GEOPOLYMERS AS INORGANIC BINDER IN 3D PRINTING APPLICATION IN CONSTRUCTION

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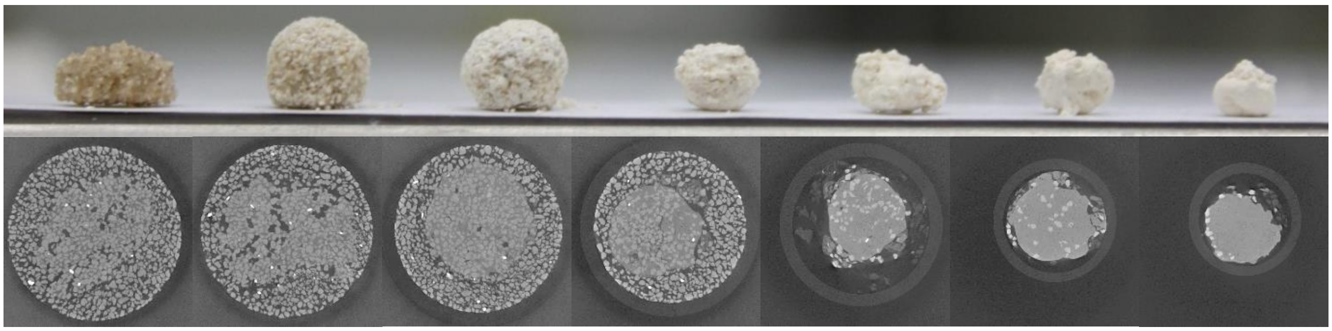

Figure 1:Top: Droplets of 20 µl of sodium silicate solution dropped on different sand/metakaolin mixes: increasing metakaolin content from left to right (0wt%, 10wt%, 20wt%, 40wt%, 60wt%, 80wt%, 100wt% metakaolin). Bottom: Microtomography images of dry geopolymer droplets, increasing metakaolin content from left to right (0wt%, 10wt%, 20wt%, 40wt%, 60wt%, 80wt%, 100wt% metakaolin).

Digital fabrication and more specifically, 3D printing allows the production of very complex shapes with no extra cost for complexity and customization. This mass customization revolution opens new possibilities for the construction industry [1]. For instance, structural elements can be designed with the exact amount of materials positioned in the right place. Recently 3D printing has been used to produce a formwork for high performance fiber reinforced concrete [2], which would reduce the environmental impact of the structure, by one third. However, this large scale binder-jet technology with organic binders (phenolic and furanic resins) causes serious problems for the indoor environmental quality of buildings through the release of volatile organic compounds when they are used as building structure.

Therefore, in this study, we replaced the organic binder with a geopolymer in a custom-built binder jet 3D printer. The sand bed of the printer contains a mix of metakaolin and silica sand, on which we print with a sodium silicate solution. The prominent Al(IV) band in an Al-NMR measurement of a printed part confirmed that a geopolymer was built during the printing process.
The printer allows adjusting the layer height, the printing line spacing and the ejection speed.
In order to find the optimal settings of the printer, test bars with varying amount of binder, line spacing and layer thickness were printed. The bars were tested in 3-point bending and compression tests, where they reached up to 1 kN and 8.5 MPa respectively, which is higher than the parts printed with the organic binder.

The immersion of silicate droplets into powder beds with different metakaolin contents was studied with micro tomography to get an insight of the spreading of the liquid in the powder bed (See Figure 1 on the bottom). The analysis of the weight of the single droplets shows that the Si/Al ratio remains constant, independently of the alumina content of the sand bed. The amount of metakaolin in the sand bed does not change the Si/Al ratio of the final part, but it changes the size of the droplet (See Figure 1 on top). Therefore, the optimal layer height can be changed by adjusting the metakaolin to sand ratio.

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[2] Wangler T., Lloret E., Reiter L., Hack N., Gramazio F., Kohler M., Bernhard M., Dillenburger B., Buchli J., Roussel N., Flatt R. (2016). Digital Concrete: opportunities and challenges. RILEM technical letters, 1, 67-75