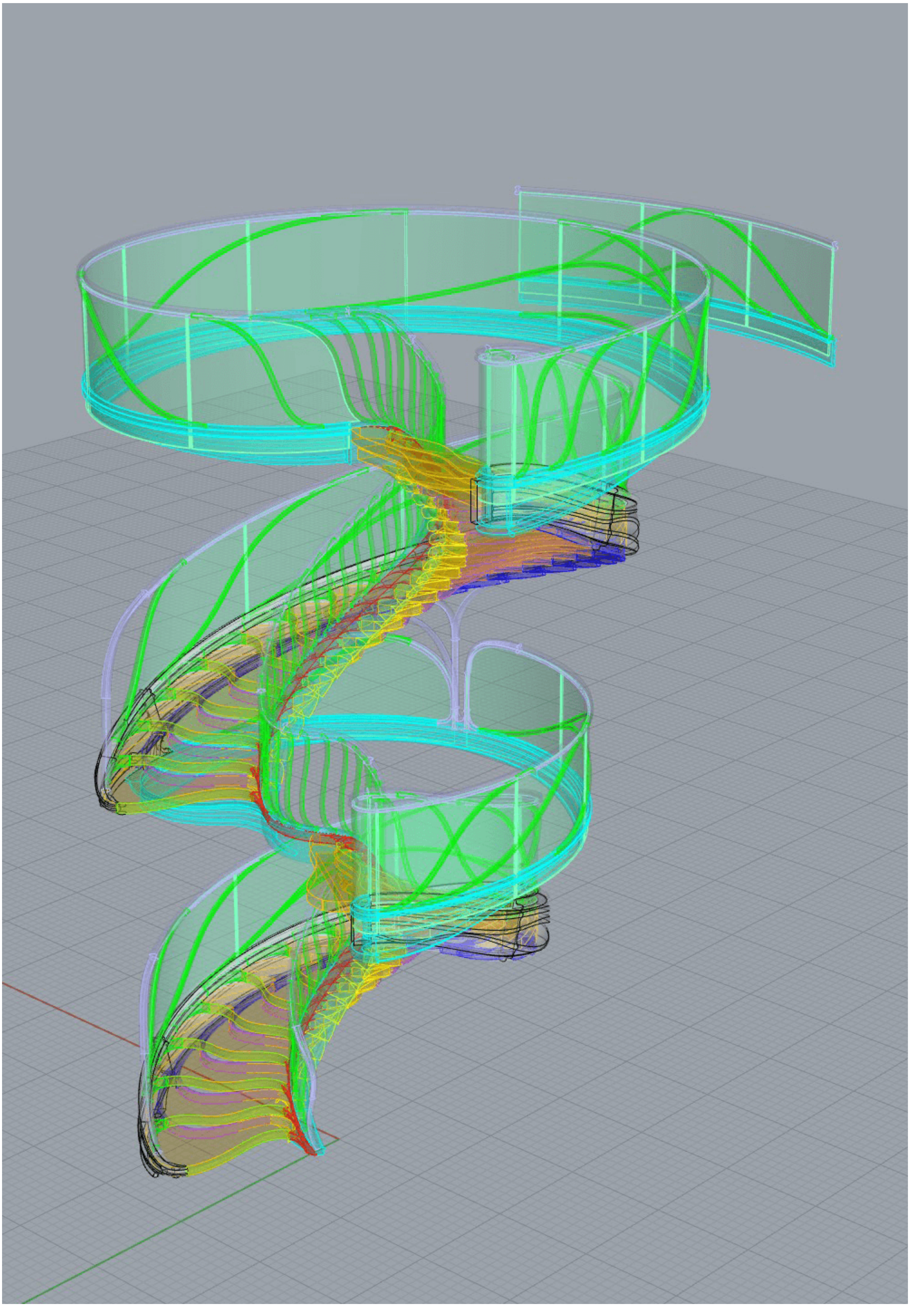
Helical Timber Staircase: Parametric Design and Fabrication of a Non-Standard Geometry

Located in Crans-Montana, Switzerland, this bespoke timber staircase project involved the design and realization of a highly complex, non-repetitive geometry within a private residence. The staircase is defined by an expanding helical form, where no two elements are identical. Each tread, baluster, and stringer detail was designed as a unique component, requiring a fully digital and parametric workflow from the earliest stages.



Parametric model showing the overall helical configuration and *variation of non-repetitive components.*

DESIGN APPROACH

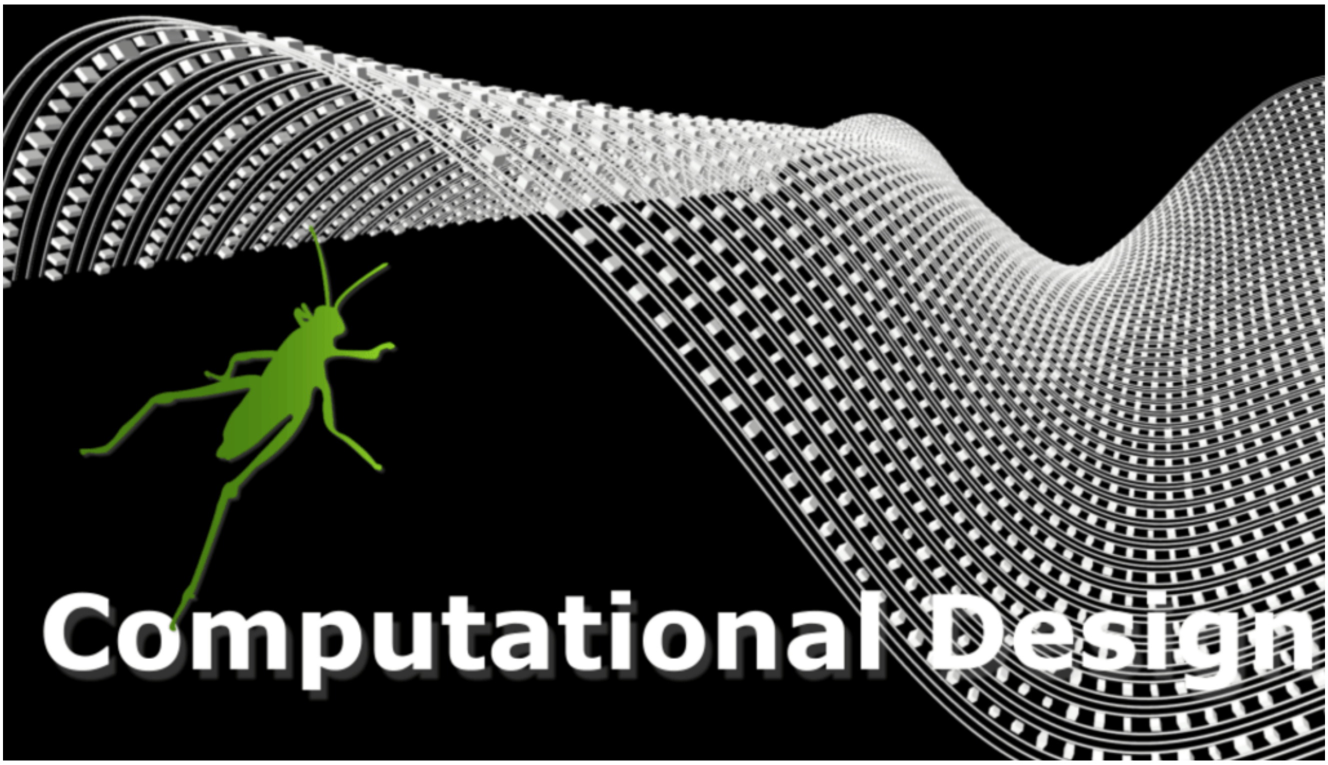
The project was inspired by the Hide staircase in London, designed by Atmos Studio, and began with a conceptual helical curve that gradually widens as it rises. The production model and algorithmic design were developed in Rhino by Super Architektura. This geometry established the foundation for a continuous, evolving form without repetition. Due to the absence of standardization and the organic nature of the design, all elements were modeled directly in 3D.

Rhino was used as the primary modeling environment, enabling precise control over complex NURBS geometry. Unlike mesh-based approaches, NURBS allowed for continuous surface definition and high geometric accuracy, which was critical given the project's reliance on smooth curvature transitions and editable parametric relationships.

Assembly of treads and internal stringer during fabrication, illustrating the alignment of unique components.

PARAMETRIC WORKFLOW

Grasshopper played a central role in structuring the design logic and enabling rapid iteration. Parametric models were developed to define the global layout of the staircase, particularly the configuration of the steps. Although each tread was unique in shape and dimension, all were generated through a shared set of geometric rules.

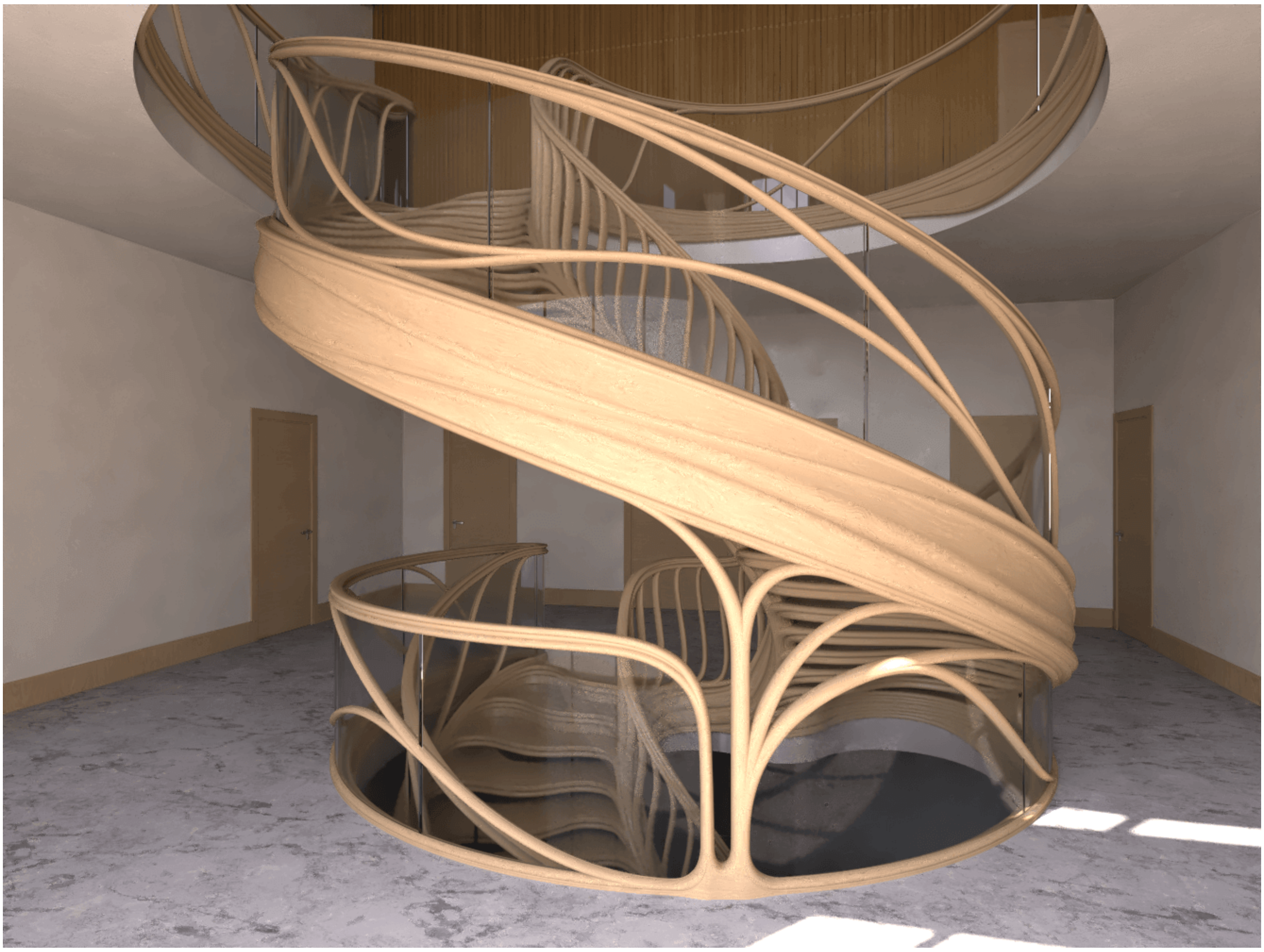


See Also

COMPUTATIONAL DESIGN WITH GRASSHOPPER

Multiple design variations were evaluated for ergonomics, visual continuity, and feasibility. The parametric setup allowed for efficient testing without the need for time-consuming remodeling. For more advanced operations, custom Python scripts were implemented to extend native capabilities, particularly for flexible blending of curves and surfaces and for accessing higher levels of geometric continuity.

In parallel, simpler, repetitive tasks were handled using Rhino macros, which proved more efficient than building full parametric definitions, particularly in cases such as applying nosing profiles to individual steps.



V-Ray render exploring a solid external stringer with increased cross-section to improve structural performance.

GEOMETRY CONTROL & CONTINUITY

A key focus of the project was maintaining smooth curvature transitions across the entire structure. Advanced curvature analysis tools were used extensively to ensure visual and structural coherence. Custom graphing methods developed within Grasshopper allowed for detailed evaluation of curvature behavior along critical sections of the geometry.

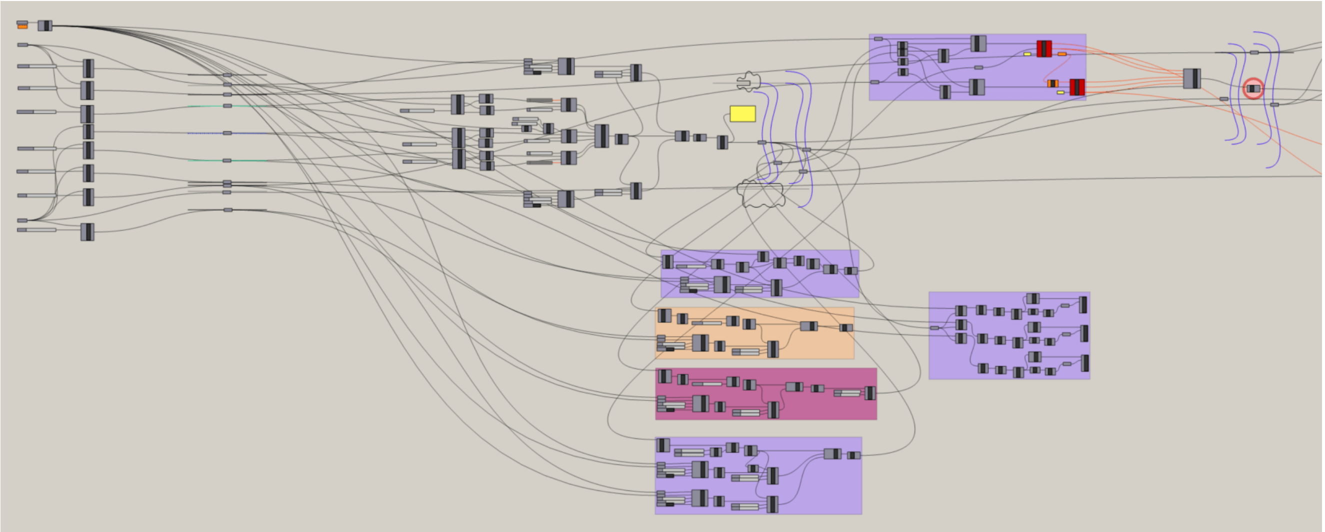
This level of control was essential in achieving a consistent design language across non-identical components, particularly in areas where manually modeled elements, such as stringers, interfaced with parametric geometries.

View from above revealing the continuous curvature and spatial compression toward the center.

FROM MODEL TO FABRICATION

The transition from digital model to fabrication required translating complex NURBS geometry into manufacturable components. The Rhino model served as the central source of truth for production data, from which detailed 2D documentation and CNC-ready files were generated in formats such as DWG and DXF.

Given the geometric complexity, certain elements required rationalization or segmentation to meet machining constraints. Individual components were exported for CNC processing, while others were produced manually using full-scale (1:1) templates derived directly from the digital model.



Grasshopper script used to control tread distribution, geometry variation, and ergonomic parameters.

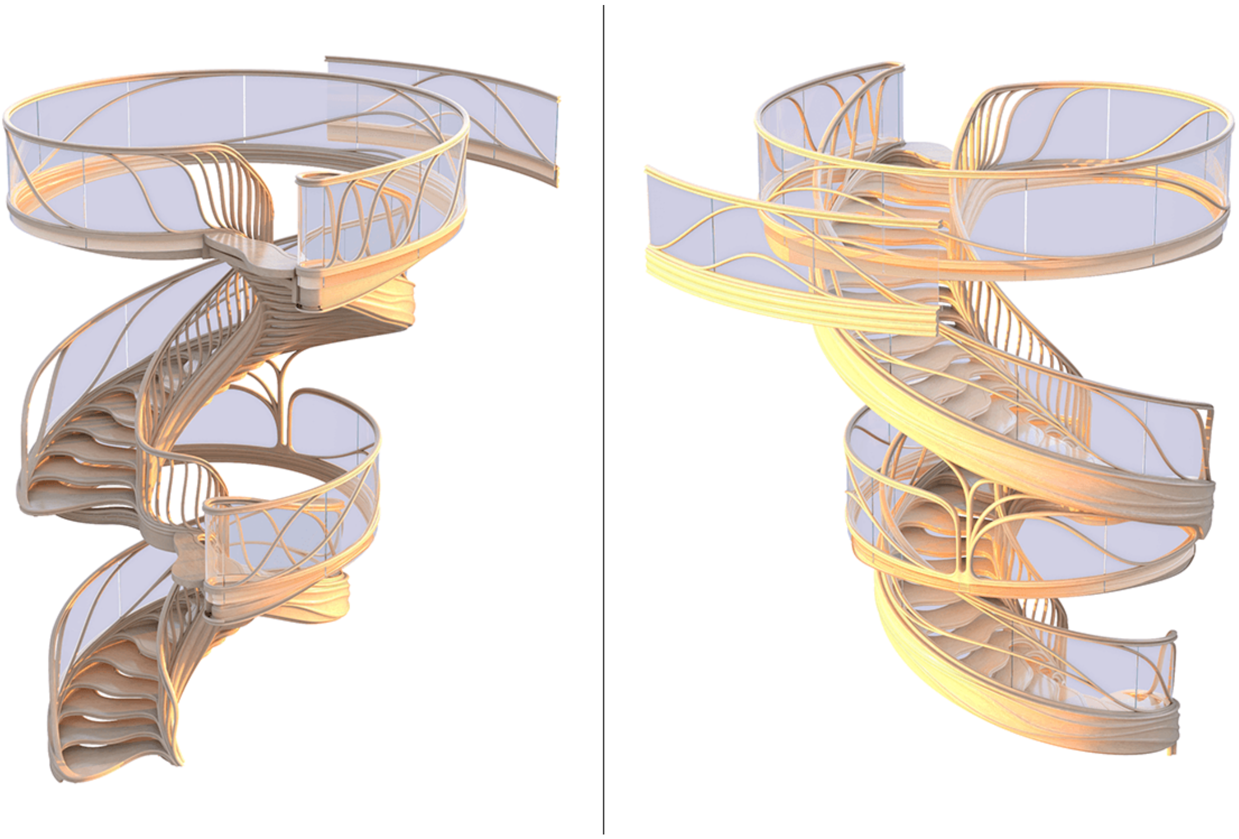
The fabrication process, carried out by GD Staircases, involved a combination of techniques including lamination of bent timber blanks, hot bending, CNC machining, and manual craftsmanship. While specific methods remain confidential, the workflow requires close alignment between digital precision and material behavior.

On-site installation of the primary structure, showing the integration of prefabricated elements.

VISUALIZATION & OUTPUT

Visualizations were produced directly within Rhino using its built-in ray tracing engine and physically based rendering (PBR) materials. Lighting, environment setup, and post-processing were also handled within the same pipeline, with additional adjustments made in GIMP, including ambient occlusion passes.

One of the key challenges was the texturing of NURBS surfaces, where non-uniform knot vectors can complicate automatic mapping. Custom tools were developed to maintain texture consistency when exporting the model to mesh formats such as OBJ and FBX. Additional renderings were made with V-Ray engine.



V-Ray renders used to evaluate overall form, proportions, and visual continuity during the design phase.

ANALYSIS & DOCUMENTATION

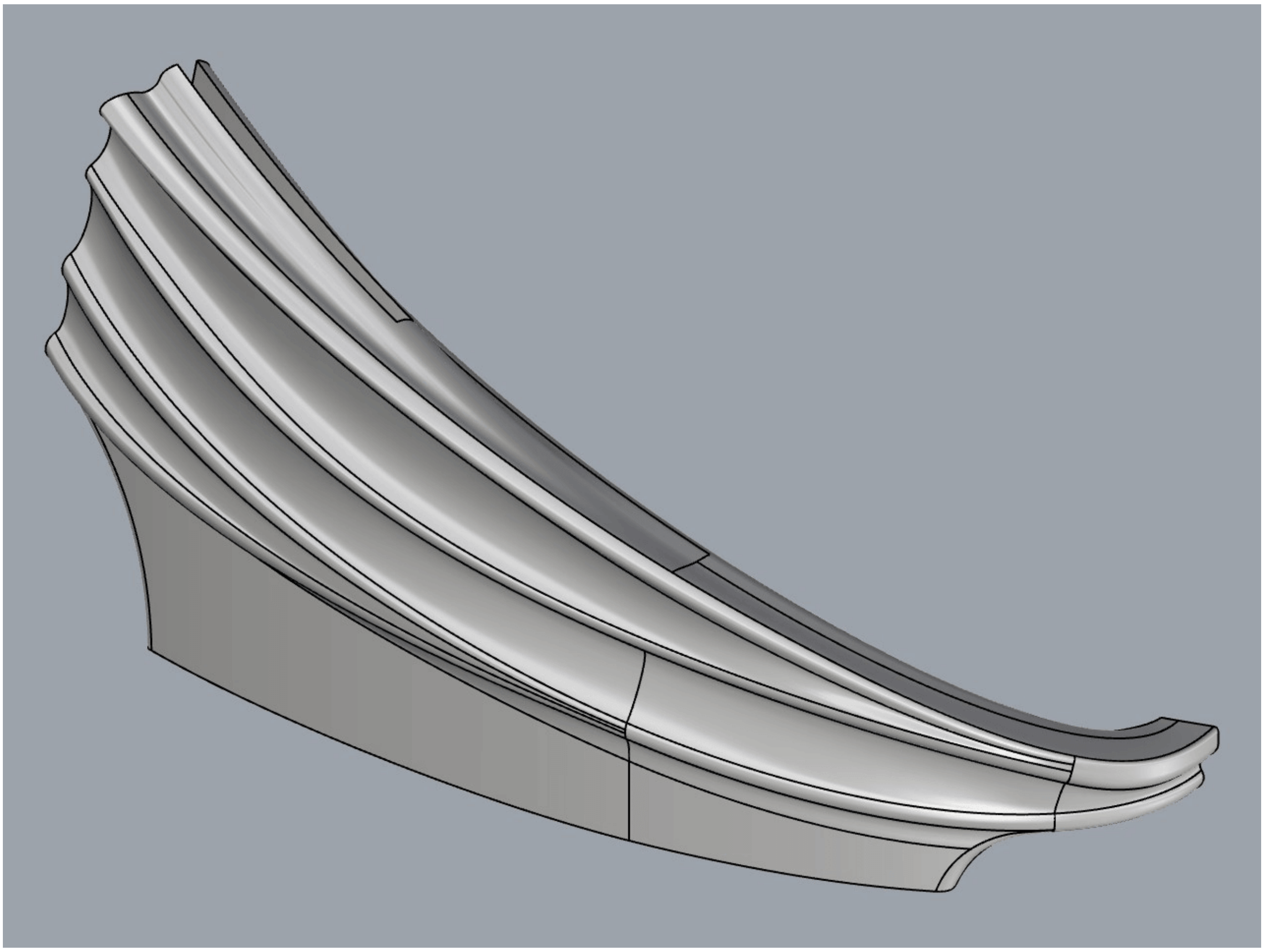
Beyond design and visualization, the Rhino model was also used to generate simplified geometry for structural analysis, which was conducted in external engineering software. The ability to derive both analytical models and fabrication data from a single source ensured consistency across all project stages.

Following the conceptual design phase and structural analysis, excessive deflection of the structure was identified, taking into account the seismic loads applicable in the Crans-Montana region.

Ground-level view emphasizing the transition between *structure, balusters, and flowing timber geometry.*

The initial design of the external stringer consisted of upper and lower profiles connected at the edges of the treads, forming an openwork structure visible from the exterior. To eliminate the need for steel reinforcement, the stringer was redesigned as a solid timber element with a significantly increased cross-sectional area.

The outer face of the stringer was further developed with a three-dimensional carved relief, extending the motif of curved tendrils used in the balusters and the timber overlays on the glass.



Detailed NURBS modeling of the stringer termination, ensuring geometric continuity and fabrication accuracy.

OUTCOME

The clarity and precision of the 3D model played a crucial role in the project’s development, enabling client approval during the first consultation. The integration of parametric design, custom scripting, and fabrication-aware modeling resulted in a coherent and highly controlled realization of a complex architectural element.

Upper-level view highlighting the expansion of the helix and its integration within the interior space.

CREDITS

Design of production model in Rhino and algorithmics: Super Architektura Michał Święciak
Design and production cooperation: Wojciech Stafiniak
Contractor: GD-Staircases Ltd. / Schody Trąbczyński
Structural Design: Marek Rawski
Interior Design: Portia Fox
Images: @rich_pick_photo