Discrete Element Modelling of Concrete Additive Manufacturing Extrusion Technology

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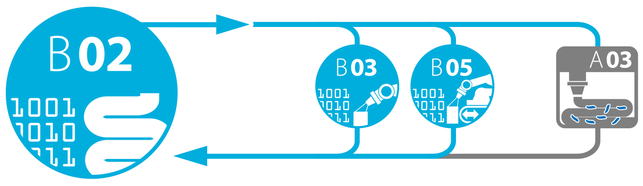
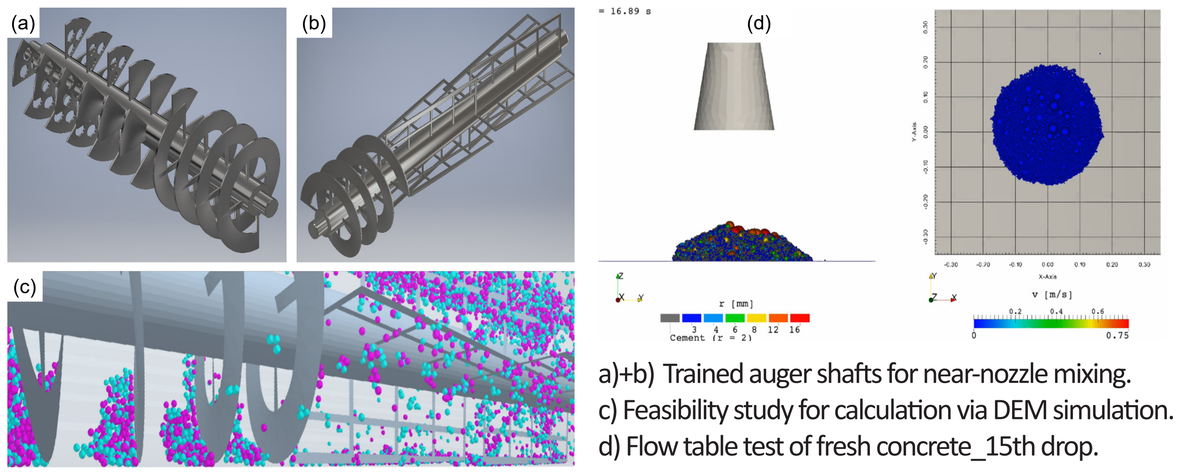
Summary



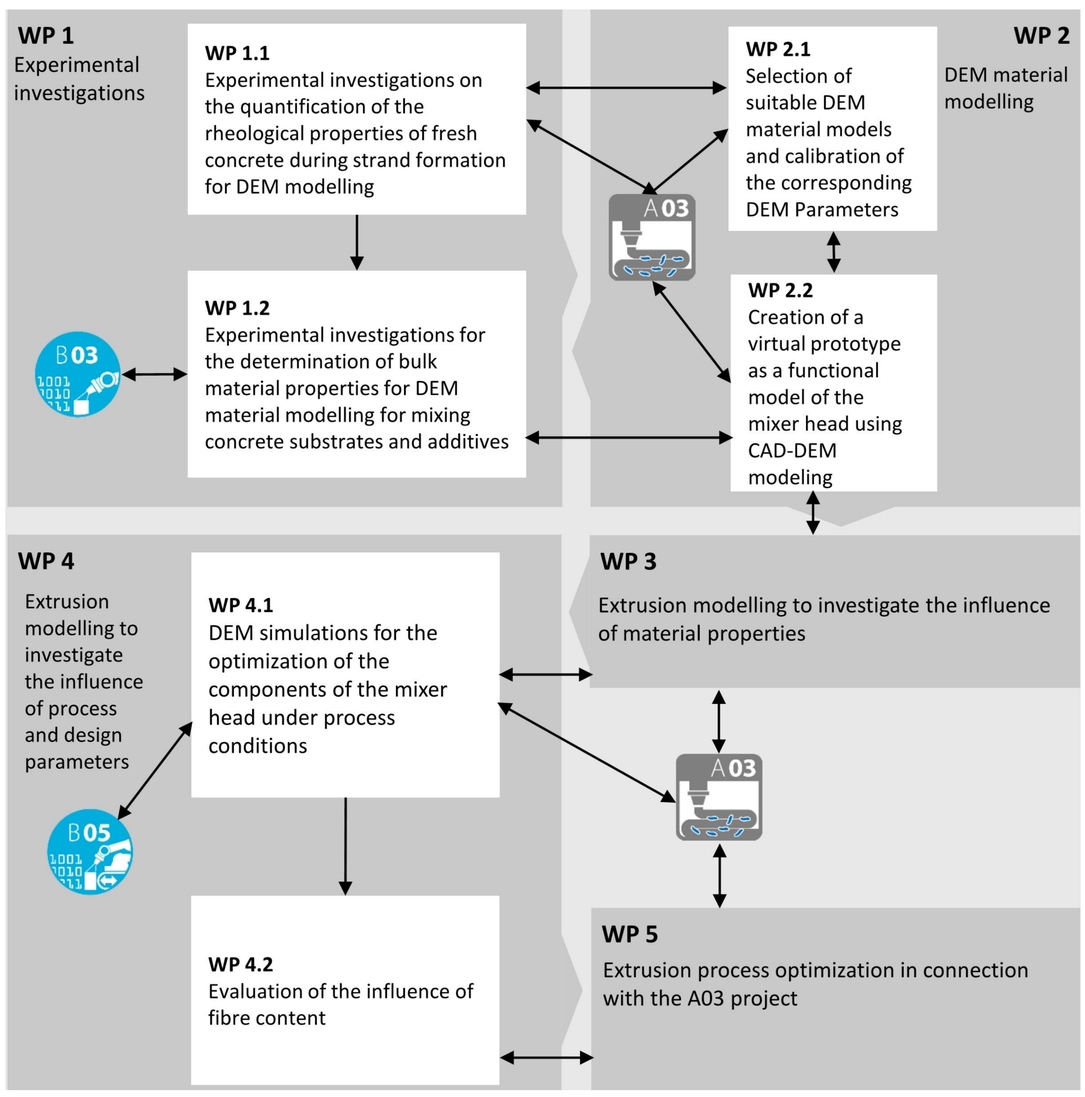
In this project, a near-nozzle mixing and compacting system for concrete extrusion is to be developed. Innovatively the pumpability of the concrete no longer needs to be taken into account. Additives such as light-weight aggregates can be added zonewise as required. To investigate the mixing, conveying and compaction process, a virtual prototype based on a parameterized 3D CAD variant design is developed and analysed kinematically and kinetically with DEM model variants. Suitable viscous DEM concrete models have to be developed and calibrated. The investigations result in a digital twin which enables the machine construction for the A03 project and virtually accompanies the investigations for additive concrete recipes as well as the reinforcement approaches in A03.

Preliminary Work

- Extensive experience in screw conveyor design and in the execution of corresponding experiments and simulations.
- The German standard VDI 2230 sheets 1-4 for the general design of screw conveyors for bulk materials was developed at the fml.
- Different types of possible auger shafts were developed, designed with 3D-CAD and investigated, e.g. Fig. a) + b).
- Preliminary work showed that the concrete mixing and conveying can be simulated with different cohesive DEM models. (Fig. c)
- The group of associated scientist Katterfeld has experience in the DEM modelling of concrete and first experience in the field of the modelling of fresh concrete could be collected during the modelling of the dynamic influences during a flow table test. (Fig. d)



a)+b) Trained auger shafts for near-nozzle mixing.
c) Feasibility study for calculation via DEM simulation.
d) Flow table test of fresh concrete_15th drop.

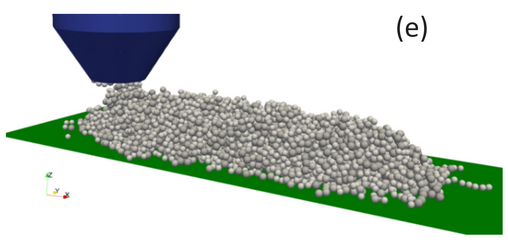


Research Questions

- How to realise a ultra-light machine for mixing, fluidisation and activation the materials before the concrete mixture is fed to the extruder for compaction?
- How to model the mixing, conveying and compaction process of concrete with additives, by using the method of discrete elements (DEM)?
- How to develop a digital twin to investigate the behavior of the ultra-light machine to create the innovative concrete recipts?
- How to avoid a strand track with a too firm consistency that tears open (Fig. e) and is therefore not suitable or to avoid too liquid strand?

Methods

- The development and control of the process of the mixing device near the nozzle and the compaction of the concrete mass in the extruder is simulated with the method of discrete elements (DEM).
- Virtual mirroring experimental results of the concrete laboratory of CBM (TUM) and the bulk material analysis laboratory of the associated scientist Katterfeld for the DEM material modelling of the concrete substrates and the intended additives.
- Using the CAD method of variant design for lean construction.
- Developing a virtual prototype based on a 3D-CAD model of the machine with an equivalent mass filling with particles for the DEM simulation of the mixing, transport and compaction process in parallel and experimentally calibrating and comparing it with the machine prototype.
- The targeted approach is based on product development methods.



(e)

- With the virtual prototype prepared and experimentally adjusted, the design and the process can be extrapolated in an ultra-light machine.
- Last version of the virtual prototype forms a digital twin with which the investigations in A03 and the experimental projects of focus area C can be accompanied to avoid malfunctions.