Characterization of a Material's Structure in 3D Concrete Printing

Master Thesis Update

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3D concrete printing or additive manufacturing is a new approach for developing concrete structures. Additive manufacturing allows for more efficient material use, freedom in design, and a safer and automated construction process. However, 3D concrete printing requires different mechanical characteristics than the concrete used in the traditional built environment. In 3D printing, fresh concrete is printed in layers on top of each other without using formwork. Fresh printed concrete should withstand two failure modes: material failure and stability failure. Therefore, two different properties must be determined: strength and rigidity. This research focuses on the strength property. Mechanical properties of the concrete are important and need to be determined to examine if the fresh material is suitable for 3D concrete printing.

Mechanical properties of fresh concrete are mainly described with rheology or soil mechanics. In rheology, a material is characterized by yield stress and viscosity. These materials behave like a fluid or could feel similar to a dough-like material. A more granular material is examined using soil mechanics, describing the material with a Mohr-Coulomb model, where the cohesion and angle of internal friction could be determined. Materials are generally classified as either rheology or soil mechanics, but the tipping point between these behaviors still needs to be determined. To describe this tipping point, the material's structure and associated failure criterion are quantified, which depends on several characteristics of the material.

To find the different characteristics of a material, such as yield stress, viscosity, cohesion, or angle of internal friction, two experimental tests are executed. RAM Extruder and Direct Shear Test. The RAM Extruder, presented in *Figure 1*, is a rheological test that determines the yield stress and viscosity of a material.

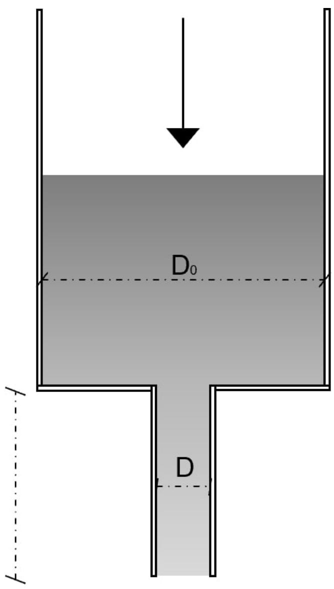

Figure 1: RAM extruder

A piston moves at various speeds and pushes the material through the die, which can vary in size. A distinction between pressure and speed dependence cannot be made. The Direct Shear Test, presented in *Figure 2*, is a test that only examines the pressure dependence of the material. This test is mainly used in soil mechanics.

The top plate moves from the bottom plate at a controlled speed, and a normal force can be applied. The shear force is measured to determine the material's cohesion and angle of internal friction.

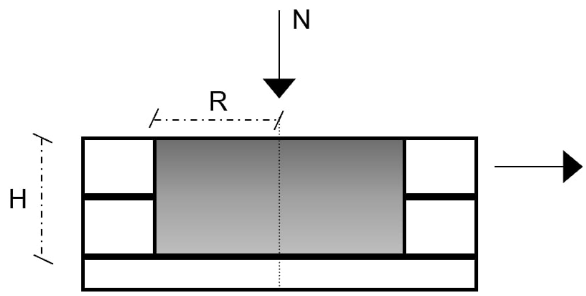

Figure 2: Direct shear test

The concrete used in this research combines CEM III-C, water, and sand in different sizes. For each mixture, the above-mentioned material characteristics are determined. However, not all material characteristics can be found with one test for all mixture varieties. For instance, a shear plane will occur within the first five millimeter of displacement with the Direct Shear Test, where the shear force will increase until a shear plane forms. After the shear plane has formed, the measured shear force will be lower. This effect is visible in *Figure 3*.

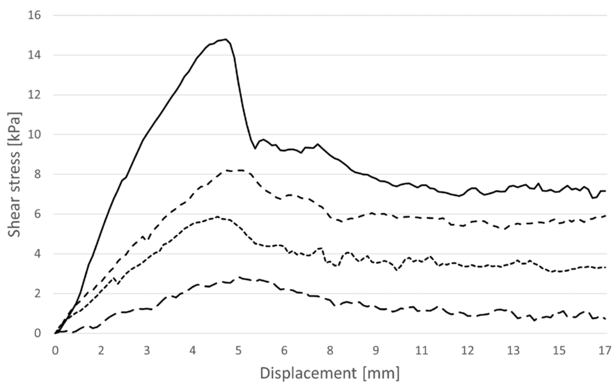

Figure 3: Example results of direct shear test

Only in some mixtures, this effect is visible, indicating a tipping point where the Direct Shear Test could be applied. With the RAM Extruder, the same tipping point is researched but approached from the rheology perspective instead of the soil mechanics.◀