

Itaca: Parametric Design and Large-Scale 3D Printing for a Self-Sufficient Farm

In the hills of Northern Italy, [WASP](#) has completed the 3D printing of [Itaca](#), the first certified 3D-printed building in Italy. Located in the Shamballa open-air laboratory for sustainable living, the project explores how parametric design and large-scale additive manufacturing can support new models of architecture based on circular micro-economies.



Crane WASP large-scale 3D printing system in operation during the construction of the Itaca walls at the Shamballa open-air laboratory in Northern Italy.

Introduced by Massimo Moretti, founder and president of WASP, during Italian Tech Week in Turin, Itaca was conceived as a prototype for a self-sufficient farm and living environment capable of producing food, water, and energy locally. The project proposes a replicable construction model made possible through the rapid transmission of digital information and the use of accessible large-scale 3D printing systems.

Beyond the building itself, Itaca functions as a research platform investigating how digital fabrication, ecological materials, and regenerative land management can operate together to support sustainable living systems.



Architectural visualization of the completed Itaca building showing the integration of hydroponic farming systems within the surrounding agricultural landscape.

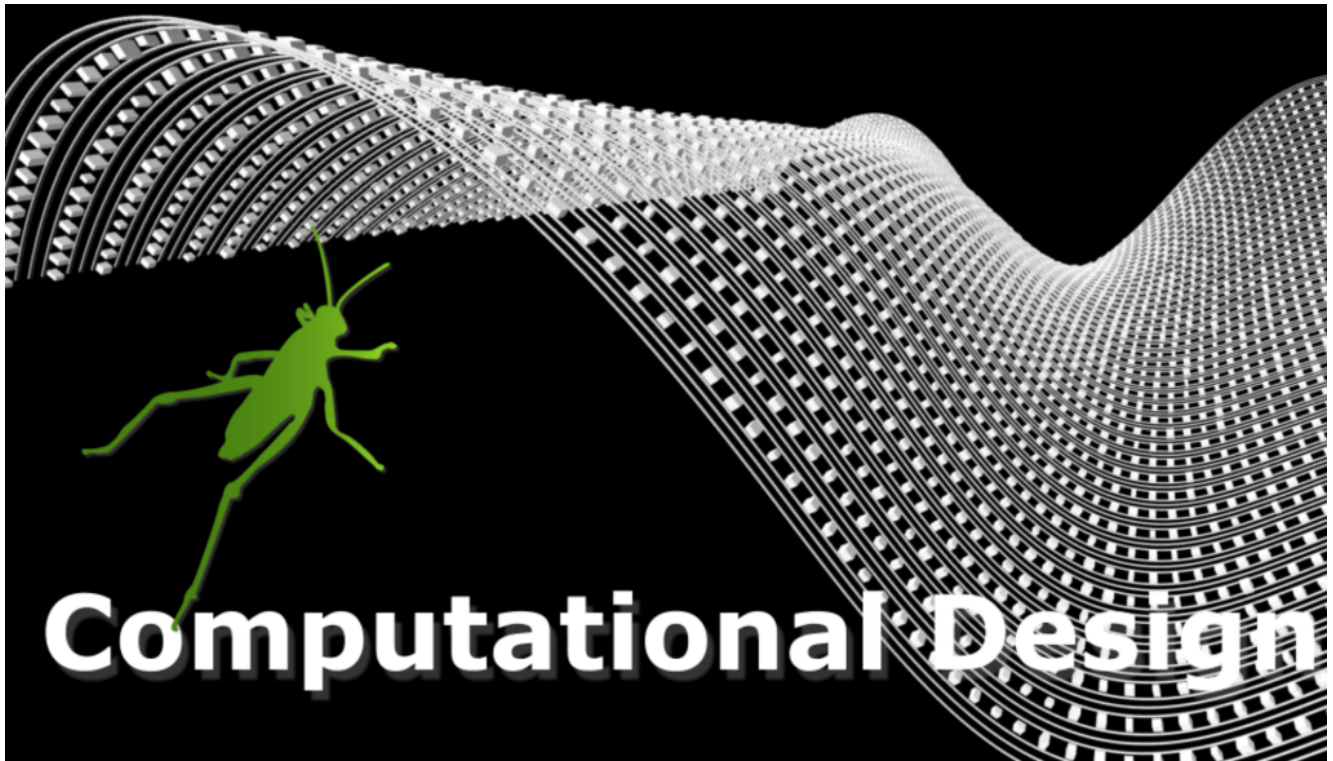
GEOMETRY & PARAMETRIC DESIGN

The architectural concept of Itaca originates from the geometry of the **Mandala**, a symbolic figure traditionally represented as a square inscribed within a circle. This geometric principle became the generative matrix of the entire architectural design.

Four symmetrical L-shaped walls form a square within a circular perimeter defined by the surrounding landscape. The resulting structure covers a total floor area of 164.9 m², with walls reaching 3.8 meters in height.

The entire design and fabrication logic were developed using [Rhino](#) and [Grasshopper](#), where a parametric workflow was used to control the printing strategy. A Grasshopper script was built from a limited number of base curves defining the primary dimensions and geometry of

the walls. From these curves, both the external shell and the internal infill structure were generated.



[See Also](#)

[COMPUTATIONAL DESIGN WITH GRASSHOPPER](#)

The internal infill was designed not only to ensure structural stability but also to create cavities capable of hosting the building's structural system, composed of steel columns and laminated timber beams. Meanwhile, the external shell incorporates a simple geometric pattern inspired by classical architectural proportions.

In certain areas, the toolpath deviates from its linear trajectory as the printer nozzle moves outward, allowing the facade texture to be produced directly during the printing process rather than applied afterward.



Architectural visualization of the interior space showing vertical hydroponic systems designed to support year-round food production within the self-sufficient farm concept.

TOOLPATH CONTROL & GCODE GENERATION

Grasshopper played a critical role in controlling the toolpath logic required for large-scale additive manufacturing.

Each wall of Itaca is composed of 710 unique printing layers, and every layer contains hundreds of coordinate points describing the movement of the printing system. These spatial coordinates are extracted from the parametric model and translated into **GCODE**, the machine language used to control the printer.

Each line of GCODE includes a movement command, feed rate, spatial coordinates, and the amount of material to extrude. Because each point corresponds to a position along the toolpath polyline, the total dataset quickly grows to thousands of machine instructions.

To manage this complexity, the project relied on a custom Grasshopper exporter capable of translating the parametric toolpath geometry directly into machine-readable instructions. This workflow enables precise control over millimetric printer movements while maintaining flexibility during the design process.

The resulting files are uploaded through the Crane Web App, an interface that allows operators to communicate directly with the printing system. Through the platform, operators can upload files, adjust printing speed and material flow, monitor the process, and interrupt the print if necessary.



Completed 3D-printed walls forming the main entrance to the Itaca building during the construction phase.

LARGE-SCALE 3D PRINTING WITH CRANE WASP

The construction of Itaca was carried out by **WASP 3D Build**, a startup dedicated to architectural 3D printing.

The building was produced using a new configuration of the [Crane WASP system](#), where four robotic arms are positioned at the vertices of a hexagonal structure. This configuration allows the simultaneous printing of four wall segments, significantly accelerating the construction process.

When operating together, the four printing arms can complete the structural shell of a house in just a few days. In the case of Itaca, each wall required approximately 24 hours of printing time.



Top view of the printed wall geometry revealing the internal cavities designed for structural reinforcement and integrated building systems.

MATERIAL STRATEGY & WALL SYSTEM

The walls were printed using a lime-based mixture without concrete, selected for its lower carbon footprint compared to conventional cement, while still meeting structural performance requirements.

The material also offers high breathability, allowing the walls to regulate humidity levels and reduce the risk of mold formation.

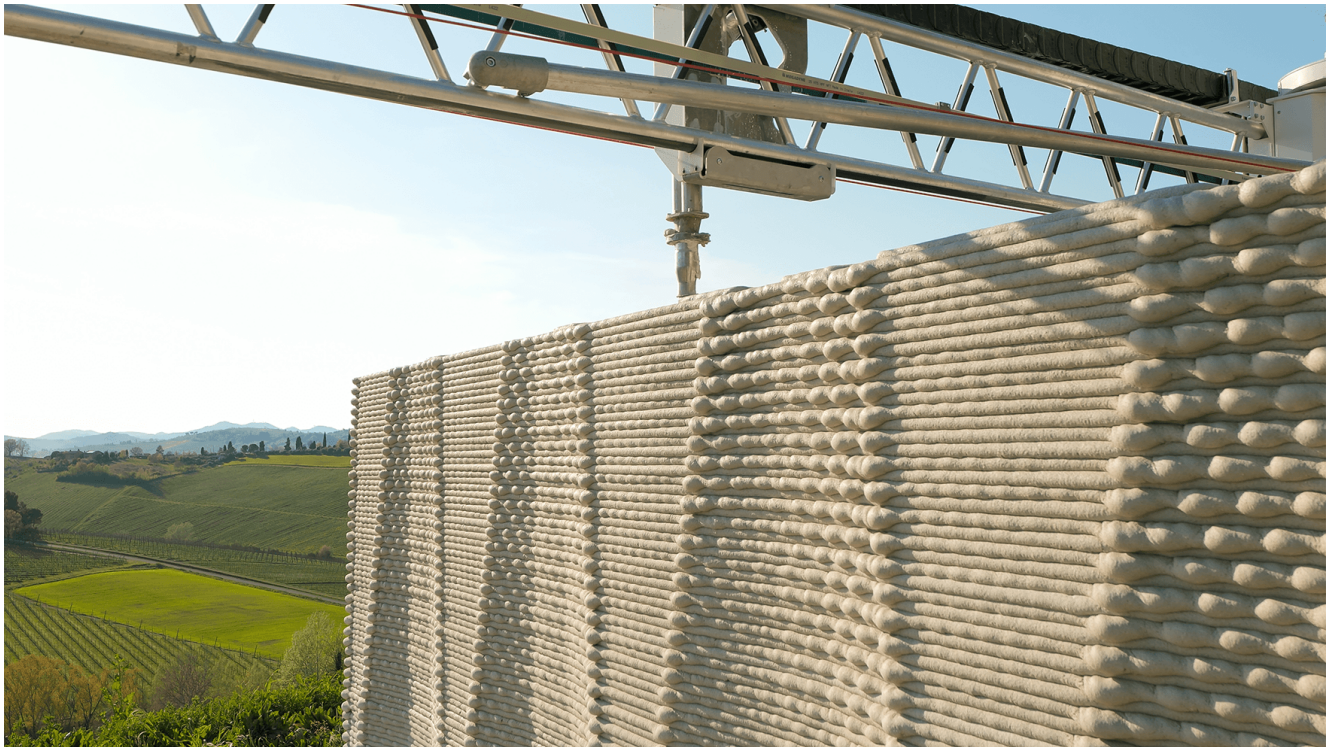
The walls were designed with a thickness ranging from 60 to 70 cm, enabling the integration of structural reinforcement and building systems. The cavities inside the walls are filled with rice husks sourced from agricultural waste, combined with natural lime powder to create internal insulation.

This approach turns the walls into ventilated structures that help regulate indoor temperature and reduce energy demand. Reinforcement columns inserted within the cavities support the future green roof and ensure compliance with seismic regulations.

Several building systems are embedded directly during the printing phase, including radiant heating, electrical wiring, insulation, and

ventilation channels, eliminating the need for extensive post-construction interventions.

By combining low-impact construction materials with natural insulating materials derived from industrial byproducts, the project achieves a negative CO₂ emissions balance.



Close-up of the printed wall texture generated directly through the controlled extrusion toolpath during the additive manufacturing process.

SHAMBALLA: A LABORATORY FOR SELF-SUFFICIENT LIVING

The Itaca building is part of **Shamballa**, an open-air research laboratory dedicated to sustainable living.

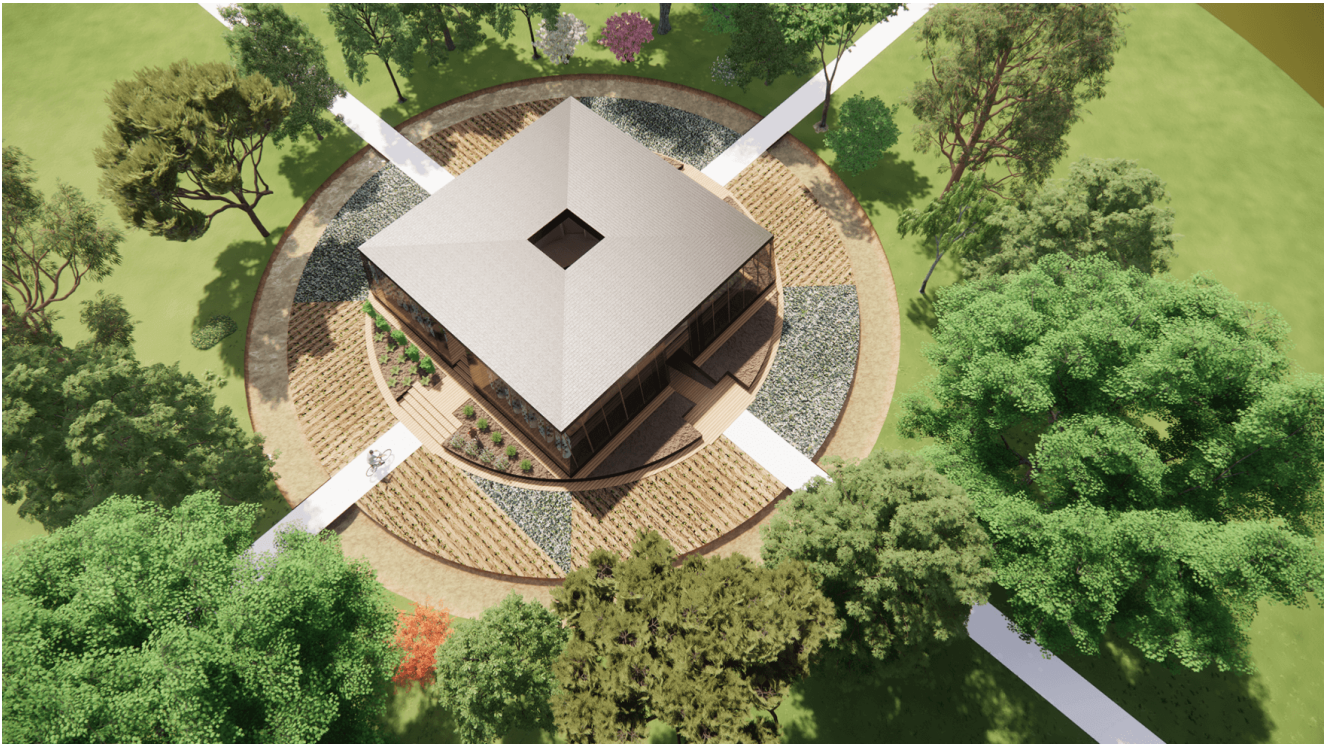
The project explores how architecture can support food, water, and energy self-sufficiency within a circular micro-economy. According to the project's research hypothesis, a circular living system with a diameter of approximately 33 meters could provide enough resources to support up to four people.

The surrounding site integrates several ecological strategies,

including rainwater harvesting basins designed to control soil erosion and store water for irrigation. These interventions help transform previously drought-prone land into productive agricultural environments.

Future developments include AI-assisted automated gardens designed to optimize crop cultivation and reduce the physical effort required to maintain a small plot of land. In addition, 3D-printed vertical hydroponic systems will allow year-round vegetable production using minimal water.

The building will also incorporate a green roof and solar panels, improving thermal performance while generating renewable energy for the farm.



Architectural visualization illustrating the project layout based on a square plan inscribed within a circular landscape inspired by mandala geometry.

REPLICABLE SUSTAINABLE CONSTRUCTION

One of the central goals of the Itaca project was to demonstrate that 3D-printed buildings can meet the same structural and regulatory standards as conventional construction, including earthquake resistance under Italian and European regulations.

Achieving certification under these stringent conditions suggests that similar construction systems could be replicated in many regions around the world. By combining parametric design in Rhino and Grasshopper, large-scale robotic 3D printing, and ecological material strategies, Itaca proposes an architectural model where digital fabrication supports both environmental regeneration and decentralized, self-sufficient living systems.

CREDITS

Project: Itaca – Self-Sufficient 3D Printed Farm

Company: WASP (World's Advanced Saving Project)

Construction: WASP 3D Build

Location: Shamballa Open-Air Laboratory, Northern Italy

Founder and Project Vision: Massimo Moretti