidences are available to support the eco-friendliness. Therefore, the study deals with the development of genetically modified bacterium amended geopolymer mortar without heat activation after casting and assessment of mechanical properties of such modified geopolymer mortar along with their Self-healing as well as crack repairing ability along with its microstructural studies. The newly designed bacterium amended geopolymer shows higher compressive, flexural and tensile strengths are also increased. Addition of transformed bacteria 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). Field Emission Scanning Microscope (FESM) images show that the geopolymer matrix with Bacteria seemed to consist of more amount of crystalline phases like Albite, Mullite, Allite etc transformed from amorphous compound than that of geopolymer mortar without bacteria. 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 bacteria amended geopolymer matrix. 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.

Avishek Chatterjee
15/5/24

B Chattopadhyay
15/5/24

15/5/24

Dr. Brajadulal Chattopadhyay
Professor
Department of Physics
Jadavpur University
Kolkata - 700 032

Professor
CIVIL ENGINEERING DEPARTMENT
JADAVPUR UNIVERSITY
KOLKATA-32