Robot aided fabrication of rammed earth elements

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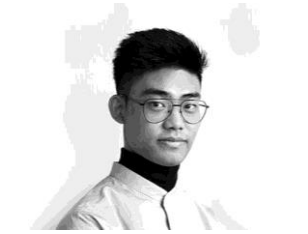

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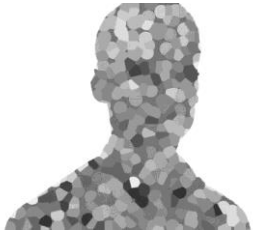

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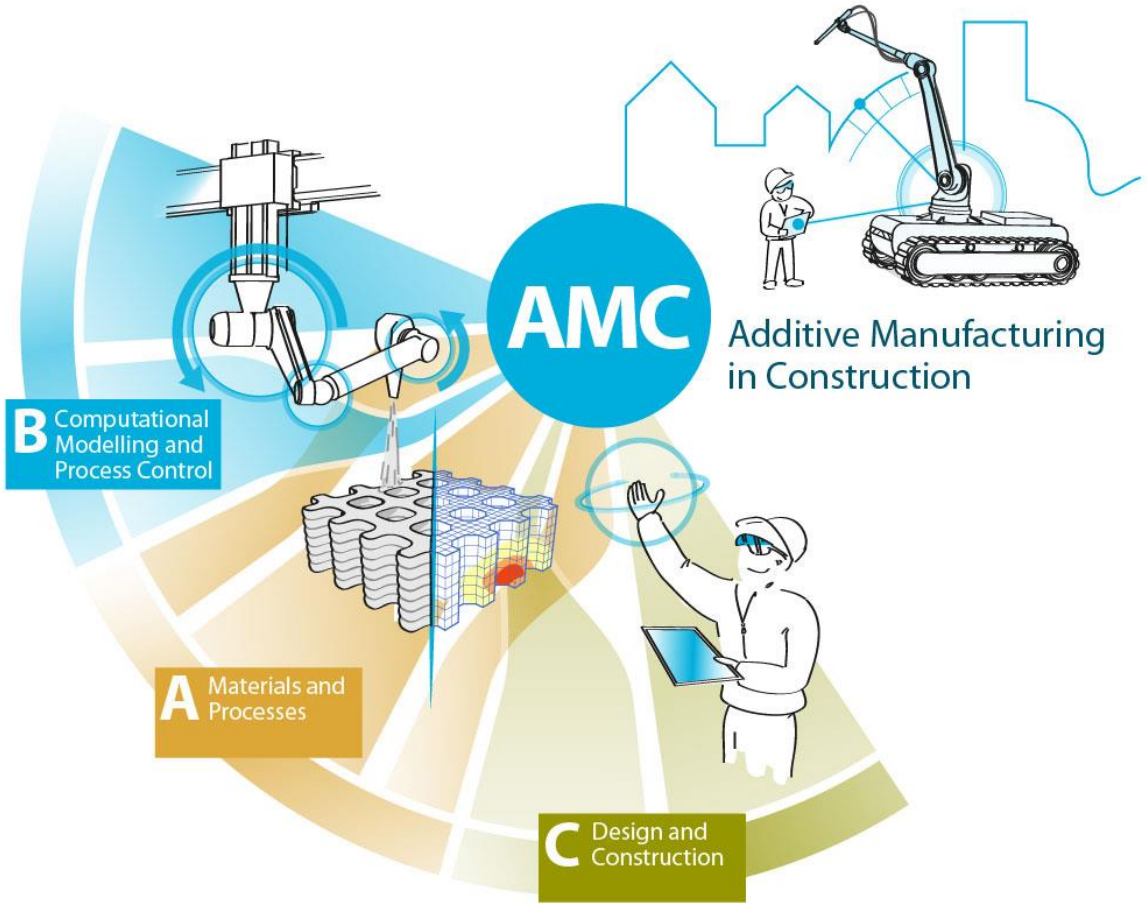
TRR 277 Additive Manufacturing in Construction (AMC)

The Challenge of Large Scale



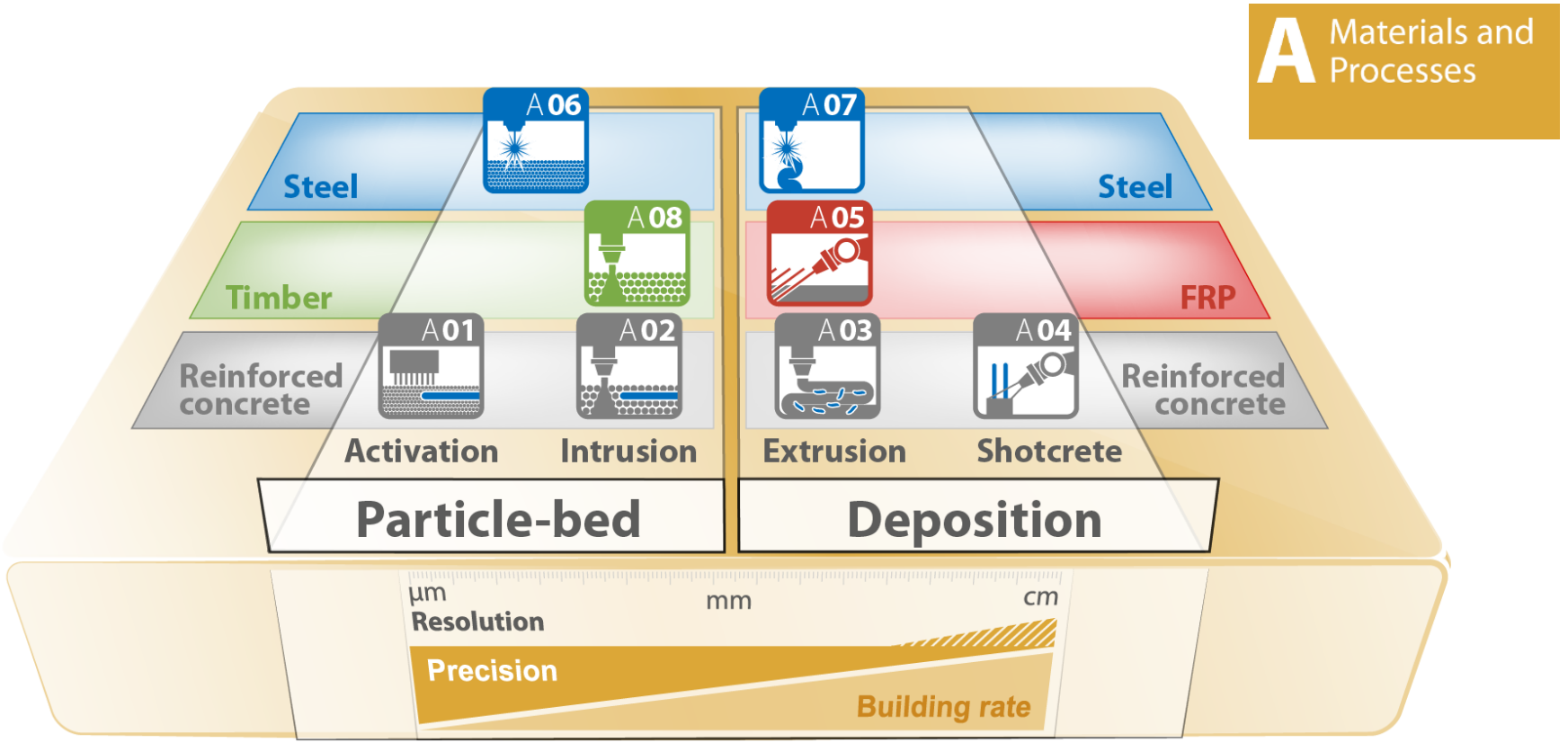
DFG Deutsche Forschungsgemeinschaft
German Research Foundation

Technische Universität Braunschweig | Technical University of Munich

Spokesperson: Prof. Dr.-Ing. Harald Kloft
Co-Spokesperson: Prof. Dr. Kathrin Dörfler

https://amc-trr277.de/

material-process interaction as basic research approach



DFG Deutsche Forschungsgemeinschaft
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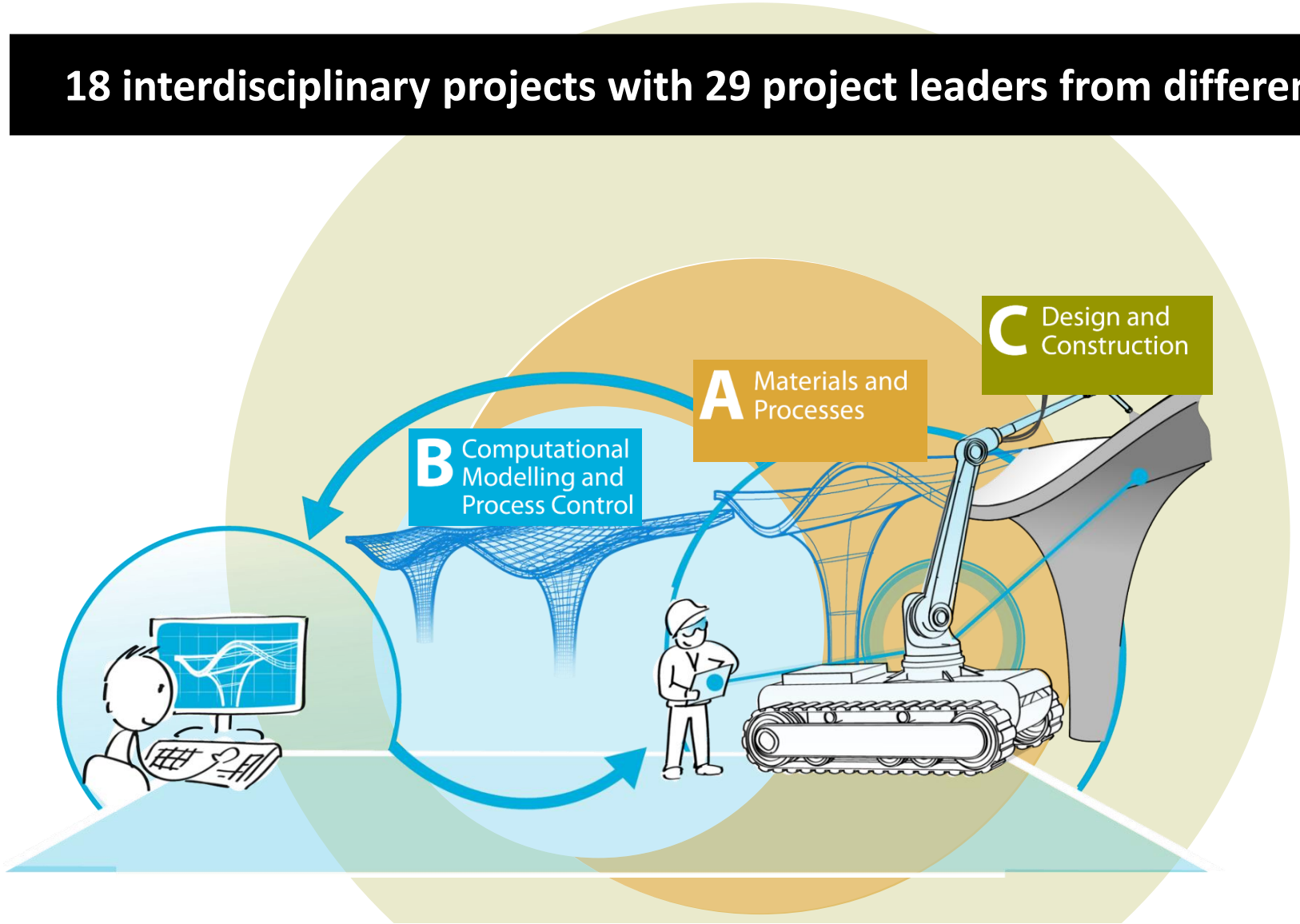
18 interdisciplinary projects with 29 project leaders from different disciplines



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DBFL | Digital Building Fabrication Laboratory

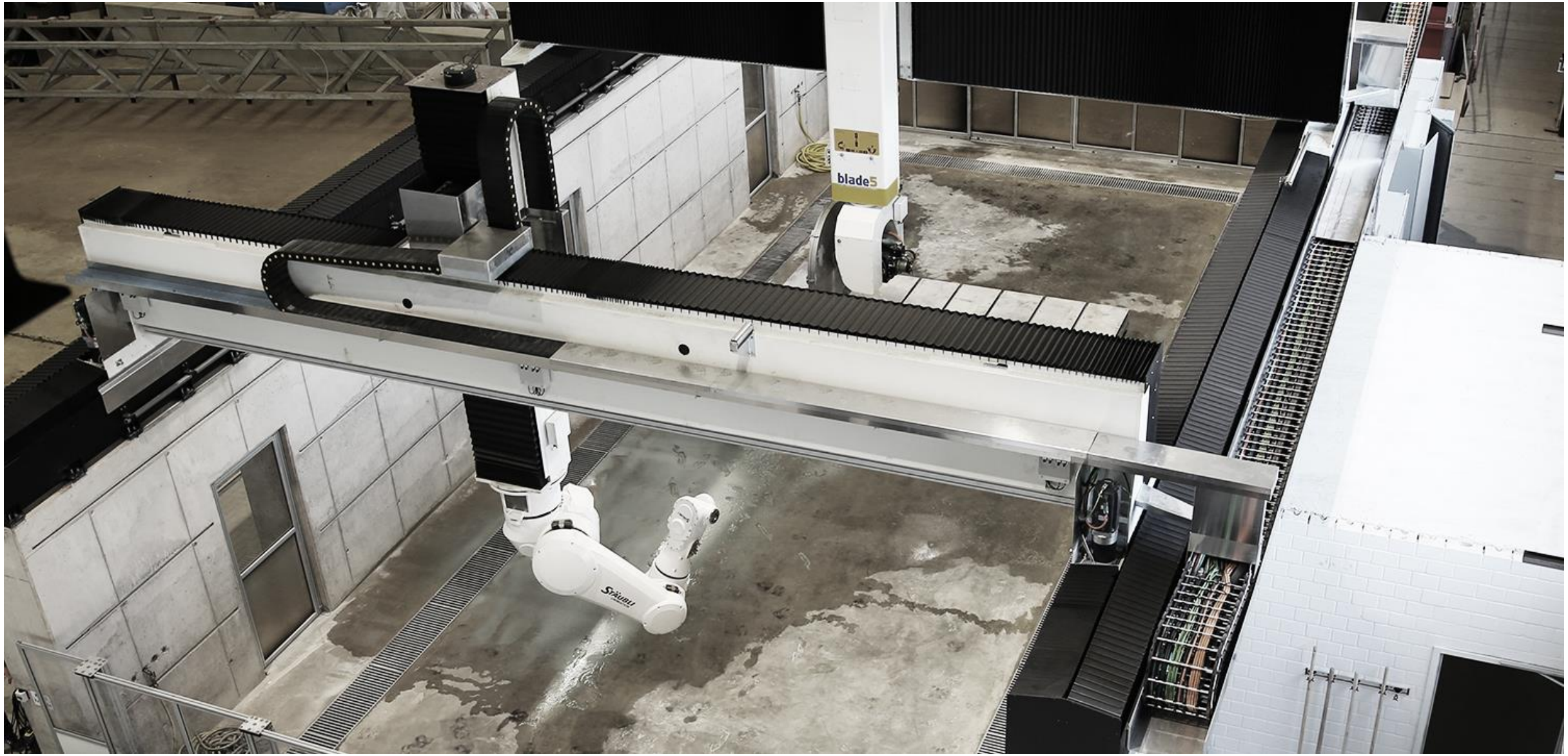
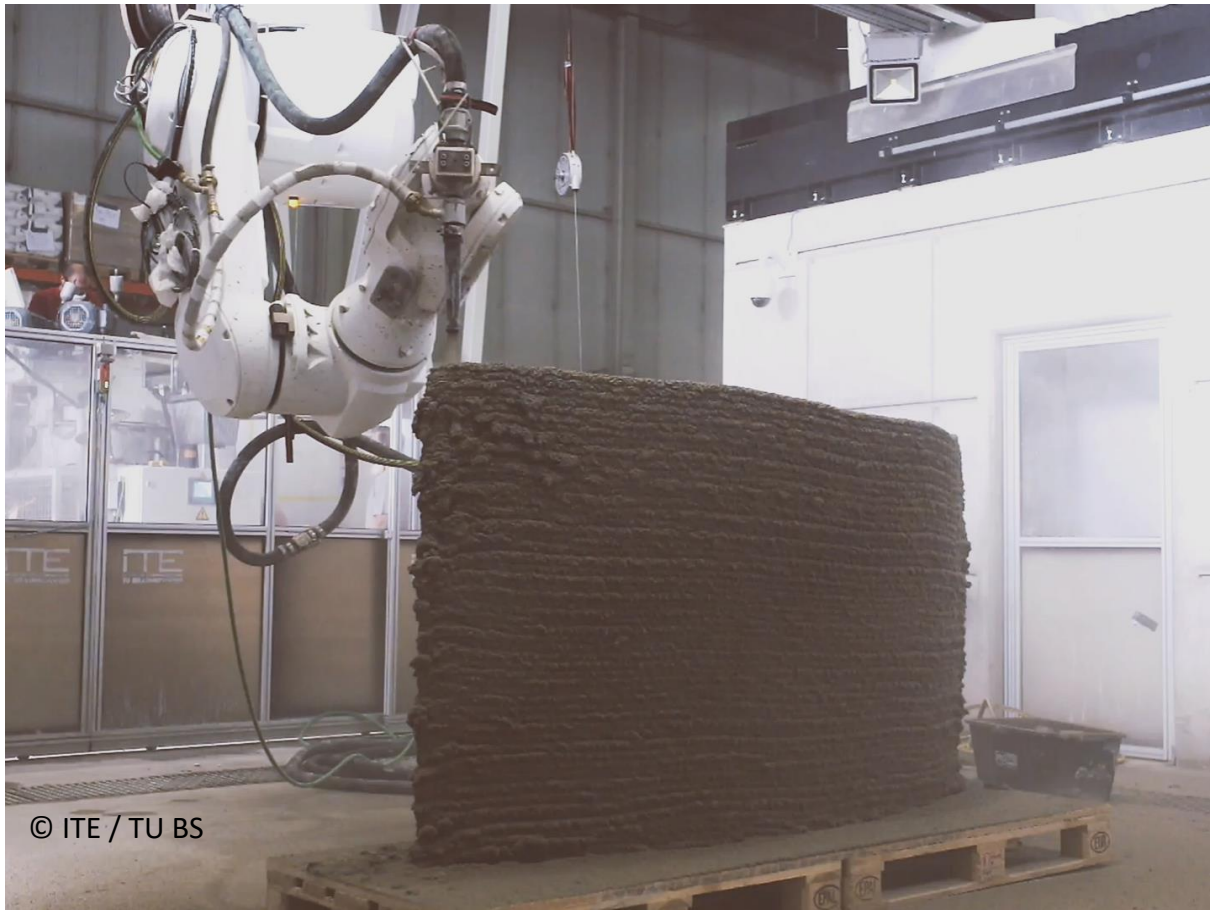


Foto: ITE / TU BS

DBFL | Digital Building Fabrication Laboratory

Foto: ITE / TU BS

Shotcrete 3D Printing (SC3DP), developed at the TU Braunschweig



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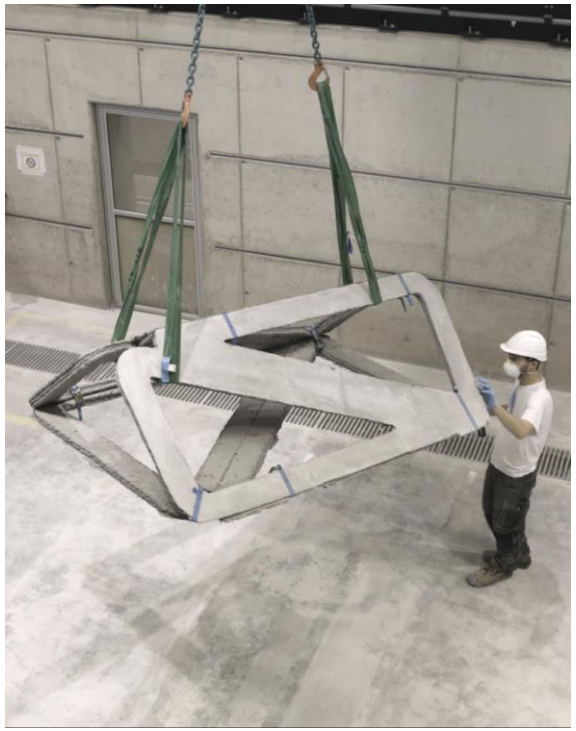
Lindemann, H.; Ibrahim, S.; Dietrich, F.; Herrmann, E.; Raatz, A.; Kloft, H.; Gerbers, R.; Dröder, K.: Development of a Shotcrete 3D-Printing (SC3DP) Technology for Additive Manufacturing of Reinforced Freeform Concrete Structures. In: Wangler, T.; Flatt, R. (Hrsg.): *First RILEM International Conference on Concrete and Digital Fabrication – Digital Concrete 2018.* RILEM Bookseries, Springer, Berlin, 2019, S. 287-298 – DOI: 10.1007/978-3-319-99519-9_27

3D-printed structural concrete elements

Columns

Wall-type Elementes



Spatial Beam Structures

Horizontal Elements

Junior Research Group “Future Urban Coastlines” (TU Braunschweig)

Research project funded by TU Braunschweig (2021-2024)

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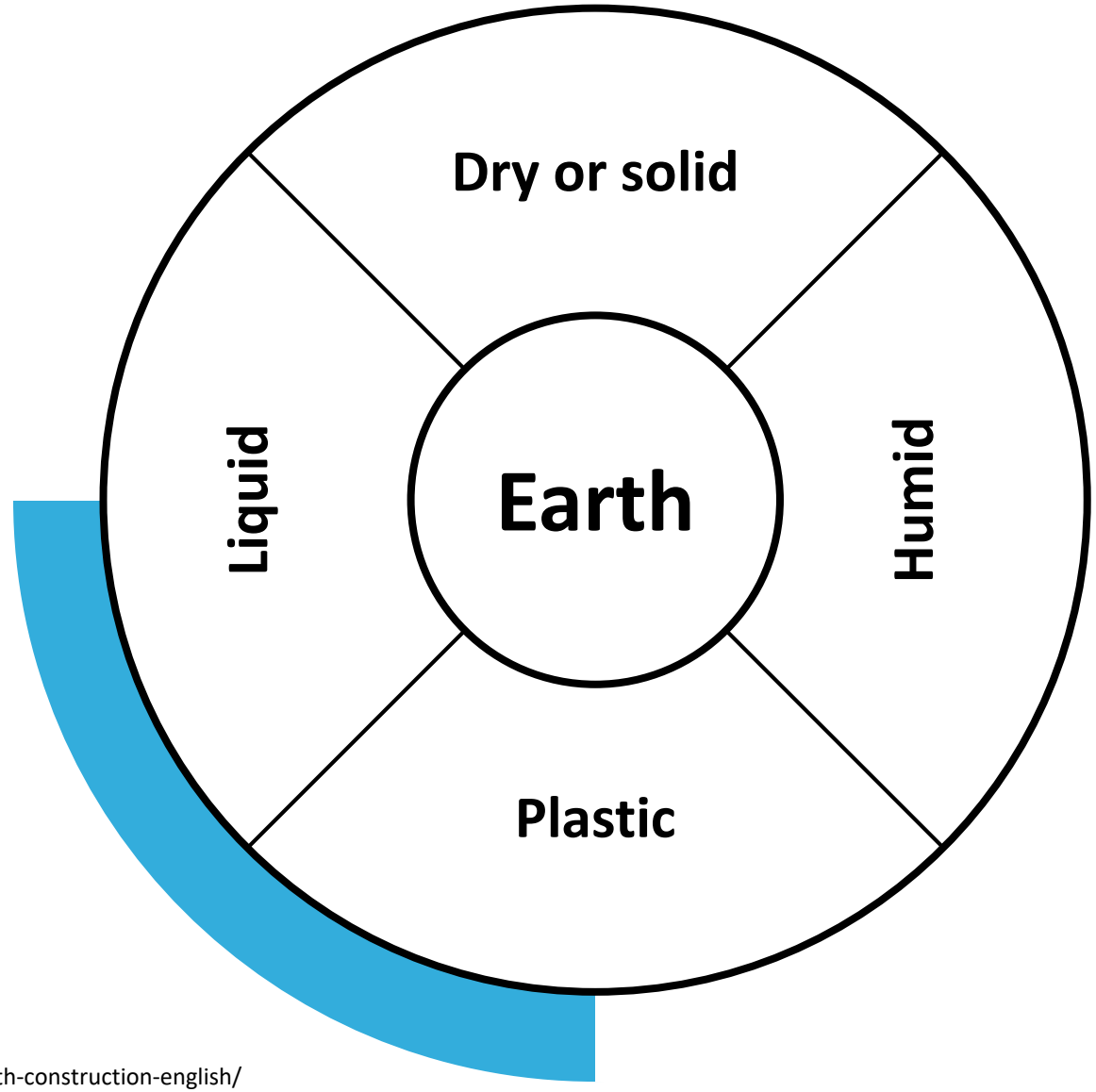
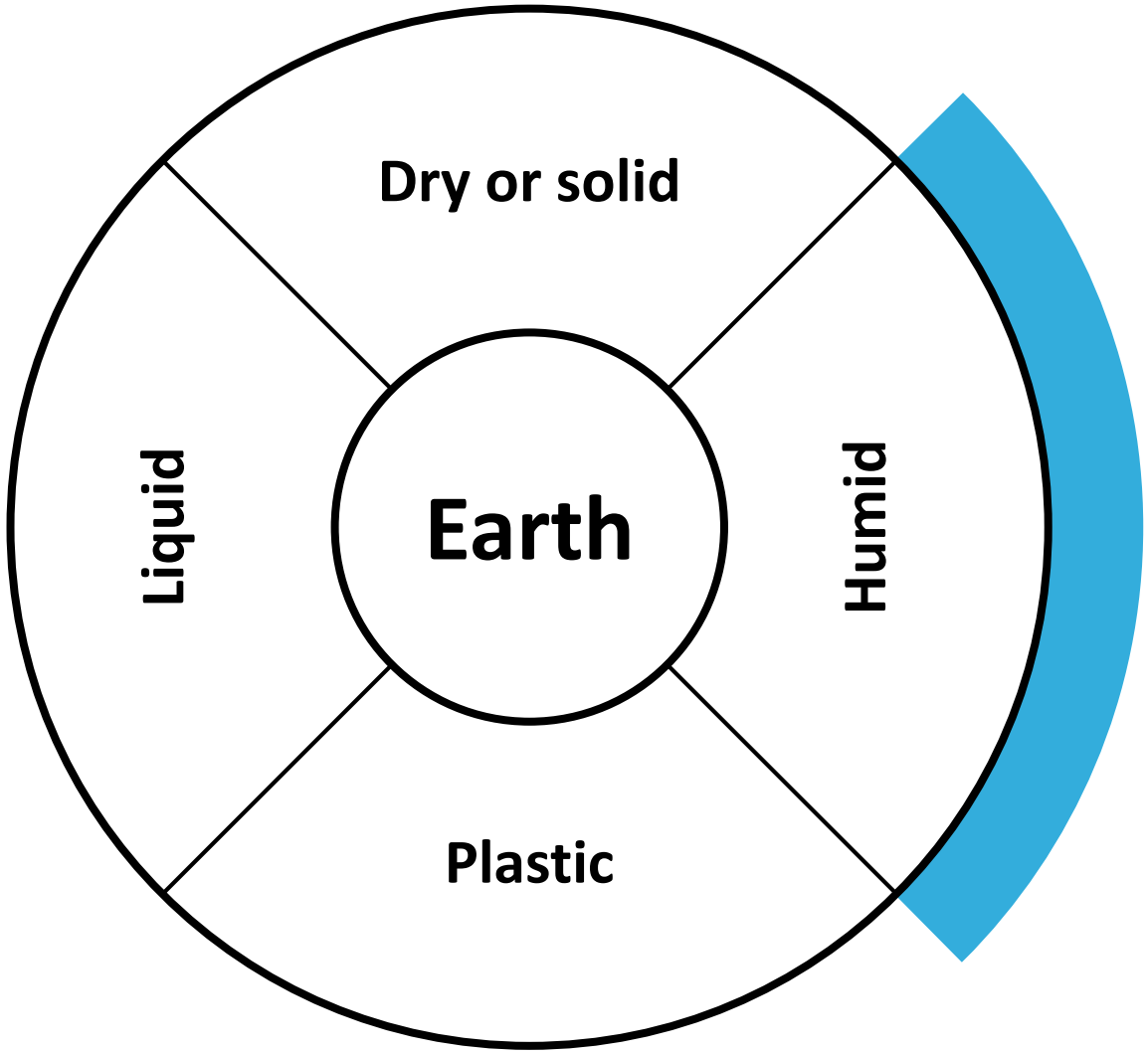
Material consistency | Extrusion based manufacturing processes



Extrusion-based manufacturing process

https://terraversa.es/the-12-techniques-of-earth-construction-english/

Material consistency | Rammed earth



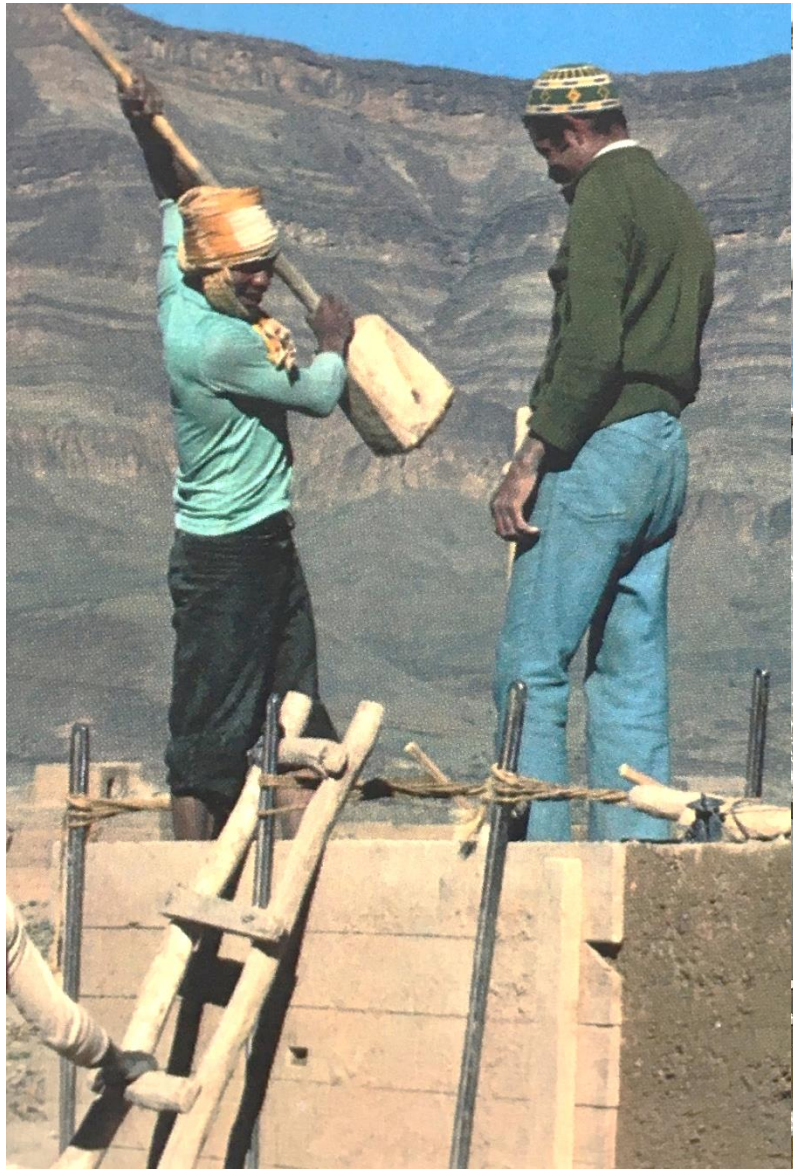
Rammed Earth

https://terraversa.es/the-12-techniques-of-earth-construction-english/

Traditional Rammed Earth construction

Traditional Rammed Earth Construction | Detier (1981)

Mechanisation | Rammed earth construction nowadays



Traditional Rammed Earth Construction | Detier (1981)

Material feeding | Image: J. Gosslar (2022)

Material Compaction | Image: J. Gosslar (2022)

Grundlage

Preliminary student work | Images: J. Gosslar

Grundlage

Preliminary student work | Video: J. Gosslar

Process efficiency through precise process control

Reduce weight

Process efficiency through precise process control

Reduce weight

Reduce formwork size

Process efficiency through precise process control

Reduce weight

Reduce formwork size

Reduce formwork stiffness

Process efficiency through precise process control

Reduce weight

Reduce formwork size

Reduce formwork stiffness

Reduce compaction energy

Process efficiency through precise process control

Reduce weight

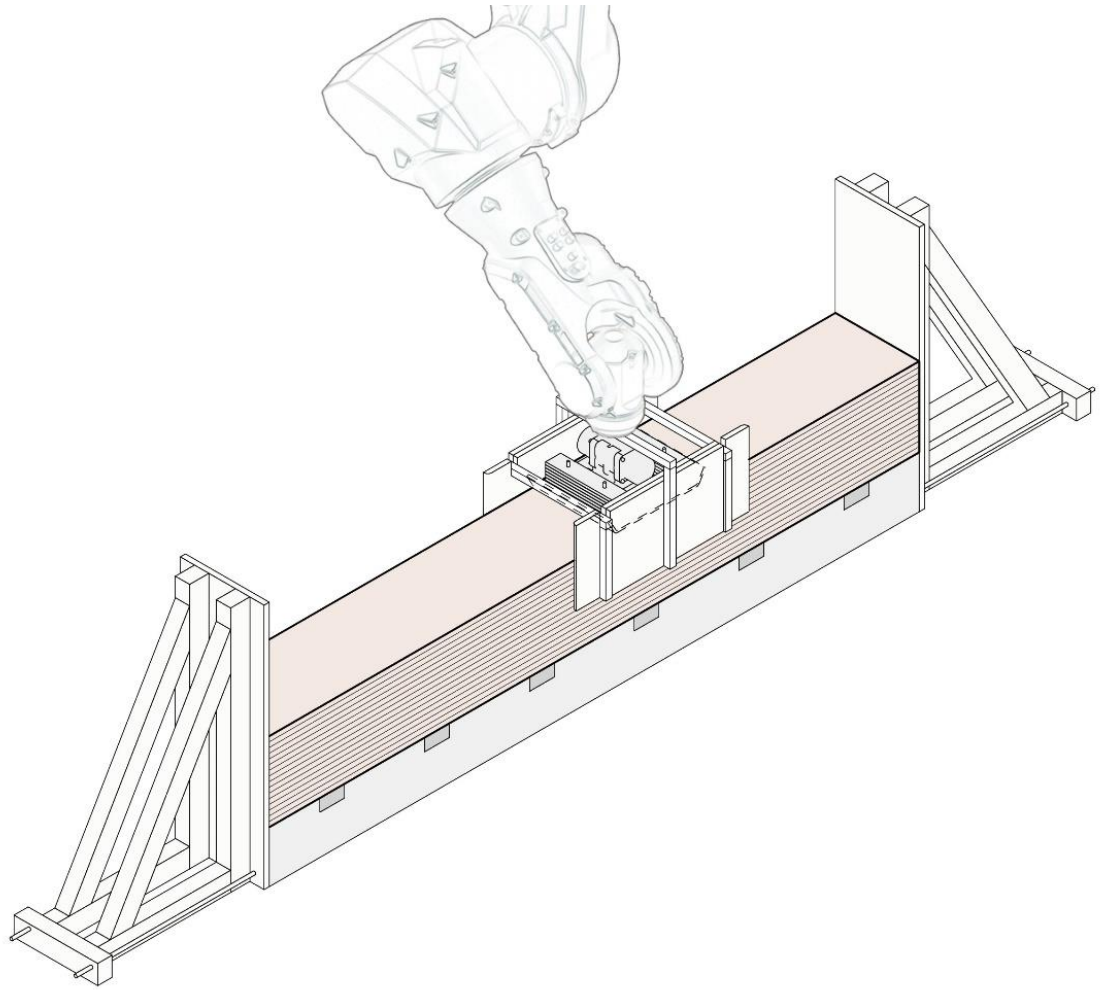
Reduce formwork size

Reduce formwork stiffness

Reduce compaction energy

Reduce layer height

Digitalisation | Robot aided rammed earth construction



Graphic: ITE / TU BS

Reduce weight

Reduce formwork size

Reduce formwork stiffness

Reduce compaction energy

Reduce layer height

Concept | Robot end effector

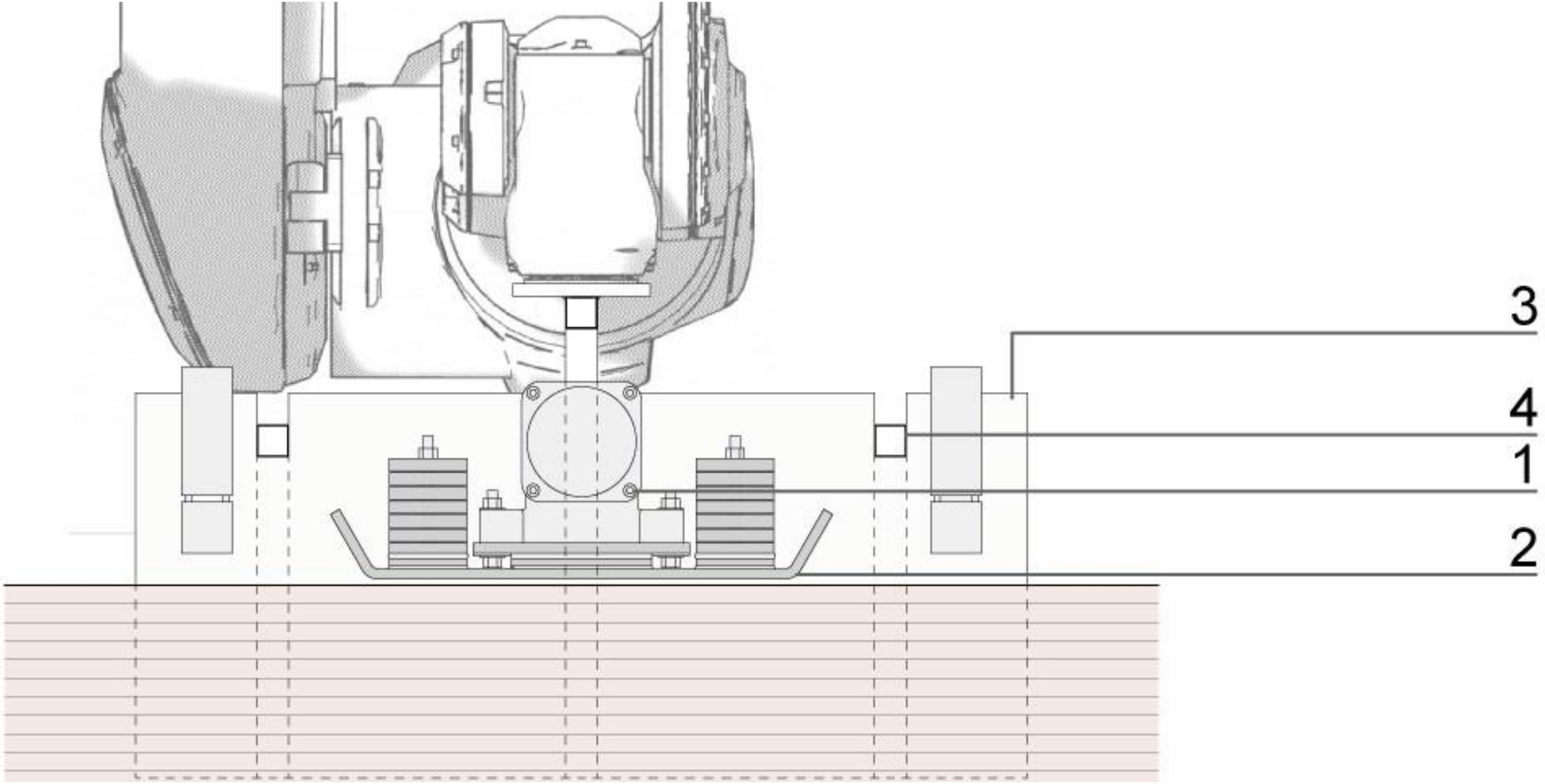
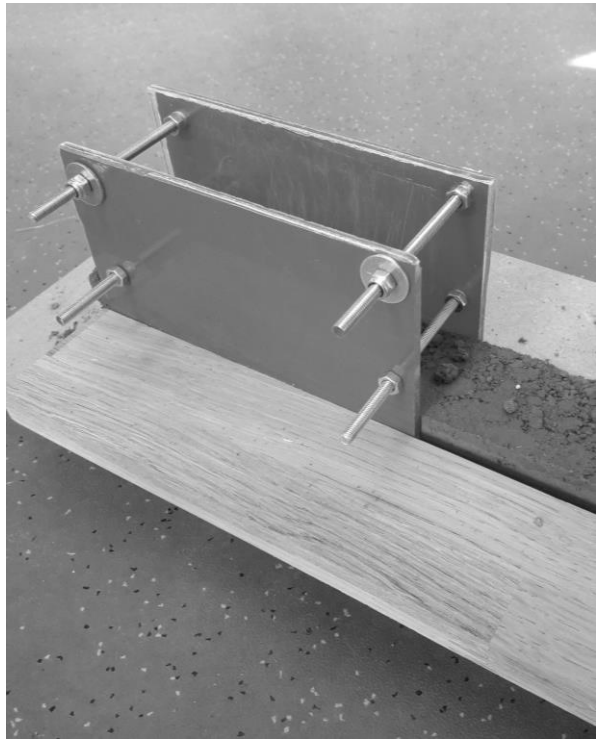


Abb.: ITE/ TUBS

Scaling up of the robotic rammed earth process

Proof of concept | Prototype 1 | Prototype 2



Manual slipform | Photo: J. Gosslar

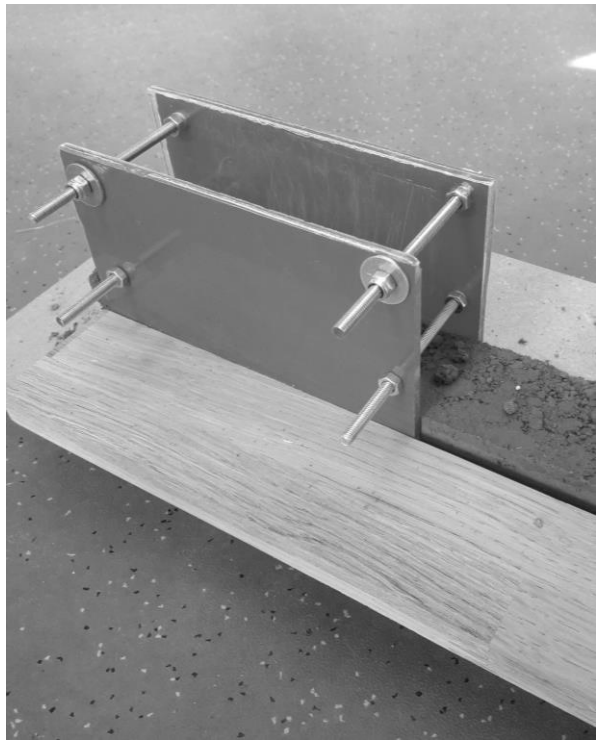
Prototype, Scale 1:10 |Photo: J. Gosslar

Prototype, Scale 1:1 | Photo: ITE/ TUBS

Prototype, Scale 1:1 |Photo: ITE/ TUBS

Scaling up of the robotic rammed earth process

Proof of concept | Prototype 1 | Prototype 2



Manual slipform | Photo: J. Gosslar

Prototype, Scale 1:10 |Photo: J. Gosslar

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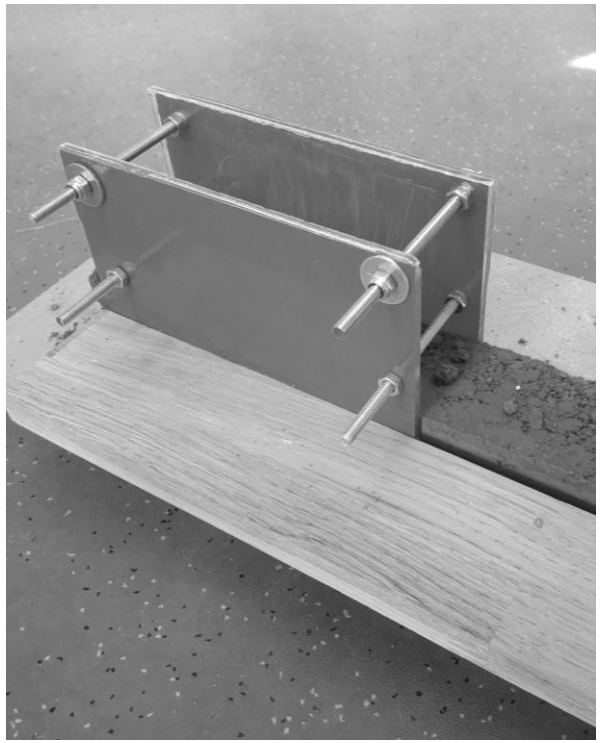
Prototype, Scale 1:1 |Photo: ITE/ TUBS

Scaling up of the robotic rammed earth process

Proof of concept	Prototype 1	Prototype 2



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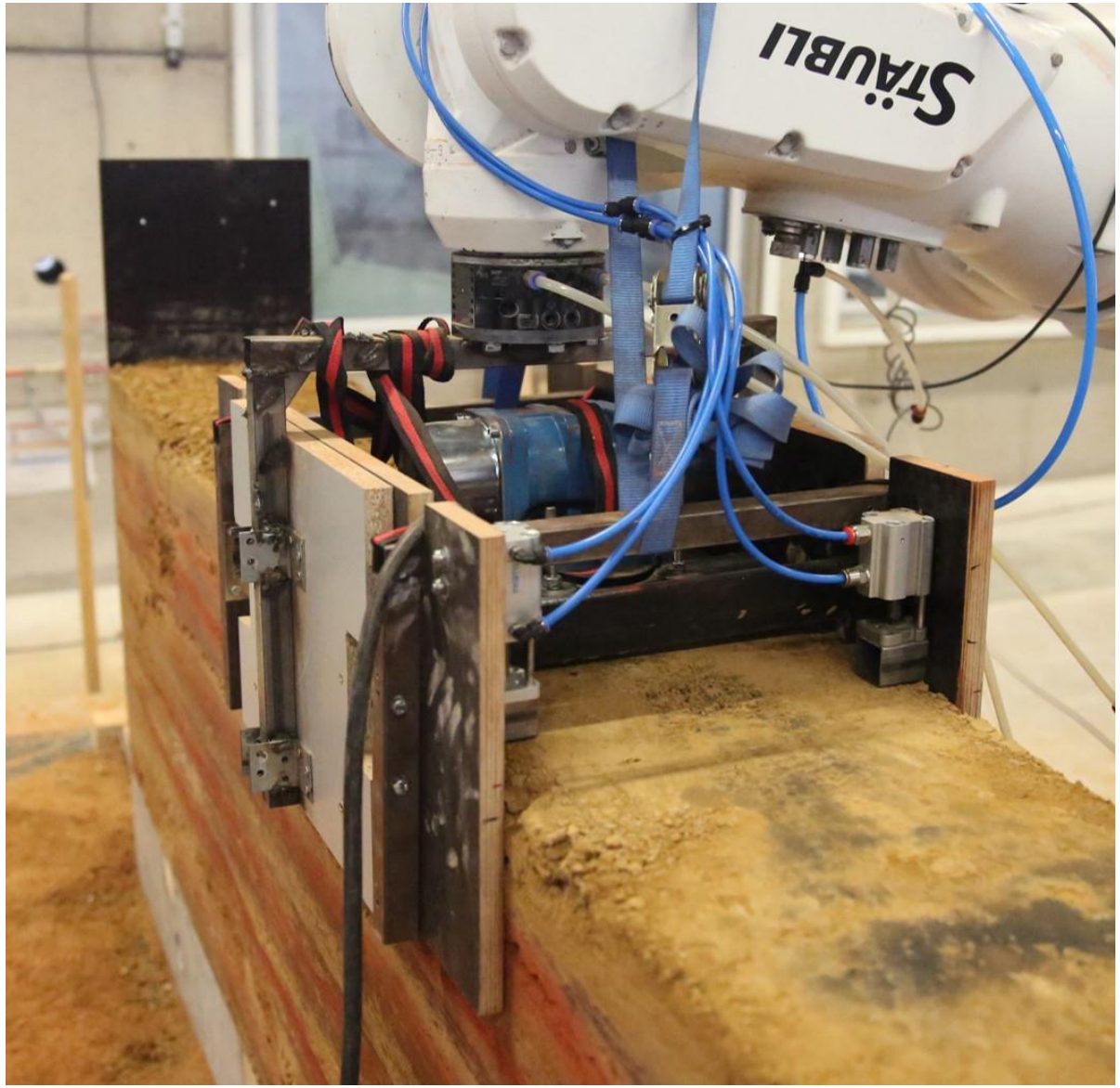
Prototype, Scale 1:1 | Photo: ITE/ TUBS

Prototype, Scale 1:1 |Photo: ITE/ TUBS

Prototypical process developement



Robotischer Schal- / Verdichtungsprozess | ITE / TU BS

Demonstrator | ITE / TU BS

Active slipform and digitally controllable compaction

1: 6 Axis Industrial Robot suspended from gantry

2: Steel frame

3: Active slip form

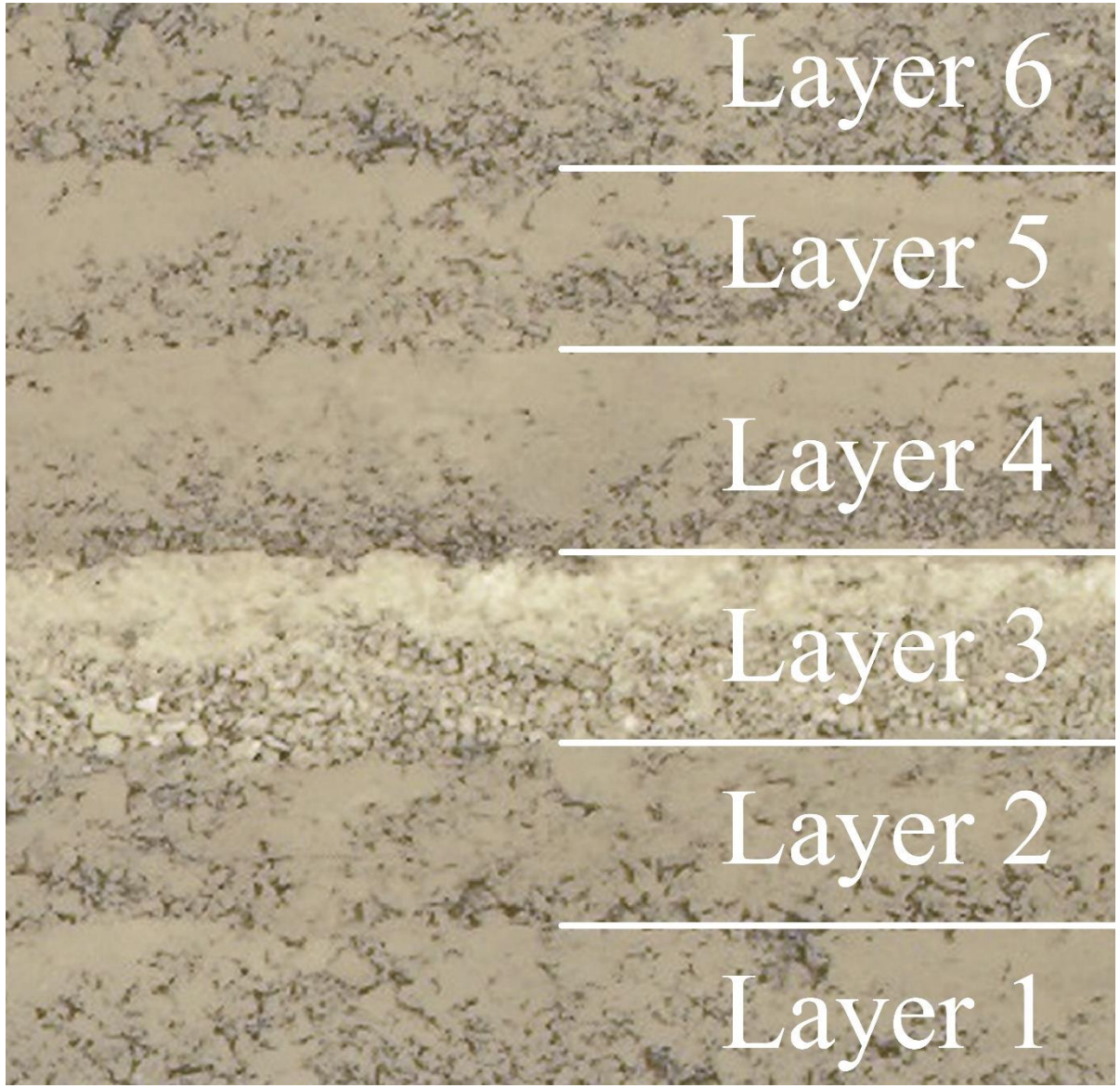
4: Compaction device

Compaction device | ITE/ TUBS

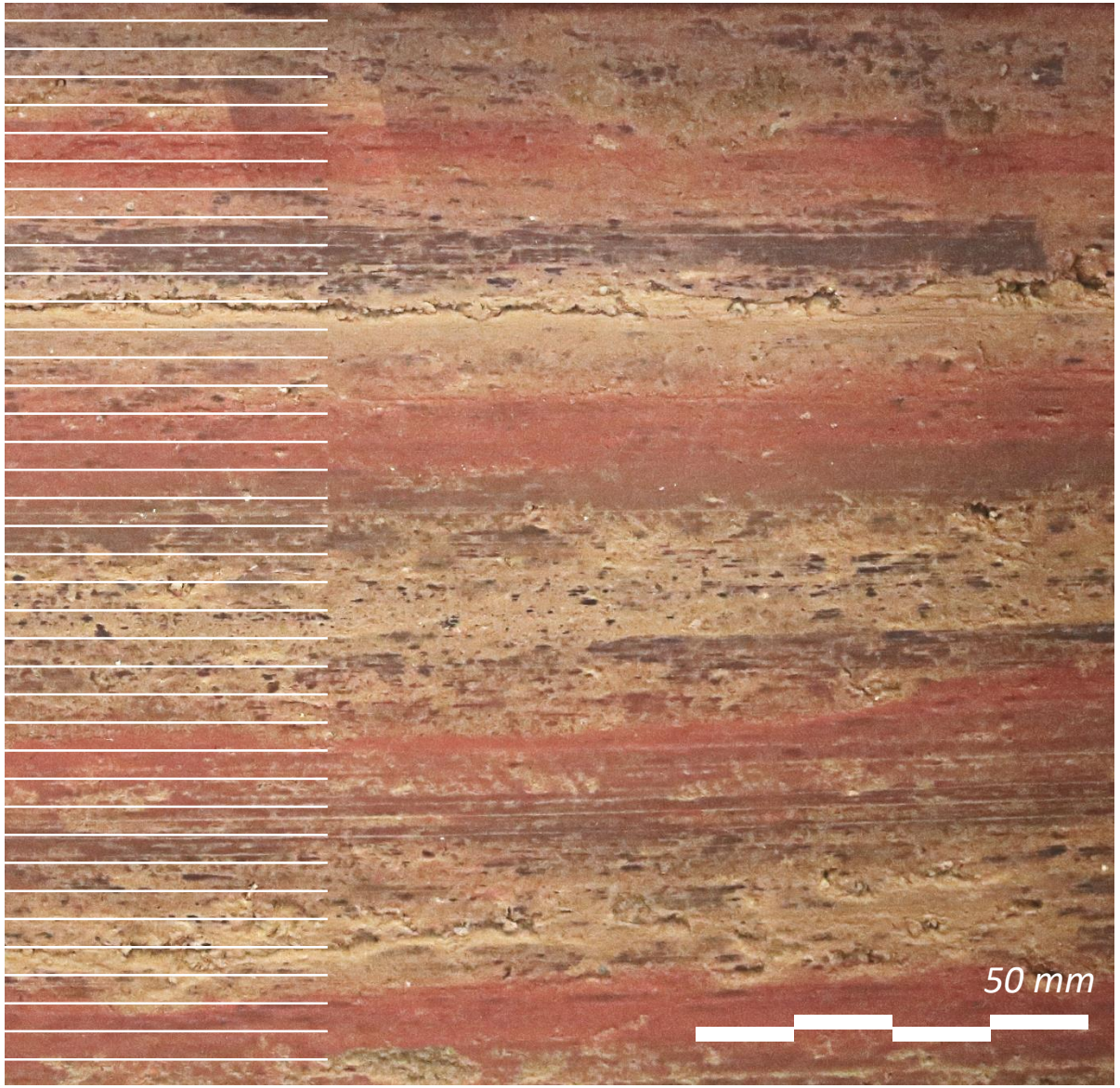
Wall element – cooperative process and automated material feeding

Images.: ITE/ TUBS

Layer height vs. consistent material properties



Rammed Earth Surface compaction | © Claytech Lehmbaustoffe



Robotic rammed earth surface compaction | © ITE / TUBS

Subtractive Post Processing of Rammed Earth

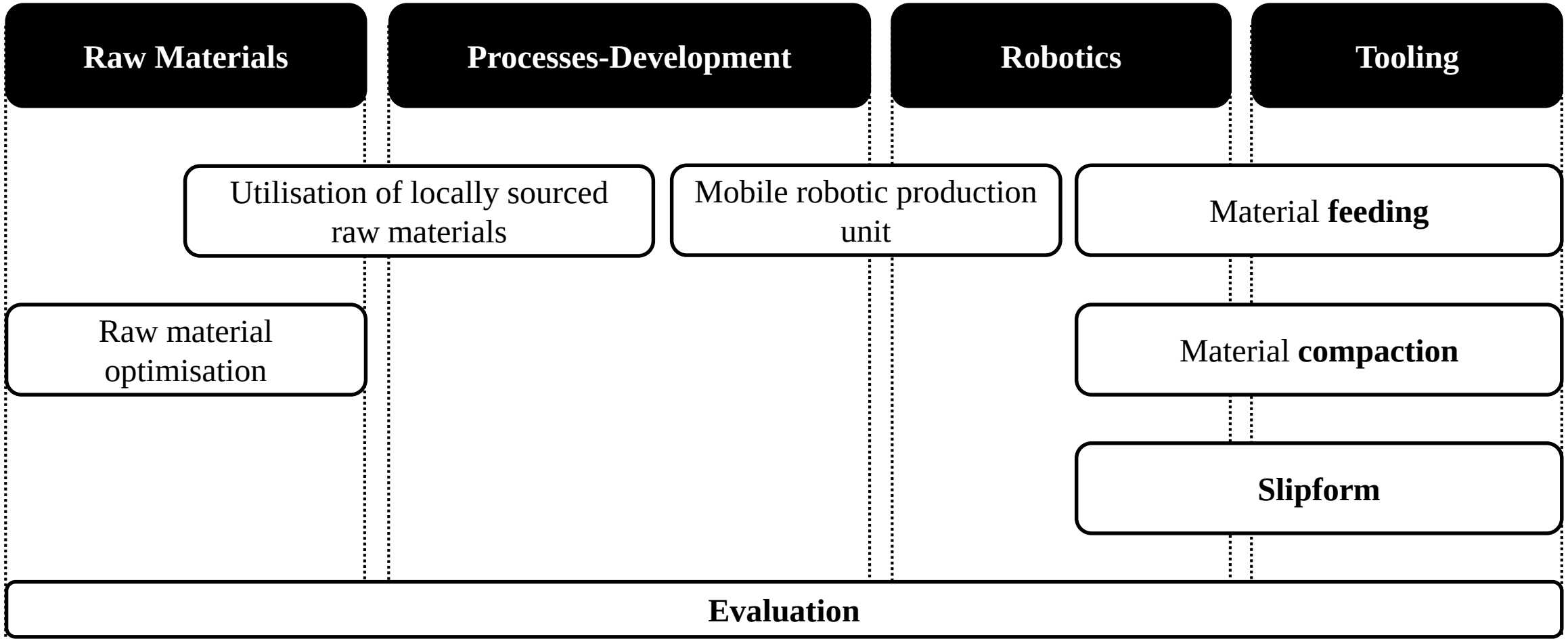
Subtraktive Nachbearbeitung mittels CNC-Kreissäge am DBFL | Abb.: ITE/TUBS

Subtractive Post Processing of Rammed Earth

Schnittbild eines erdfeucht bearbeiteten Stampflehmprobekörpers mittels CNC-Kreissäge | ITE/TUBS

Schnittbild eines trocken bearbeiteten Stampflehmprobekörpers mittels Schleifwerkzeug | ITE/TUBS

Outlook | Mobile, robotic rammed earth: From the lab to on-site production



Research program within the research project initiated by Golehm: https://www.golehm.de/ | ITE / TUBS

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