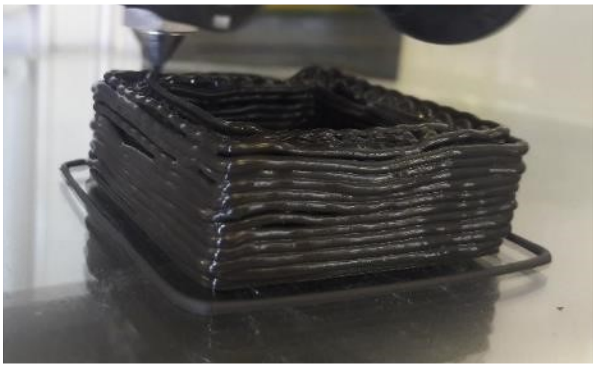
Optimization of Inorganic Polymers for 3D Printing

3D printing is one of the latest state-of-the-art technologies for construction applications. The use of a 3D printer is more economical and time efficient, eliminates the formwork, requires less labor, has less safety risks and minimizes construction errors. Further, the sustainability is increased because less construction waste is generated. With 3D printing a new market can be entered, as the binder can be sold as an ink instead of a cement. In this case, the regulation will be different and might go in the direction of performance-based criteria.

Only a small body of literature is available concerning printing with alternative binders, such as alkali activated materials, that originates from slag. The commonly used alkali activated material for 3D printing are ground granulated blast furnace slag, metakaolin or fly ash, but not yet an Fe-rich slag. In this research, an Fe-rich inorganic polymer (IP) will be 3D printed. An IP is produced by alkali activation of an Fe-rich slag, which is a metallurgical residue and is only used nowadays for low value applications. IPs are proven to be interesting for building applications and are able to achieve mechanical performances similar or even superior compared to traditional cement. Furthermore, IPs have a lower carbon emission compared to the cement.



1) Product development

Literature was reviewed to have an idea of the benchmark, criteria and additives used in the cement industry which are necessary to make a cementitious binder printable. Companies/research facilities visits were conducted to investigate printing cementitious binder. The rheological behavior of a fresh paste inorganic polymer with the addition of several rheology modifiers to obtain a rheological behavior suitable for printing was researched. A benchmark, such as printable clay or cement mortar, was used to compare with the inorganic polymer rheological behavior. Reactivity assessment of the inorganic polymer binder by calorimetry was done.

2) Durability assessment

Drying and autogenous shrinkage of the inorganic polymer must be minimized as much as possible, preferably below 1.5 mm/m. The shrinkage can be lowered by the used of aggregates or shrinkage reducing agents. Investigating the mechanical properties of the inorganic polymer, the compressive strength must be at least 15 MPa. Investigating the freeze-taw behavior and leaching of heavy metals. Characterizing the microstructure of the engineered inorganic polymer matrix by Scanning Electron Microscope.

3) Printing

Printing small scale structures was done after the inorganic polymer is engineered with suitable rheological behavior and low shrinkage values. Characterizing the microstructure and mechanical properties of the printed structures was done to investigate the bonding of the printed layers.