INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Studies on Enhancement of Stability, Rheology, and Mechanical Performance of 3D Printable Foam Concrete

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SHORT ABSTRACT

Multifunctional properties are a requirement due to the increasing need for the thermal resistance, acoustic insulation, fire resistance, and etc. for the modern construction. Nevertheless, the material must be both mechanically sound and porous in order to fulfil these requirements. One such concrete that satisfies the demands of modern building is foam concrete (FC). FC is a cellular concrete produced using binder, fine aggregate or filler, foam and water as ingredients. Proper control in dosage of foam can result in wide range of densities ranging from 300 to 1800 kg/m^3. FC is a unique, non-structural and low-cost light weight concrete with special properties such as low density, high acoustic insulation, low thermal conductivity, high energy absorption capacity, good fire resistance, and good freeze and thaw resistance. The aforementioned properties of FC are mainly dependent on the microstructure of FC which is influenced by the foam production parameters (air pressure, type of foam generator), foam stability (drainage, density, size, shape, and etc.) and surfactant characteristics (type of surfactant, viscosity, surface tension, and etc.). FC has an extensive spectrum of demands to satisfy an array of applications.

Adopting the new-era construction methods for FC structures accelerates the construction simultaneously lowering costs and labour demands. Extrusion-based 3D printing is the most popular approach for additive manufacturing despite the fact that there are other methods as well. 3D concrete printing (3DCP) is a technology that can build the structure layer by layer by extruding through the nozzle. Further, to design the 3D printable foam concrete (3DP-FC) mixture, dimensional stability plays an important role. During and after printing, extrusion of highly flowable materials like FC presents numerous challenges. High flowability restricts the buildability whereas the more stiffness leads to collapsing of the foam bubbles. The stability of foam concrete mixes is highly dependent on the volume of the foam added to the mortar, stability of the lamella around air bubble and spacing between the air bubbles. These parameters may vary with type of foaming method (mixed or pre-foaming method), surfactant characteristics, rheology of the paste surrounding the bubble and pressure applied during the extrusion process. Hence, there is a need to address these issues from 3DCP perspective.

This research proposes to improve the stability and buildability of 3DP-FC through enhancing the surfactant characteristics, rheology of the air voids and paste content. A two-stage enhancement was carried out. First one is improving the stability of 3DP-FC by improving the surfactant characteristics. Whilst the other is to improve the rheology via adopting various admixtures. In stage 1, the influence of surfactant characteristics on extrudability and stability of 3DP-FC is studied. Different studies on fresh state related, printability and air void characterization have been carried out for two different surfactants (natural and synthetic based) along with different foam stabilizers. Based on the experimental outcomes it can be suggested that the surfactant solution with viscosity above 5 mPa.s and surface tension less than 31 mN/m can result in stable 3DP- FC mixes. Further, the volume of foam in the mix is found to have significant impact on printability characteristics. Unlike traditional foam concrete, the variation in stabilizer concentration and density of concrete for the stable mixes studied, did not show much impact on the fresh state related characteristics (slump, slump flow and static yield stress) and air void microstructure. Furthermore, the structural build-up achieved is restricted to 15 and 10 layers for 1300 and 1000 kg/m^3 respectively. Therefore, to improve the structural build-up of 3DP- FC, rheology of the paste should be improved.

In stage 2, study was conducted to improve the buildability and mechanical properties of 3DP-FC through replacement of the sand with fly ash (FA) and addition of polyvinyl alcohol (PVA) fibers. The results shows that FA improved the buildability, however, reduced the stability of 3DP-FC. Fibers, on the other hand helped in improving the stability. Moreover, the addition of FA improved the compressive and flexural strengths of 3DP-FC, compressive being the dominant improved property. Interestingly, strength improvement beyond 28 days was found to show insignificant improvement. Microstructural studies were conducted to understand the limited pozzolanic reaction after 28 days and these results are in line with the obtained compressive and flexural results. This is due to the low water to solids ratio adopted for achieving the buildability causing the unavailability of calcium dissolute (pore water) to react with FA. Further, addition of PVA fibers reduced the thermal conductivity for all the mixes. But for mixes with FA replacing sand, thermal conductivity increased due to the bubble breakage. However, this was compensated by the addition of PVA fibers which resulted in reduction in the dry densities of 3DP-FC mixes. Nonetheless, density has significant impact on water absorption characteristics of 3DP-FC as observed from experimental results mixes. It is to be noted that increase in air content and the reduction in solid content in concrete mixes resulted in decreased inter-void thickness and closer proximity of air voids subsequently enhancing the likelihood of interconnection among entrained air voids. Addition of FA as a sand replacement reduced water absorption due to the bubble breakage. Additionally, fiber addition to sand replaced mixes has reduced the water absorption due to the pore refinement in the matrix surrounding the fiber.