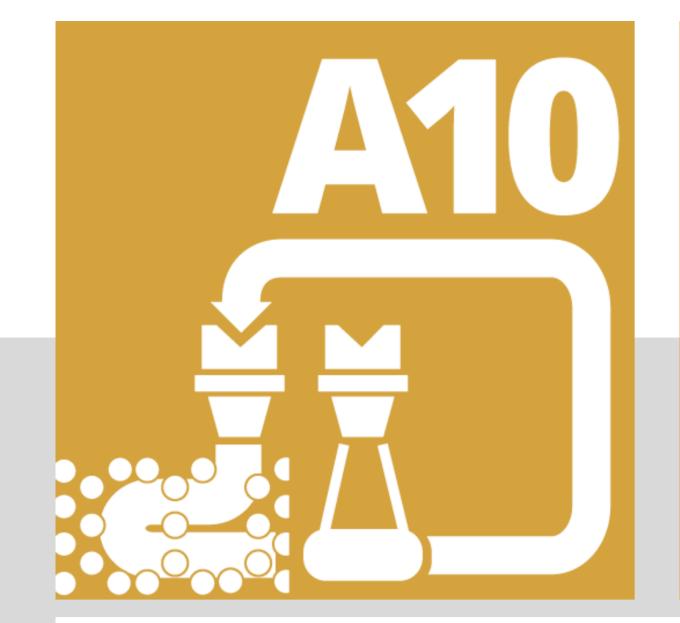
# Additive Manufacturing in Construction 2<sup>nd</sup> funding period: The Opportunity for Large Impact





New Project: Earth Additive Manufacturing (EAM) – Material and **Process Combinations for AM with Earth-based Materials** 

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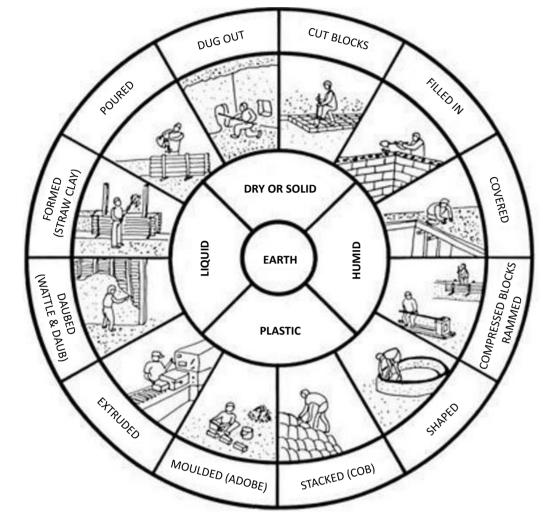


Fig. 1: Traditional building methods [1]

### Project aims

Conception and investigation of two novel EAM processes: Depositionbased Sprayed Earth Additive Manufacturing (SEAM) and particle-bed-Intrusion Earth Additive Manufacturing (IEAM) with the following aims:

- Fundamental characterization of earth-based materials
- Investigation of the material-process interaction
- Exploration of geometrically differentiated architectural components
- Exemplary fabrication at full construction scale

[1] Auroville Earth Institute, Unesco Chair Earthen Architecture. Available at https://www.earth-auroville.com/world\_techniques\_introduction\_en.php

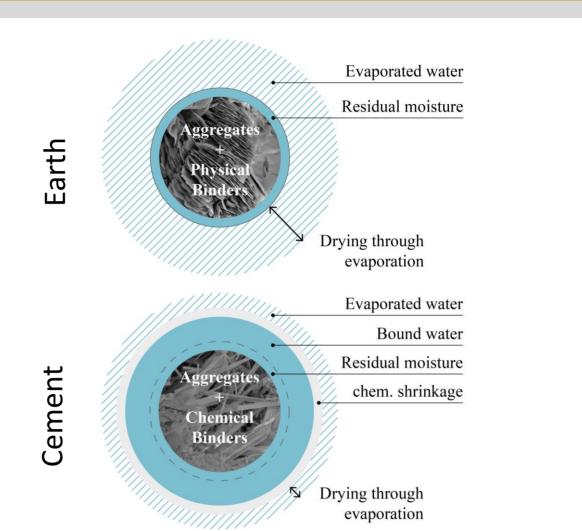




Fig. 2: Drying vs. Hydration

### **Preliminary work**



Rammed Earth.



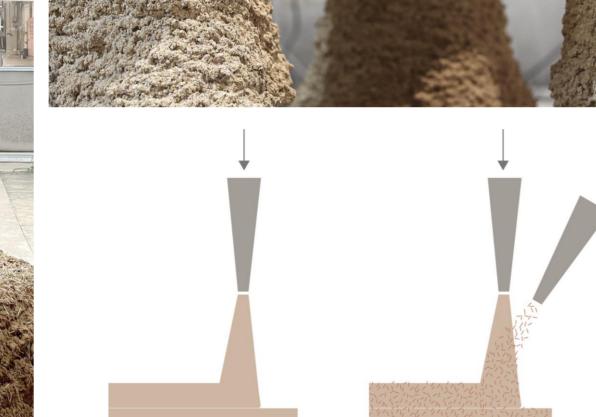
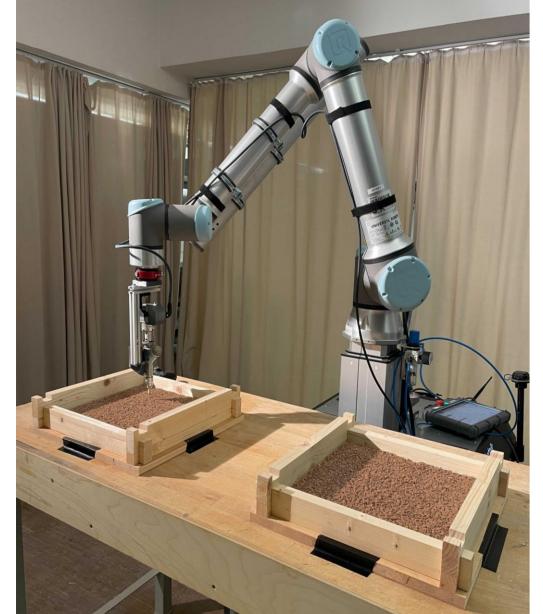


Fig. 4: Experimental studies on Robotic Fig. 5, 6 and 7: Experimental studies on Sprayed Earth Additive Manufacturing









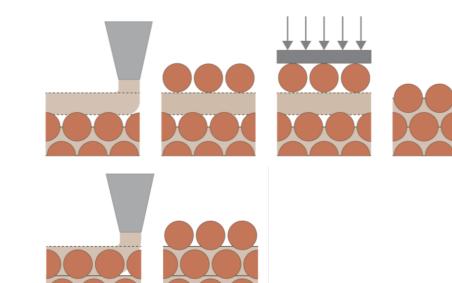
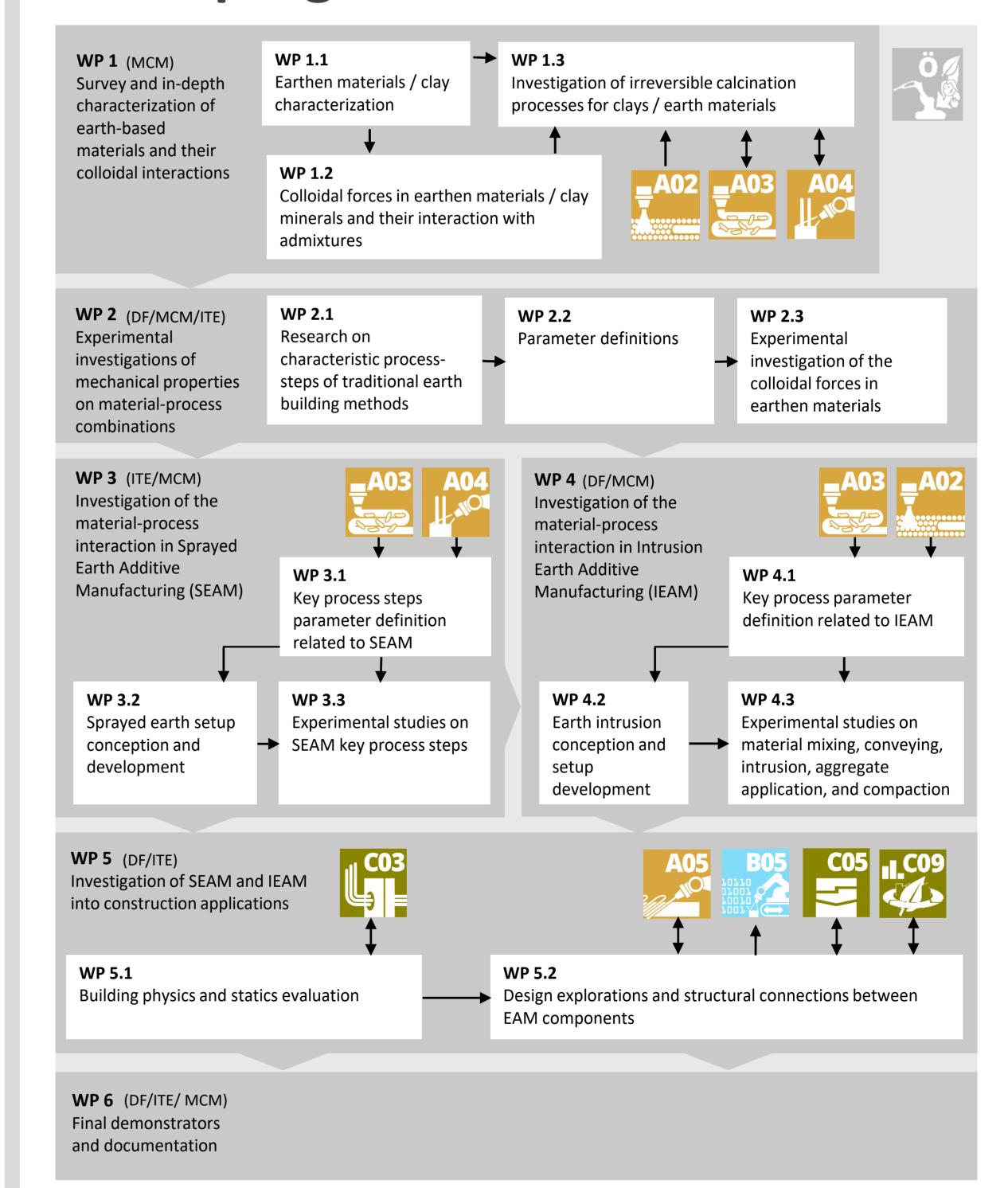


Fig. 8, 9, 10, 11 and 12: Experimental studies on Intrusion Earth Additive Manufacturing (IEAM).

### Work programme



#### Methods

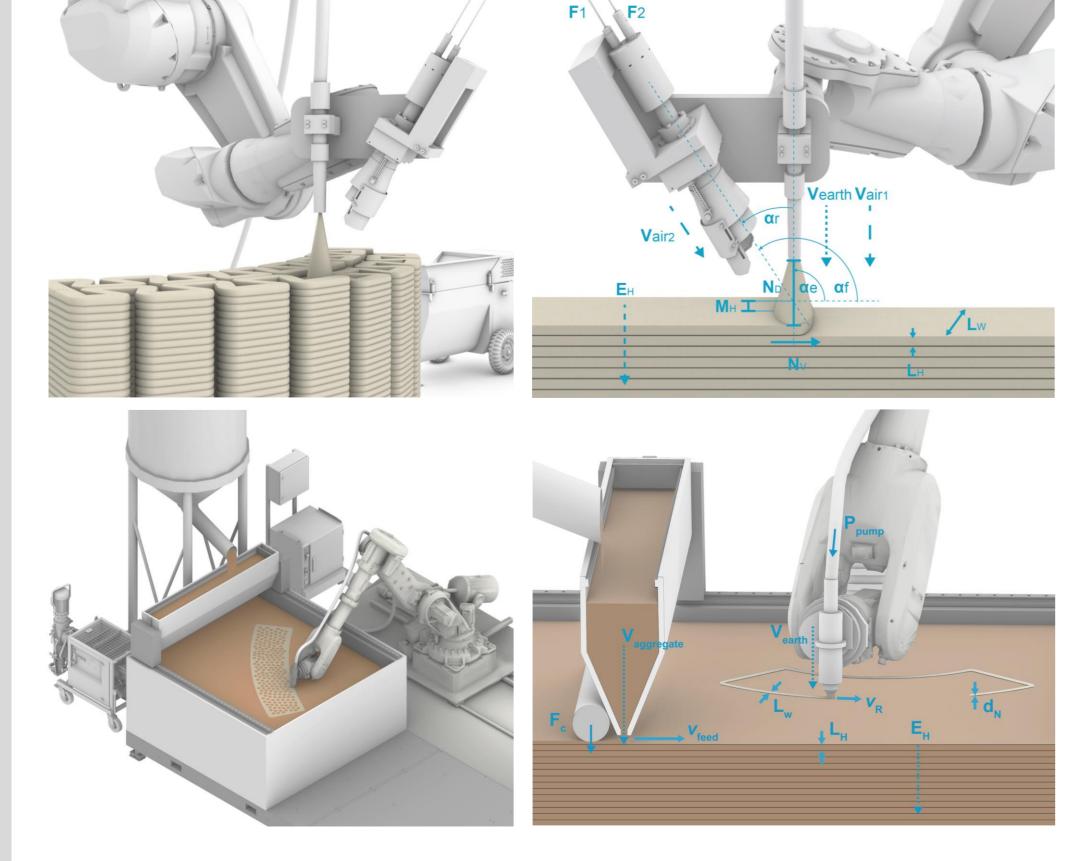
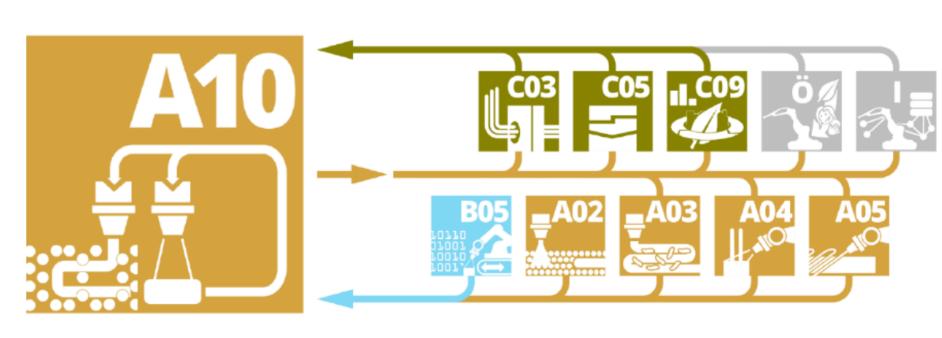


Fig. 13 and 14: Sprayed Earth Additive Manufacturing nozzle distance  $(N_D)$  and velocity  $(N_V)$ , layer width  $(L_W)$  and height  $(L_H)$ , earth hardening rate  $(E_H)$ ; volume earth  $(V_{earth})$ , volume air  $(V_{air1}$  and  $_2)$ , fiber types  $F_1$  and  $F_2$ ; spray angle earth  $(a_e)$ , fibers (a<sub>f</sub>) and relative earth-fiber angle  $(a_r)$ , mixing height  $(M_H)$ .

Fig. 15 and 16: **Intrusion Earth Additive Manufacturing** volume flow earth ( $V_{earth}$ ) and aggregate  $(V_{aggregate})$ ; aggregate feed speed  $(v_{feed})$ and robot speed  $(v_R)$ ; layer height  $(L_H)$ and width  $(L_W)$ ; nozzle distance  $(d_N)$ ; earth hardening  $(E_H)$ ; compaction force  $(F_{compaction})$ ; pump pressure  $(P_{pump})$ .

## **Key collaborations**



# Outlook 3<sup>rd</sup> funding period

- Further investigation of SEAM and IEAM to create a robust and fully automated AM process, including design and individual processes
- Sophistication of tools, effectors and materials characterization
- Transfer knowledge on sustainable earth-based materials for cement replacement into other concrete AM technologies
- Upscaling of the technology for real-world building applications