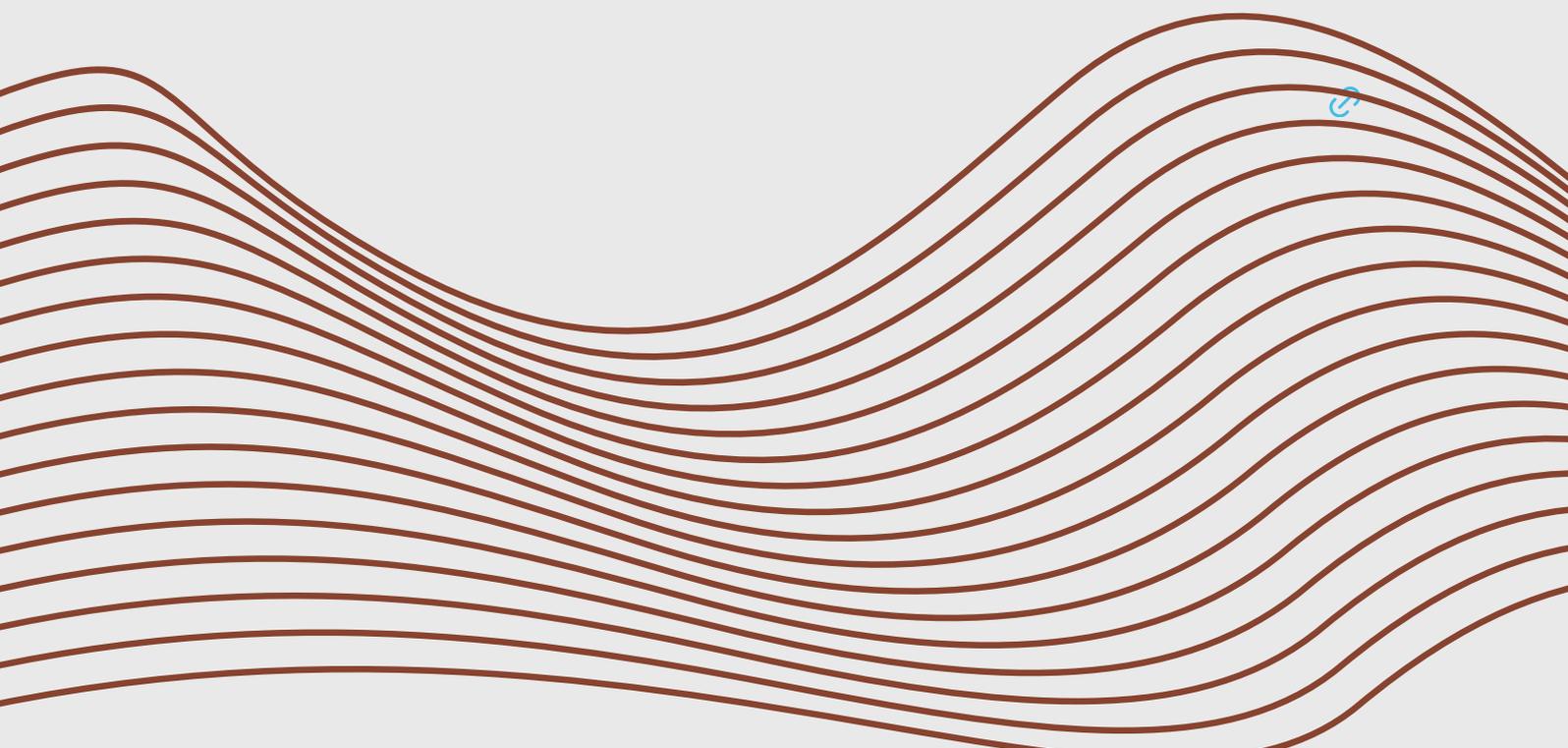




2025-1-PL01-KA210 VET000355378

# Best Practice Guide



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## Fluid-2-Clay



Year:	2025
Partners:	Vertico / EKWC (NL)
Category:	Aspiration
Technology:	Type V (Robotic)   Pump (Ion-Active)
Material:	Class A (Unfired clay)
Geometry:	Non-Planar

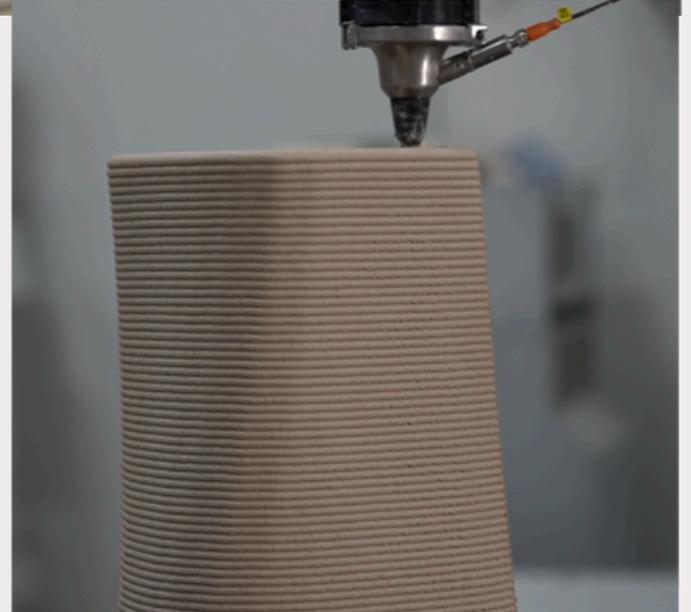
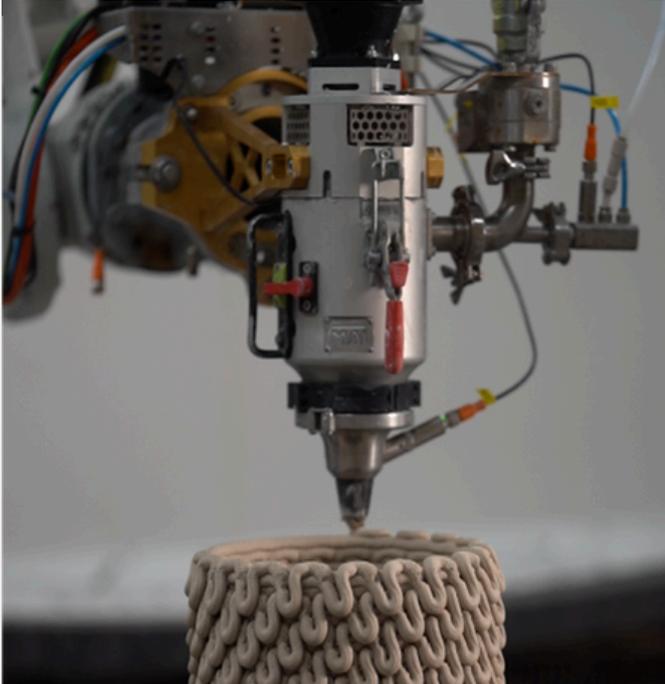
The Fluid-2-Clay project, a collaboration between Vertico (3D concrete printing experts) and EKWC (European Ceramic Workcentre), marks a significant leap in materials science. While traditional earth printing relies on high mechanical force to extrude viscous paste, this project introduces a chemical approach: Ion Activated Clay Deposition.

Using a Type V: Articulated System (6-axis robot), the setup employs a specialised 2-Component (2K) feed. Instead of a stiff paste, the machine pumps a continuous liquid clay slurry. The core innovation is the nozzle, where the slurry is mixed in situ with electrolytes. This interaction leverages Electric Double Layer (EDL) theory, triggering a rapid thixotropic reaction that transforms the pumpable fluid into a structurally stable gel the instant it is deposited.

Crucially, this innovation focuses on printability rather than firing. By mastering this phase change chemically rather than thermally, the project validates Class A (Raw) standards. It delivers the strength required for complex, non-planar geometries without compromising the material's reversibility. While the printing process maintains full circularity (unfired), real-world outdoor applications would require additional weatherproofing or surface stabilisation to preserve the structure.



# Fluid-2-Clay





## ESA Mars Habitat

Year:	2024
Partners:	Vertico / TU Delft (NL)
Category:	Aspiration
Technology:	Type V (Robotic)   Pump + Screw
Material:	Class B (Regolith)
Geometry:	3D (Voronoid)

The ESA Mars Habitat project, a collaboration between Vertico, TU Delft, and the European Space Agency, explores 3D printing with raw Martian soil on Mars. The project aims to minimise the need to ship materials to Mars by maximising In-Situ Resource Utilisation (ISRU), printing directly with local Martian soil.

The project used a 6-axis robot (Type V: Articulated System) coupled with a continuous pump. The objective was to determine how much Vertico base mix (a 3D concrete printing material) could be replaced with Martian soil while maintaining printability. The research found that an impressive substitution rate of 70% was possible. This success is attributed to particle distribution: Martian soil contains extremely fine particles and a high Specific Surface Area (SSA), which creates a sticky, cohesive mix that remains pumpable if the water content is properly adjusted.

By determining the correct water dosage, the team achieved this 70% substitution with MGS-1 (Martian earth simulant) while keeping the hydraulic binder content strictly below the 8% threshold, thereby classifying it as Class B (Stabilised). This offers a crucial lesson for printing on Earth: it demonstrates that particle distribution is a primary driver of printing performance and that local soils can achieve structural integrity with minimal chemical stabilisation.



# ESA Mars Habitat





# InnovA58 Acoustic Barrier



Year:	2024
Partners:	Terrestrial (Netherlands)
Category:	Aspiration
Technology:	Type V (Robotic)     Jetting (Shot-Earth)
Material:	Class B (Stabilized)
Geometry:	3D (Wall)

The InnovA58 Acoustic Barrier project is a collaboration between Terrestrial (process developer), Vertico (robotics), and Summum Engineering (Structural Design), commissioned by ProRail to advance sustainable infrastructure. The project shifts from static prefabrication to autonomous on-site manufacturing, using a custom mobile robot on tracks developed by Vertico to print the structure continuously as it moves along the highway.

The fabrication utilises Shot-Earth 3D Printing (SE3DP), a high-velocity deposition method distinct from extrusion. Rather than depositing a viscous paste, the system pneumatically projects a mixture of earth, gravel, and bio-fibres (hemp or miscanthus). This kinetic energy ensures immediate compaction and high density, achieving structural integrity without formwork or cementitious binders.

Summum Engineering optimised the design into a doubly curved 'crinkle-crinkle' geometry. This sinusoidal form is designed to remain entirely in compression, enabling the wall to resist extreme wind and train loads without steel reinforcement. By adjusting the particle distribution of local soils and utilising this mobile kinematic setup, the project validates the scalability of earth construction, delivering a 90% reduction in CO2 emissions compared with conventional concrete barriers.



# InnovA58 Acoustic Barrier





# Hope Village Center



Year:	2025
Partners:	Hassell / IAAC (Tanzania)
Category:	Applicability
Technology:	Type IV (SCARA)   Pump + Screw
Material:	Class A (Local Earth)
Geometry:	3D (Hub)

The Hope Village Community Building is a project by Hassell, developed in collaboration with the charity One Heart. Designed by ClarkeHopkinsClarke as part of a wider masterplan, the project aims to provide housing, education, childcare, and skills training to lift vulnerable young people in Tanzania out of poverty.

The building features semi-permeable walls, 3D printed from locally sourced clay, paired with a corrugated iron roof engineered by Eckersley O'Callaghan. The walls were produced using a WASP Crane 3D-printing system, with clay sourced within a 25-mile radius of the site. 3D printing was selected for the walls' complex geometry, which admits controlled amounts of sunlight and airflow, enabling passive climate regulation.

When selecting materials, the project team adopted a holistic approach to sustainability, considering environmental and social impacts before and during construction, using low-impact, locally sourced clay, and planning for the building's end of life to ensure the material is 100% recyclable. The result is a highly sustainable building that reflects its surrounding environment, meets the needs of the local community, and pushes the boundaries of large-scale earthen 3D printing globally.



# Hope Village Center





## Lib Earth House Model B

Year:	2025
Partners:	Lib Work / WASP (Japan)
Category:	Applicability
Technology:	Type IV (SCARA)   Pump + Screw
Material:	Class B (Earth + Lime)
Geometry:	2.5D (Planar)

Lib Work's Lib Earth House is a construction experiment that combines large-scale 3D printing with a timber frame to create an earth-based home. The process begins with a conventional foundation. A gantry-style 3D printer is then installed on the foundation and prints the external wall shell layer by layer. Because the printer follows a programmed path, it can produce both straight walls and curved forms with consistent thickness.

After printing, the machine is removed, and a wooden structural frame is built within the printed shell. This hybrid approach is important: the timber frame carries the major structural loads, while the printed earth walls serve as the building envelope and shape-giving element.

The printing material is a mix of soil, lime, and plant fibres without cement, designed to lower embodied carbon compared with reinforced concrete. Lib Work presents the project as a response to labour shortages and as a pathway to faster, more standardised on-site housing fabrication.



# Lib Earth House Model B





## To Grow a Building

Year:	2025
Partners:	MIT / WASP (Italy)
Category:	Aspiration
Technology:	Type IV (SCARA)   Pump + Screw
Material:	Class A (Living Soil)
Geometry:	Non-Planar

WASP and architect Nof Nathasohn collaborated to create a new threshold where mechanical precision meets nature's unpredictability, titled "To Grow a Building". Developed as part of the WASP Residency Programme for the Venice Biennale, the project explores the concept of living architecture.

Combining a new 3D printed material made 100% from local Massa Lombarda soil and embedded with selected seeds from 14 different plant species, the project moves beyond sterile construction. Over time, the seeds awaken and their sprouts and roots spread through the material, forming a natural reinforcement system that binds the structure.

Their design was based on botanical data, ensuring each element provides the precise moisture and light conditions required for the plants to mature. Once complete, the structure becomes a living, breathing ecosystem, attracting insects by providing food and habitat while supporting biodiversity. By collaborating with nature rather than dominating it, the design embraces the passage of time, allowing the architecture to evolve and adapt with the seasons.



# To Grow a Building





## Intrusion Earth AM

Year:	2024
Partners:	TU Munich (Germany)
Category:	Accessibility
Technology:	Type V (Robotic)   Batch (Intrusion)
Material:	Class A (Earth Paste)
Geometry:	3D (Volumetric)

The Intrusion Earth AM (IEAM) project, part of the A10 research framework at TU Munich, establishes a distinct fabrication logic within additive manufacturing. Investigating material-process interactions, this research introduces a particle-bed strategy, distinct from standard deposition methods, in combination with extrusion-based techniques.

Using a 6-axis robotic arm (Type V: Articulated System), the setup extrudes a Class A (Earth Paste) material composed of clay, sand, and straw fibres. The fabrication follows a cyclic five-step workflow: first, Earth printing deposits the clay, immediately followed by Aggregate deposition of recycled brick. This is followed by a Compacting step, in which mechanical pressure forces the paste to intrude into the aggregate voids. Once levelled, the cycle repeats.

Crucially, this mechanical intrusion strategy aims to decouple pumpability from buildability. By relying on compaction rather than flow, the process minimises mixing water. This significantly reduces shrinkage and drying time while increasing green strength. Validated through 1:4-scale demonstrators, the project shows that mastering the reciprocal dependencies between paste rheology and aggregate grain distribution enables high structural fidelity without chemical stabilisation.



# Intrusion Earth AM

(a)



(b)



(c)



1:20 Model



1:4 Prototype





## Living Soil Wall

Year:	2022
Partners:	Univ. Virginia (USA)
Category:	Aspiration
Technology:	Type V (Robotic)   Pump (Paste)
Material:	Class A (Soil + Seeds)
Geometry:	3D (Vessel)

University of Virginia (UVA) researchers are exploring a new idea: 3D-printing soil into structures that also function as living planting systems. Rather than adding greenery later (such as planters or green roofs), their approach aims to build with the landscape by printing a soil-based form that supports plant growth from the outset.

They create a printable “soil ink” by mixing local soil with water, then extrude it through a nozzle to build shapes layer by layer—similar to concrete 3D printing, but using earth as the primary material. An educational advantage of this method is that it is potentially low-energy and circular: the printer mainly needs energy for motion and pumping, and failed prints can be broken down, remixed, and printed again.

To make the structures biologically active, the team tested two strategies: printing soil and seeds in separate layers, and mixing seeds into the soil before printing. Both approaches produced prototypes that sprouted. A major technical challenge is water management: extrusion compacts the soil and reduces air spaces, causing printed soil to dry faster and limiting suitable plants to drought-tolerant species.



# Living Soil Wall





# TOVA

Year:	2022
Partners:	IAAC (Spain)
Category:	Applicability
Technology:	Type IV (SCARA)   Pump + Screw
Material:	Class A (Earth + Aloe)
Geometry:	3D (House)

TOVA is a collaboration among the Institute for Advanced Architecture of Catalonia (IAAC), WASP, and UN-Habitat, investigating large-scale additive manufacturing with raw earth as a reversible construction system. As Spain's first 3D-printed building, TOVA aims to achieve a near-zero carbon footprint and produce zero waste.

The project was realised using a Type IV: Polar System (Crane WASP), enabling large working envelopes and continuous deposition while maintaining precise control over toolpath geometry. From a material perspective, TOVA operates within Class A: Raw / Reversible standards. The printed mixture is based on locally excavated soil, processed and calibrated on site with natural stabilisers, including cellulose and aloe. As the building is exposed to rain, a wooden roof and a natural coating derived from egg whites were applied for protection.

The architectural geometry is deliberately contoured, using curvature, wall thickening, and internal cavities to achieve structural stability through form rather than reinforcement. Critically, TOVA demonstrates a zero-waste construction cycle: at the end of its life, the structure can be crushed, rehydrated, and returned to the soil, positioning additive earth construction as a viable circular alternative to conventional building systems.



TOVA



[www.earth3d.eu](http://www.earth3d.eu)



# Skylos

Year:	2022
Partners:	Emerging Objects (USA)
Category:	Aplicability
Technology:	Type IV (SCARA)   Pump + Screw
Material:	Class A (Adobe)
Geometry:	3D (Shell)

The Skylos project, a collaboration between Emerging Objects and the Frontier Drive-Inn, explores additive manufacturing for sustainable, vernacular shelter. Moving beyond reliance on heavy industrial infrastructure, the project prioritises mobility and rapid deployment, enabling on-site fabrication in remote environments.

The research utilises a Type IV SCARA system coupled with a pump-and-screw mechanism. This lightweight, kinematic setup is designed to extrude a traditional Class A (Adobe) mix. By utilising locally sourced mud, silt, and straw without cementitious stabilisers, the project achieves a fully reversible, low-carbon building lifecycle. The extrusion process relies on the thixotropic properties of the wet earth to retain shape immediately upon deposition, eliminating the need for chemical accelerators.

Structurally, Skylos is defined by its 3D (Shell) geometry. The design integrates sinusoidal corrugations and surface textures to enhance stability. This geometric stiffening compensates for the material's lack of tensile strength, enabling vertical thin-shell construction. By combining ancient material science with accessible robotics, Skylos demonstrates the potential of raw earth to meet modern housing needs through automated, resilient construction.



Skylos



[www.earth3d.eu](http://www.earth3d.eu)



# Urban Reef Bio-Composites

Year:	2022
Partners:	Urban Reef (Netherlands)
Category:	Aspiration
Technology:	Type III (Delta)   Continuous (Screw)
Material:	Class A (Raw / Bio)
Geometry:	3D (Complex)

Urban Reef is a research-driven initiative exploring how cities can evolve into bio-inclusive environments that support multiple forms of life. In response to biodiversity loss inherent in dense metropolitan areas, the project challenges human-centred urban design by introducing living, adaptive structures.

Using large-scale LDM 3D printing with a Delta WASP 40100 Clay system, Urban Reef fabricates "Reefs"—algorithmically designed microhabitats. The geometries are highly complex and porous, engineered to retain water, regulate humidity, and create diverse microclimates. These structures serve as urban micro-refugia, providing favourable conditions for plants, fungi, and microorganisms to thrive.

The material composition is strictly Class A (Raw/Bio), comprising clay composites, mycelium, seeds, and recycled organic matter. By avoiding cementitious binders, the project ensures the structures remain chemically compatible with organic growth. By combining digital fabrication with ecological material research, Urban Reef offers a scalable model for climate-resilient cities. The project demonstrates how additive manufacturing can move beyond static shelter to create environmentally regenerative infrastructure that meets the needs of all living things, not just humans.



# Urban Reef Bio-Composites





# TECLA

Year:	2021
Partners:	WASP / MCA (Italy)
Category:	Applicability
Technology:	Type III (Delta)   Pump + Screw
Material:	Class B (Earth + Lime)
Geometry:	3D (Dome)

TECLA is an experimental housing project that demonstrates how digital fabrication and natural materials can transform contemporary construction. Developed by WASP and designed by Mario Cucinella Architects (MCA), the project meets the global demand for affordable, low-impact housing through a circular building model.

Built in Massa Lombarda, Italy, TECLA is the first fully 3D-printed habitat constructed simultaneously by multiple collaborative printers (Crane WASP system). The project's primary objective was to transform raw earth into a high-performance architectural system. The design features a double-dome geometry that integrates the structure, roof, and envelope into a single continuous form. This morphological approach optimises structural stability while providing thermal insulation and natural ventilation.

The material strategy uses Class B (Earth + Lime), sourcing local soil mixed with a small percentage of hydraulic lime to ensure durability against weathering while maintaining a low carbon footprint. TECLA marks a major milestone in on-site digital construction, demonstrating that modular, multi-printer technology can fabricate large-scale structures from locally sourced, reusable, and recyclable materials. It offers a replicable model for sustainable housing adaptable to diverse climates and social contexts.



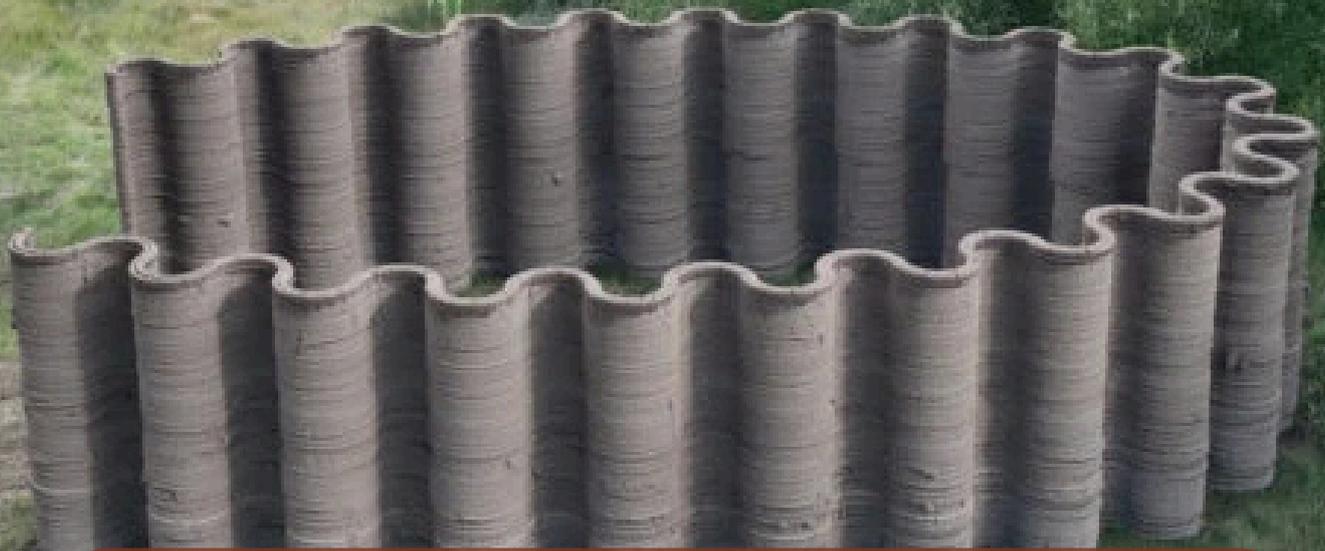
TECLA



[www.earth3d.eu](http://www.earth3d.eu)



# Muddy Robots



Year:	2021
Partners:	UC Berkeley (Rael)
Category:	Applicability
Technology:	Type V (Robotic)   Pump + Screw
Material:	Class A (Adobe)
Geometry:	3D (Dome)

Muddy Robots is a research-led architectural project by Ronald Rael at UC Berkeley, exploring how robotic additive manufacturing can revitalise earth construction to address contemporary housing crises. Building on Rael's work at the intersection of technology and culture, the project critiques industrialised building practices by revisiting ancestral earthen knowledge.

The project employs a Type V (Robotic) system that integrates advanced digital fabrication with traditional adobe construction. Drawing on Rael's heritage, the project reimagines earth as a healthy, culturally significant material for large-scale production. A key innovation is the development of mobile, accessible construction systems capable of printing on site, even in challenging terrain. This includes the fabrication of the world's first on-site 3D-printed mud roof, inspired by Nubian vault technology.

Rather than focusing on individual self-building, Muddy Robots proposes scalable, code-compliant solutions for mass housing. By advocating a return to natural, biodegradable (Class A) materials, the project offers a sustainable alternative to high-VOC, resource-intensive methods. It shows that advanced robotics can be leveraged not to erase traditional craft but to scale it for a healthier built environment.



# Muddy Robots





## Casa Covida

Year:	2020
Partners:	Emerging Objects (USA)
Category:	Applicability
Technology:	Type IV (SCARA)   Pump + Screw
Material:	Class A (Adobe / Straw)
Geometry:	3D ((Coiled)

Casa Covida is an experimental housing project in the high-alpine desert of Colorado's San Luis Valley. Developed by Emerging Objects in response to the social and spatial needs that emerged during the pandemic, the project reimagines domestic architecture through the lens of collective living, resilience, and connection to place.

The structure is built using a portable on-site 3D printing system featuring a lightweight SCARA robotic arm (Type IV). This setup enables continuous material delivery, allowing the fabrication of structures far larger than the printer itself. The dwelling comprises three interconnected living units — designed for sleeping, bathing, and gathering — and is constructed using traditional adobe (sand, silt, clay, water, straw).

Technically, the project integrates low-tech manual processes with advanced digital fabrication. The use of Class A (Adobe/Straw) material ensures the building maintains a strong spatial relationship with the landscape and the ground, while remaining fully biodegradable. By bridging ancestral knowledge and contemporary construction technologies, Casa Covida demonstrates a flexible, accessible, and locally rooted model for sustainable housing that requires minimal infrastructure to deploy.

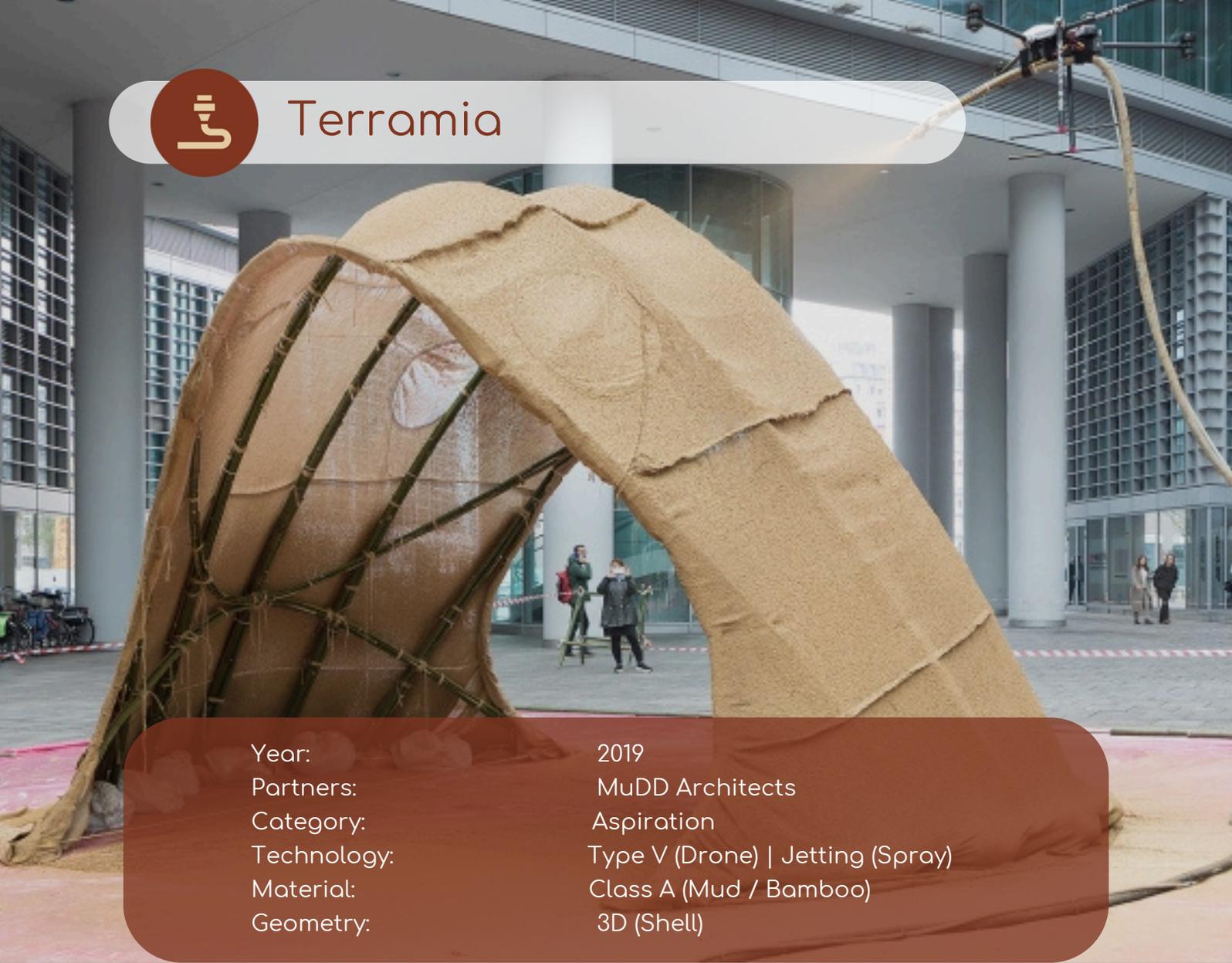


# Casa Covida





# Terramia



Year:	2019
Partners:	MuDD Architects
Category:	Aspiration
Technology:	Type V (Drone)   Jetting (Spray)
Material:	Class A (Mud / Bamboo)
Geometry:	3D (Shell)

Terramia is an experimental pavilion exploring fast, affordable, and sustainable construction methods for emergency housing. Developed by MuDD Architects, the project uniquely combines digital fabrication technologies with natural materials to propose a robust alternative to conventional lightweight emergency shelters.

The structure comprises three doubly curved earthen shells, formed using a bending-active system of bamboo and CNC-cut jute fabric. The core innovation is the use of aerial drones (Type V) to lift the fabric formwork and spray it with a mortar made from clay, sand, and rice husks. This "bioshotcrete" approach eliminates the need for heavy machinery or complex scaffolding. The sprayed earthen mix forms a durable, bio-based structural envelope.

Supported by Summum Engineering, Terramia combines shotcrete principles with wattle-and-daub traditions, aided by robotics. By leveraging drones for material delivery and formwork positioning, the project demonstrates how digitally assisted earth construction can deliver resilient, code-compliant, and scalable solutions for transitional housing, using agricultural by-products and local soils to achieve a high-performance shell.



Terramia



[www.earth3d.eu](http://www.earth3d.eu)



## Wall with Staircase

Year:	2019
Partners:	IAAC / WASP
Category:	Applicability
Technology:	Type III (Delta)   Pump + Screw
Material:	Class A (Earth)
Geometry:	3D (Stair)

This experimental project, developed by WASP in collaboration with the Institute for Advanced Architecture of Catalonia (IAAC), explores the structural potential of on-site 3D printing for load-bearing earth construction. The prototype features a 40 cm-thick 3D-printed wall that seamlessly integrates a functional staircase, demonstrating how architectural elements can be embedded directly within printed structures.

Produced on the Crane WASP 3D printer (Type III), the wall uses a bio-based clay-and-rice-fibre mix supplied by RiceHouse (Class A). The printing process took approximately 40 hours and consumed two cubic metres of material. A key design strategy was internal surface modulation, which optimised structural performance and stability while maintaining material efficiency.

The project also investigated hybrid construction systems that allow wooden elements to be naturally anchored into the printed wall during fabrication. This validates the potential to integrate carpentry with printed earth without mechanical fasteners. The collaboration contributes to a broader research agenda focused on developing affordable, scalable, and sustainable on-site 3D printing solutions for humanitarian applications and future architectural models.



# Wall with Staircase





## Hearth (Mud Frontiers)



Year:	2019
Partners:	Emerging Objects
Category:	Applicability
Technology:	Type IV (SCARA)   Pump + Screw
Material:	Class A (Adobe / Wood)
Geometry:	2.5D (Wall)

Part of the "Mud Frontiers" research by Emerging Objects, *Hearth* examines how traditional earthen building practices can be reimagined using advanced digital fabrication. Developed across the historic borderlands of the Rio Grande watershed, the project draws heavily on the earthen architecture and pottery traditions of the Ancestral Pueblo and Indo-Hispano cultures.

Using a portable robotic 3D-printing system (Type IV: SCARA), locally harvested soils were transformed directly into architectural elements on site. *Hearth* is one of four experimental installations — alongside *Beacon*, *Lookout*, and *Kiln* — that examine structural performance, thermal behaviour, and cultural expression in 3D-printed mud.

The project investigates the potential of using mud, clay, water, and straw to build contemporary, full-scale structures. By combining ancestral craft knowledge with robotic additive manufacturing, *Hearth* demonstrates that accessible, low-labour, and environmentally responsible construction is feasible. It offers a scalable model for future earth-based architecture that respects the cultural heritage of its location while utilising readily available, sustainable materials.



## Hearth (Mud Frontiers)





## A. Clay Rotunda



Year:	2021
Partners:	ETH Zurich
Category:	Aspiration
Technology:	Type V (Robotic)   Batch (Place)
Material:	Class A (Unfired Clay)
Geometry:	3D (Cylinder)

The Clay Rotunda is an experimental earthen structure that forms the soundproof outer shell of the SE MusicLab in Bern. Developed by ETH Zurich, the project addresses the urgent need for low-impact construction by combining traditional clay building expertise with advanced computational design and robotic fabrication.

Unlike extrusion-based projects, this structure uses a "Batch (Place)" method. A mobile robotic system (Type V) precisely placed over 30,000 soft clay bricks in situ. The data-driven fabrication process integrated structural analysis and material behaviour to guide the placement of each unit. The resulting free-standing cylindrical form stands 5 metres high and has a diameter of nearly 11 metres, with a wall thickness of only 15 cm.

Stability is achieved through an undulating geometry rather than reinforcement. The project showcases the acoustic and climatic regulation properties of unreinforced clay (Class A), as well as its zero-waste lifecycle. By treating the clay brick as a digital pixel, Clay Rotunda offers a scalable model for sustainable, emission-free architecture that bridges high-tech research and craft-based construction practices.



## A. Clay Rotunda





## B. Impact Printed Earth



Year:	2024
Partners:	ETH Zurich (Switzerland)
Category:	Aspiration
Technology:	Type V (Robotic)   Jetting (Shooting)
Material:	Class A (Excavated)
Geometry:	Non-Planar

Developed by Gramazio Kohler Research at ETH Zurich, "Impact Printed Earth" introduces a novel fabrication logic based on kinetic energy rather than chemical setting. The project employs multiple robotic platforms and is categorised as a Type V: Articulated System, evolving from a laboratory gantry to an autonomous mobile excavator to enable the transition from pre-fabrication to direct in situ construction.

The core innovation is the high-velocity deposition of dense material. A custom end-effector extrudes and portions earth pellets, projecting them at speeds of up to 10 metres per second. This kinetic impact generates immediate cohesion, enabling the system to process a stiff, high-yield-stress mix (75% excavation waste) without the pumpability constraints or liquefaction risks inherent in standard extrusion.

Optimised for Class A (raw) materials distinct from cementitious binders, the process achieves immediate consolidation suitable for 1- to 2-storey structures. By combining this "shooting" mechanism with potential reinforcement integration, the project demonstrates how ballistic deposition can unlock geometric complexity within circular supply chains. Critically, although the robotic architecture enables outdoor fabrication, the raw earth material remains hydrophilic; exposed structures therefore require protective surface finishing to prevent erosion.



## B. Impact Printed Earth





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# Best Practice Guide

## Partners



VERTICO



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