Rolex Learning Center in Lausanne

Architects:	SANAA Kazuyo Sejima & Ryue Nishizawa, Tokyo
Structural design:	Bollinger + Grohmann, Frankfurt am Main Walther Mory Maier Bauingenieure AG, Münchenstein, Switzerland INGPHI SA, Lausanne, Switzerland
Consultant engineering firm (preliminary designs):	SAPS Sasaki and Partners, Tokyo
General contractors:	Losinger Construction AG, Bussigny, Switzerland
3D consulting:	DesignToProduction
Completion:	2010

The Rolex Learning Center on the campus of the École Polytechnique Fédérale de Lausanne (EPFL) is based on a landscaped foundation slab, which generates the most varied spatial situations through a kind of artificial topography. The building, with its area of 166 × 121 m with a central library, study rooms, facilities and services for the acquisition of knowledge along with exhibition rooms, conference halls, a cafeteria and a restaurant, is intended to be the focal point of campus life and has a decisive effect on the appearance of the campus. The reinforced concrete foundation slab and the membrane roof with a substructure made of steel and glued laminated timber beams flow up and down in waves of up to 30° of incline. A homogenous perfect shell transfers the forces without bending stresses and can therefore be extremely thin. However, even introducing a door opening into such a perfect form can cause structural and formal problems. SANAA's landscape integrates around 14 patios with diameters of 7–50 m, creates visual relationships and the most varied spatial qualities and results from a design process in which considerations regarding the supporting structure were just one aspect amongst many others.

The task for the structural engineers was to discover the local shell and arch impact within the master geometry as well as carefully modifying it in close cooperation with the architects. Identifying qualities in an existing structure replaced the form-finding process. The load-bearing behaviour of a landscape like this is varied so there are no areas which represent a single type of supporting structure. Several analyses also revealed weak points within the geometry which would have meant a disproportional dimensioning of the concrete shell. The snake-like course of the forces within the membrane, high bending moments and deviation forces along with a lack of bearings in the patio areas made a reworking necessary. By shrinking and displacing the patios, it was possible to ensure that forces between the edges of the shell flowed in straight lines. This modification of the overall form and the position of several patios took place in close cooperation with the architects in an iterative process which lasted throughout the whole design period.

1 View of the roof landscape with the cut-out patios

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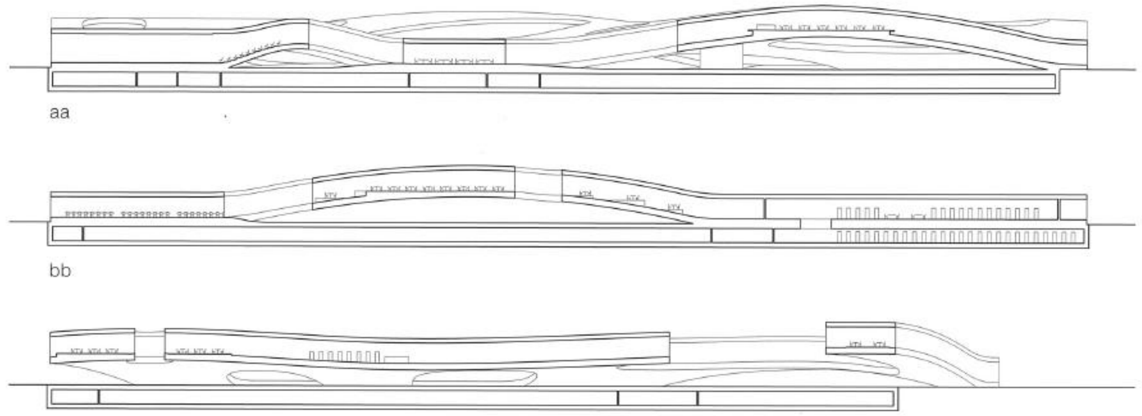

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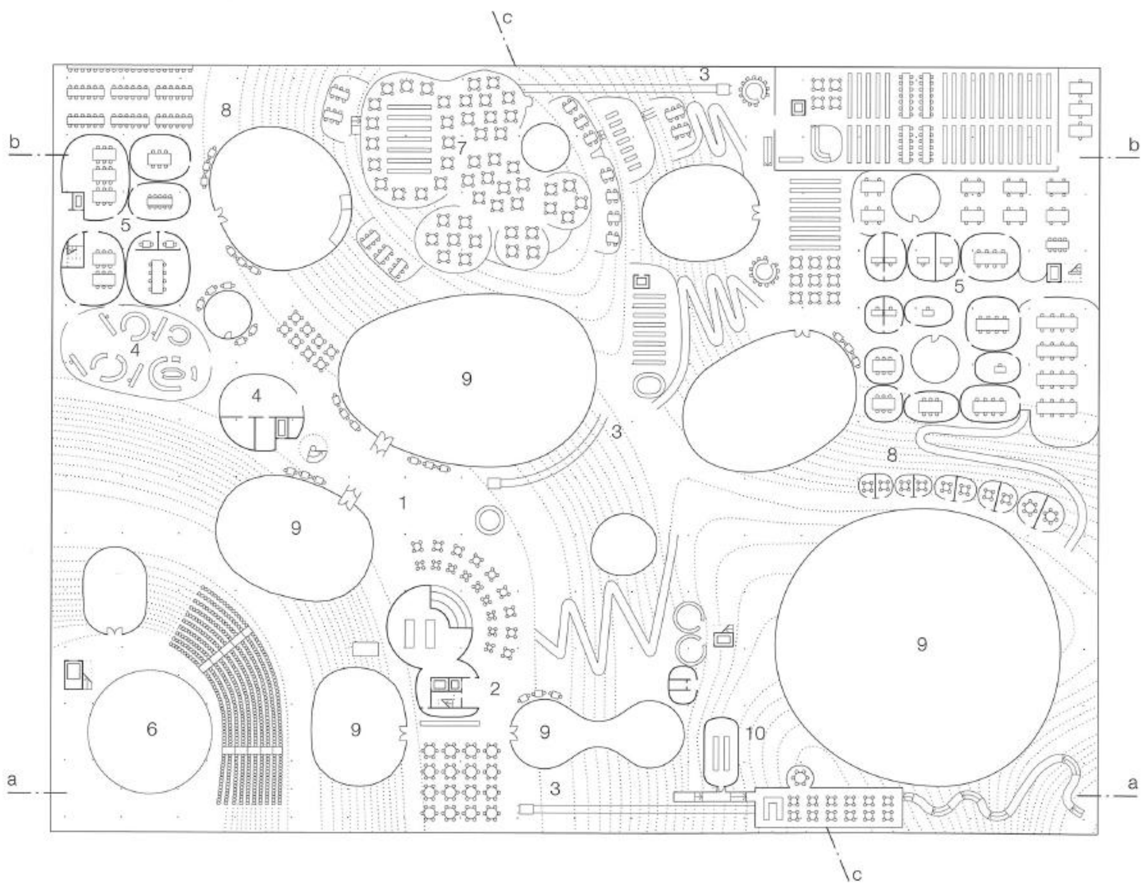
During the competition and the first design phases the architects developed the geometry using physical models. Similar to a topographical model, the various heights were represented in layers. The first 3D models were based on the architects' contour models which were transitioned into continuous digital surface models. Surfaces like this have two dimensions which unfold in space straight or curved, limited or limitless. At the same time the geometry describes each point contained using x-, y- and z-coordinates in three dimensions. An object represented in this way does not lie inside or outside of a limitation but is the limitation itself. In the digital world this contradiction is not problematic. In the modelling program the surface can be manipulated directly or via a control polygon associated with it, and is tangible and controllable. Textures simulate materials and depth and allow the surfaces to appear as objects. However, if they are to be transitioned into built reality then the contradiction of surface and volume must be overcome. A type of bi-axial coordinate system makes it possible to unequivocally identify points, curves, bends and directional vectors at each point of the surface. This information can be used to arrange constructive elements. The surface now serves as a representation of a three-dimensional large-scale form and at the same time as a guiding geometry for a constructive system. For the structural design, digital surface models were needed in order to, for example, quickly and precisely generate and analyze vertical sections. They were used for the first rough analyses with the aid of the finite element method in which the surface is transformed into a network of finely dispersed meshes.



1 Main entrance
2 Café, bar, canteen
3 Inclined lift
4 Bank, bookshop
5 Offices
6 Multi-functional area
7 Library terraces
8 Work places
9 Patio
10 Restaurant, lake view

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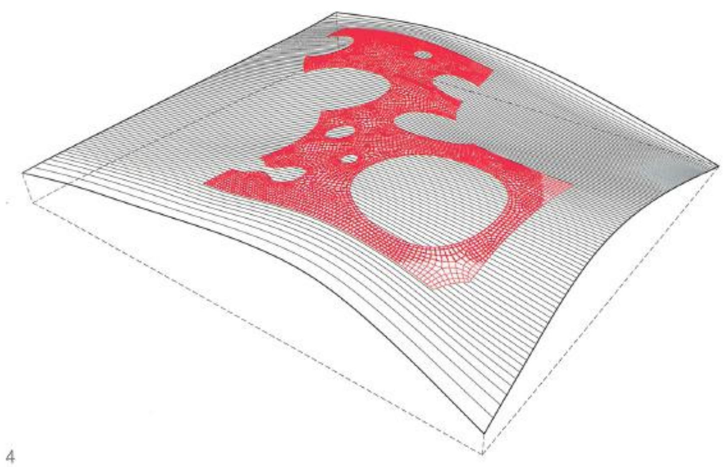

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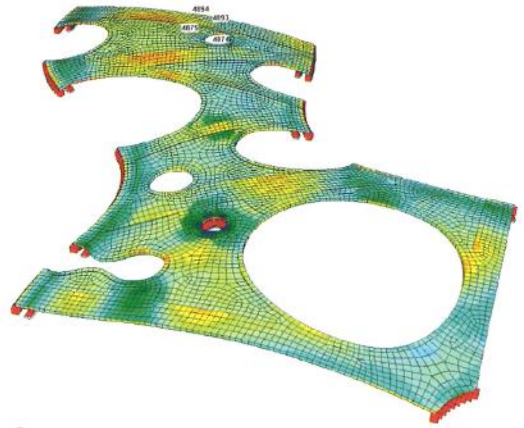

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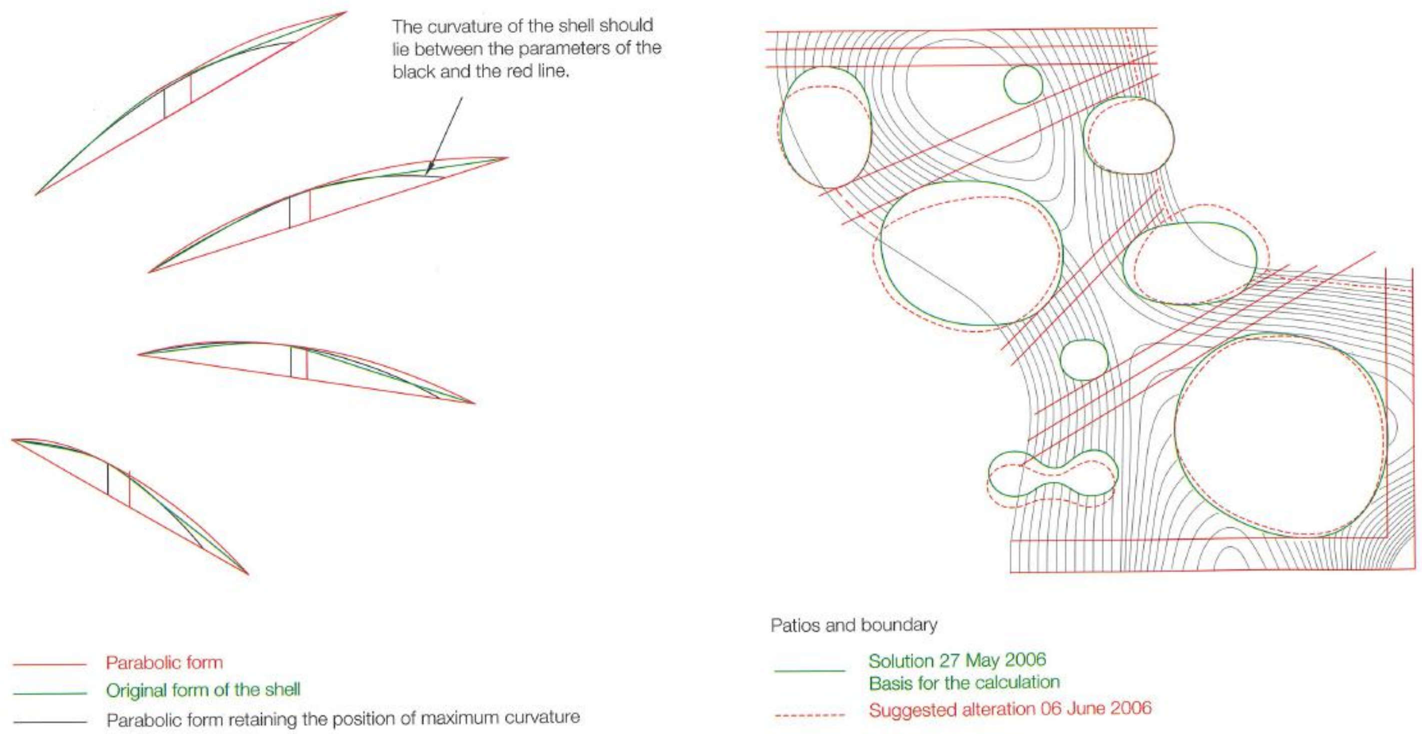
The computed results were manually checked again and again in parallel using simple 2D models and calculations. From these early analyses it was possible to determine initial criteria for the geometry, which were then used for the design in close cooperation with the architects:

- Adaptation of the location and position of the patios in such a way that load-removing arches can be spanned between them
- Optimization of the arch geometry in terms of symmetry and as parabolic a form as possible
- Avoidance of counter-curvature at the bearings which has an unfavourable effect on the load-bearing behaviour.

The support structure concept developed from this is based on a series of load-removing arches as the primary supporting structure and so-called ceiling zones which span between these arches. There are bending loads in all areas, unlike with pure shell support structures.
When calculating the system, three aspects were decisive: the confirmation of sufficient cross-section sizes under the loads acting on them, distortion and

2 Sections, scale 1:1200
3 Ground plan, scale 1:1200
4 Superimposition of surface model and finite element network
5 Visualization of the tension distribution in the shell
6 Position of the supporting arches in sections and as a ground plan



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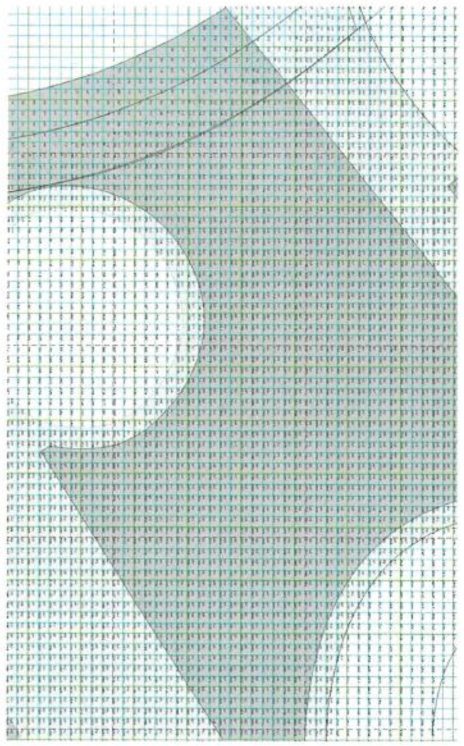
stability. These parameters were examined in a finite element software environment under the influence of crack formation, creeping and contraction of the concrete over an extended period.
The results from these analyses were transferred again and again into three-dimensional surface models. This step was necessary as the finite element networks often represent the geometry in an abstracted way and therefore make a precise formal architectonic evaluation impossible.
In the following phases, the exact geometrical description of the landscape served as a basis for the construction planning and ultimately for the implementation of the project. Even at an early stage the design team worked closely with the general building contractor. Due to the complexity of the task, the boundaries between support structure design and workshop planning could not be clearly drawn. The planning process relied on a continuous digital chain between geometric resolution and the subsequent generation of the working drawings. The details which a formwork plan needed to contain, so that the formwork construction and reinforcement could be carried out, could not be derived from standard procedures.
The three-dimensional surface model served as the basis for the formwork construction. Two-dimensional drawings did not prove effective in this case. Nevertheless, a series of coordinates were made available in the form of plans. In a 50 × 50 cm grid, a set of plans gave details of the z coordinate, in other words, the respective height and local thickness of the concrete shell. A second set of plans provided the xy coordinates of the bearings, patio edges and zones of varying slab thicknesses. This information



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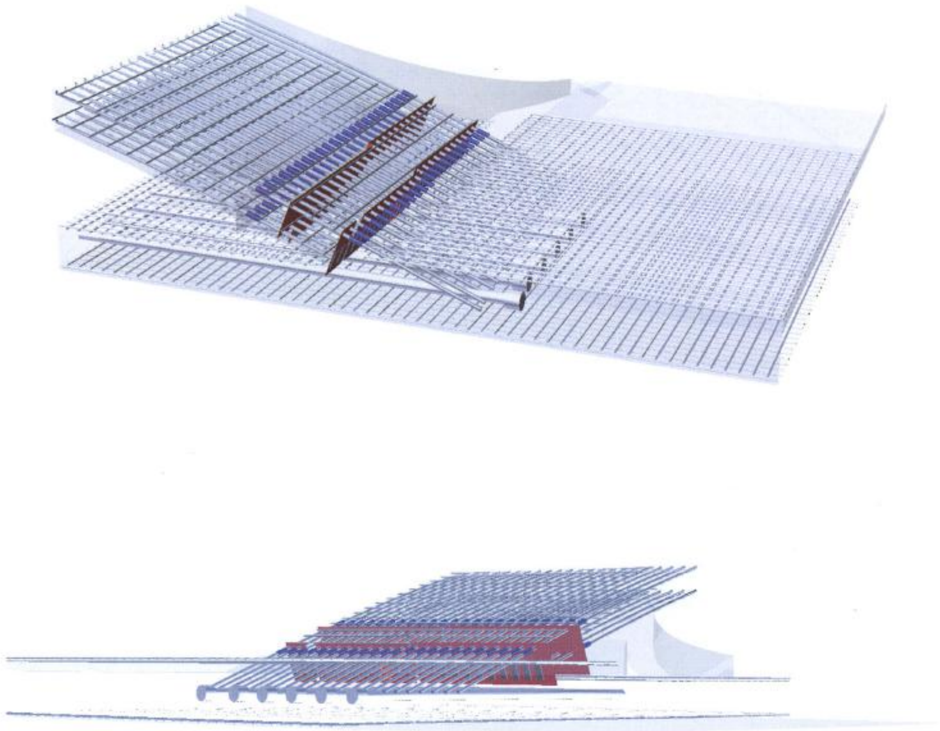

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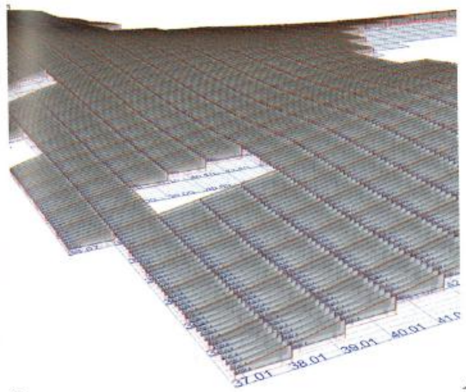

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provided the basis for the calibration of the formwork benches in alignment with an on-site measurement. The generation of the plan could be automatically derived from the 3D models using macro-scripting. Scripting, a simplified form of programming, allows large amounts of repetitive modelling work to be automated and rule-based tasks to be processed and evaluated efficiently. Alongside time savings and a high degree of accuracy, the reduction of monotonous work (and hence susceptible to error) was an advantage of automation. The prefabricated formwork consists of a series of 2.5 × 2.5 m benches, whose surfaces follow the course of the curvature of the landscape to be concreted. Each bench is made up of two wooden beams and an array of seven wooden ribs which lie on top of it. A laminated pulpwood board forms the surface. The contour form of the wooden ribs defines the geometry of the formwork. The generation of its geometry and subsequent translation into tool paths for the computer-controlled blank cutting of the ribs could be automated and thus speeded up a lot.
The experience from this and other projects with complex three-dimensional geometry show that the 2D plan – which has been the standard design tool up until now – is increasingly losing in significance faced with pure 3D planning.

Klaus Bollinger,
Manfred Grohmann, Oliver Tessmann

7 Automated listing of coordinates
8 3D reinforcement bearing
9 Constructive 3D model of the formwork
10 Formwork bench consisting of two main beams, seven wooden ribs and a laminated pulpwood board
11 Formwork benches in use
12 Rendering

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