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An Approach for a Passively Shaded Glazed Steel Façade Utilizing Digital Design Strategies

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Abstract

Resembling the harsh surfaces of the nearby alpine mountains, the geometry of the glazed steel façades of the new Dynafit Headquarters in Kiefersfelden is based on energy driven design principles. Built with a vertical and horizontal tilt the valleys of the serrated glass façades are oriented along the solar inclination during summertime. Triangular shading panels that are fitted into the valleys and oriented perpendicularly to the solar inclination in combination with solar control coatings on a triple-insulation glazing minimize solar heat gains while keeping views to the surrounding alpine landscape with only passive shading systems. Structurally the façade acts as a folded plate structure formed through a grid of hollow steel profiles that is glazed on site with hidden fixations, sealed and mechanically secured through local pressure plates. For design and execution, a 3D parametric geometry model was utilized that served as a basis for structural and energetic simulations. Local climate data were imported into the model and informed the geometry of the facade, the performance of which was investigated through solar radiation studies within the model. Furthermore, the adjacent serrated metal-clad facades were generated based of the glass facades' geometry. Harvesting the potential of these design strategies, the highly performative façade is intertwined with the character of the building which blends into the landscape around it.

Keywords

Energy driven design, glazed steel facade, advanced geometry, passive shading systems, digital design

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1. Project Introduction

A building, which arises as a part of the landscape around it, the architect Barozzi Veiga describes the character of the new Dynafit Headquarters in Kiefersfelden. Located at the entrance of the alps in close proximity to the German-Austrian border, the building references the alpine mountains and valleys with a geometry of two intersecting triangular prismatic volumes – a geometry in which edges and surfaces strive to transform themselves into a new landscape of their own.

The ca. 29,0 m high building on a floor plan of ca. 25 m x 56,5 m accommodates a kindergarten, office floors, a flagship store, laboratories, as well as residential spaces for the northern Italian mountaineering clothing and gear brand on the upwardly tapering storeys. Two largely glazed facades, be ca. 1.450 m² on the tilted East- and West-facing surfaces allow for views to the surroundings as well as they guide light into the deep interior spaces. The secondary vertical facades, covering ca. 3.100 m² on the two volumes' back and triangular side surfaces are enclosed by a metallic ventilated façade system resembling the appearance of the glazed facades.

Fig. 1: Site photo (knippershelbig).

2. Integration of the architectural concept and the solar shading performance by the façade geometry

A key challenge to the design of the two glass facades was the aim to overlay the architectural concept with the need for a highly performative shading system to meet energy performance requirements. This idea resulted in a concept of a serrated glass façade system with external perforated metal shading panels, that were oriented according to solar radation, reducing unwanted solar heat gains during summertime, and making use of them during winter.

Fig. 2: Concept sketch of the shading concept of the glazed facades system. (knippershelbig).

To create the facades' geometry, a parametric three-dimensional CAD-model was developed within the environment of Grasshopper in Rhinoceros 3D. An average solar radiation vector was generated for each of the two tilted glass facades by creating an average of all solar rays impacting the facades' surface. To generate these vectors, open-source local hourly solar radiation data were imported into the parametric model and filtered to sort out the hourly solar radiation vectors that do not impact each of the glass facades' surfaces. Two average vectors were then computed from the remaining vectors, resulting in the average solar radiation vectors for each façade.

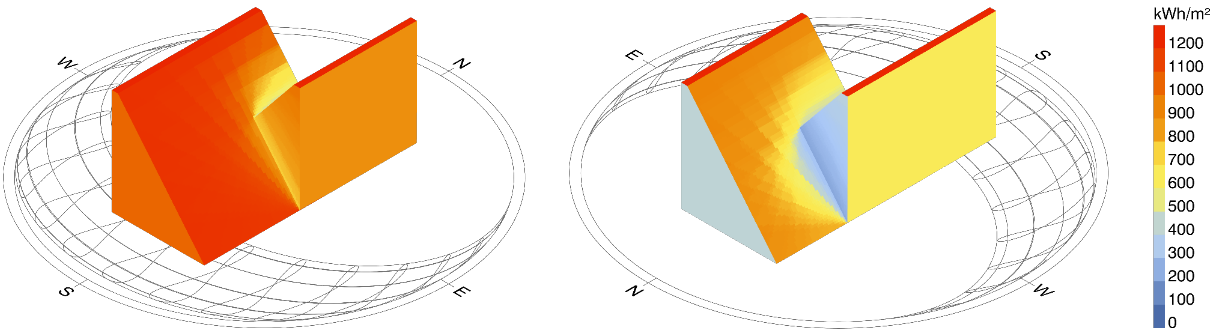

Fig. 3: Solar radiation study of the building geometry. (knippershelbig).

Each of the two tilted glass facades are based on an individual serrated geometry, the ridges of which are oriented parallel to the facades' average solar radiation vector in elevation, creating a pattern of mountain- and valley-folds on the facades' surfaces. Transversally to these ridges, triangular metal shading panels are fitted into the resulting valleys which are oriented perpendicularly to the described vectors. To create a homogenous appearance, the same serrated geometry concept was then applied to the vertical back and triangular side facades of the building. In these areas, the façade is designed as a serrated, rear-ventilated metal clad enclosure in front of insulated and load bearing concrete walls.

In analogy to the glass facades, triangular metal panels are added as an architectural feature creating dynamic light patterns on the facade throughout the day.

The geometry of the facades was separately generated for each of the two prismatic building volumes. To achieve clean corner conditions, the opaque facades' geometry was computed first by creating a serrated primary axis grid based on the buildings' inclination and mirrored symmetrically along the building corners. The axis grid of the glass facade was then generated by creating primary axis lines based on the intersection points of the opaque facades' grid with the façade edge and the average solar radiation vector of the glass façade surface. The metal shading panels were then generated as a triangular surface within the façade valleys, oriented perpendicularly to the average solar radiation vector.

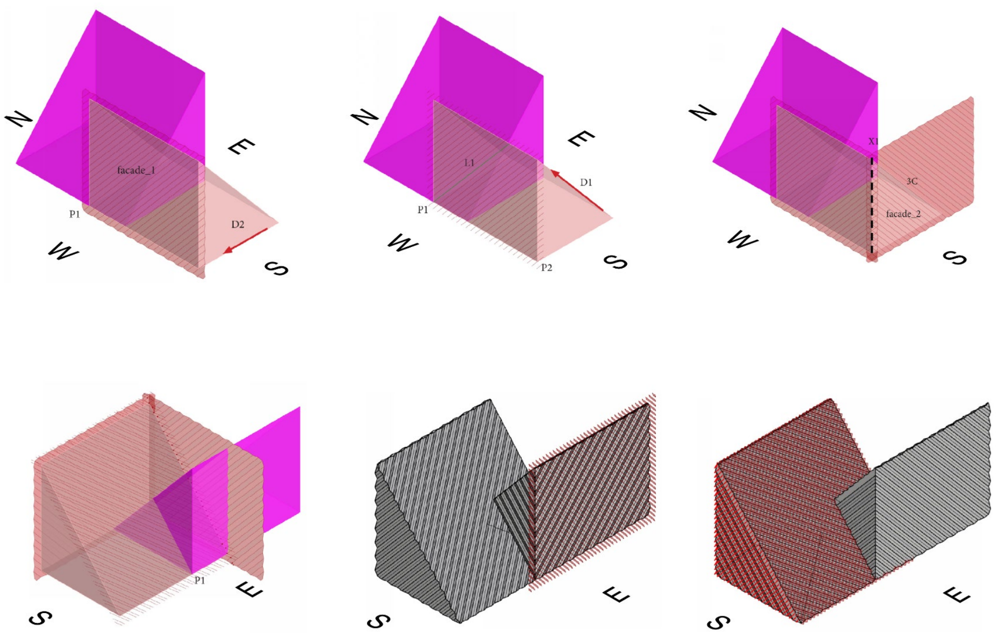

Fig. 4: Concept sketches for the geometry generation of the opaque and glazed façade systems. (knippershelbig).

The shading performance of the concept was verified by performing solar radiation simulations identifying a shading coefficient of the exterior metal panels. The shading coefficient was approximated by evaluating the solar irradiation on the serrated facades' outer surface, once with and once without the triangular shading panels, and then dividing the first by the latter value.

To do so, the average solar radiation was computed on a representative section of the serrated façade without consideration of the exterior shading panels by performing a raytracing-based irradiation simulation within the environment of the parametric model under implementation of local digital climate data with the use of Honeybee and Ladybug within Grasshopper. The same simulation was then performed considering the exterior shading features as metal panels with light grey colour.

On the eastern facade the results showed that the serrated geometry and external shading features were able to reduce solar radiation on the façade surface by ca. 53%, even exceeded on the western façade with a reduction of ca. 63%.

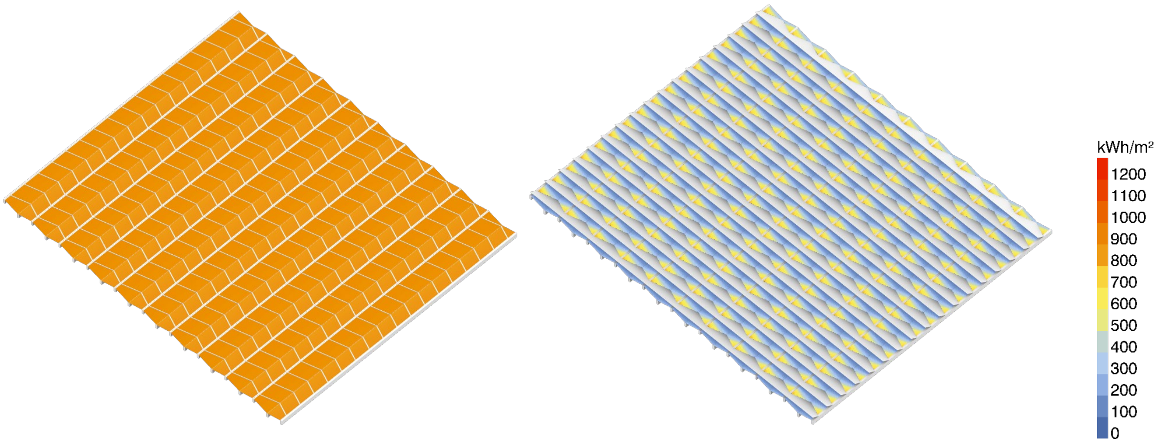

Fig. 5: Solar irradiation study of the western façade surface for verification of the shading concept of the tilted glass façade. (knippershelbig).

Together with a highly performative solar control coating on the glazing with a total energy transmittance (g-value) of 0.3, the strict requirements for solar heat gain were met with the use of these passive shading measures only. In the office floors additional interior white textile curtains prevent glare issues in the working spaces.

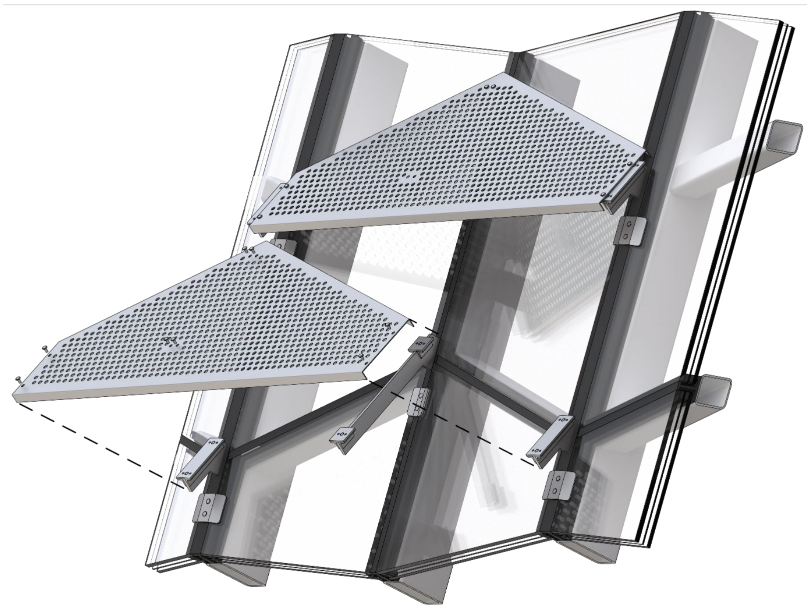

Fig. 6: 3D visualization of the glass façade system (knippershelbig).

Another key challenge was the transformation of this complex geometry into a constructive system. The inclined glazed facades are realized as a steel stick façade with an external gasket and glass carrier system. With a 61° tilt, the insulated glazing units are considered as overhead glazing, requiring laminated safety glass on the interior side. To meet the requirements of DIN 18008, the units are structurally two-side-supported by local clamps on the mullions hidden below the metal shading panels and additionally secured by toggle fixations, which engage in a channel within all glass edges. The rhombically shaped glazing units of up to ca. 1.200 mm x 3.300 mm are continuously running over multiple transoms to reduce installation effort, keeping the intermediate transoms in between as structural ghost transoms. The glass joints are sealed with wet silicone seals to minimize joint elevations. The aluminium folded shading panels are supported by local steel knife plates that are mounted on the screwing channel of the façade system and sealed all around. By doing so, the façade appearance is reduced to only the serrated glass surfaces and the metal shading panels. This clear construction concept is underlined by perpendicularly oriented metal plates along all building edges, entrance vestibules and punch windows that create a clean boundary around all façade surfaces and the building corners. In the atrium of the building, multiple rhombically shaped operable vents were integrated into the façade for smoke exhaust requirements.

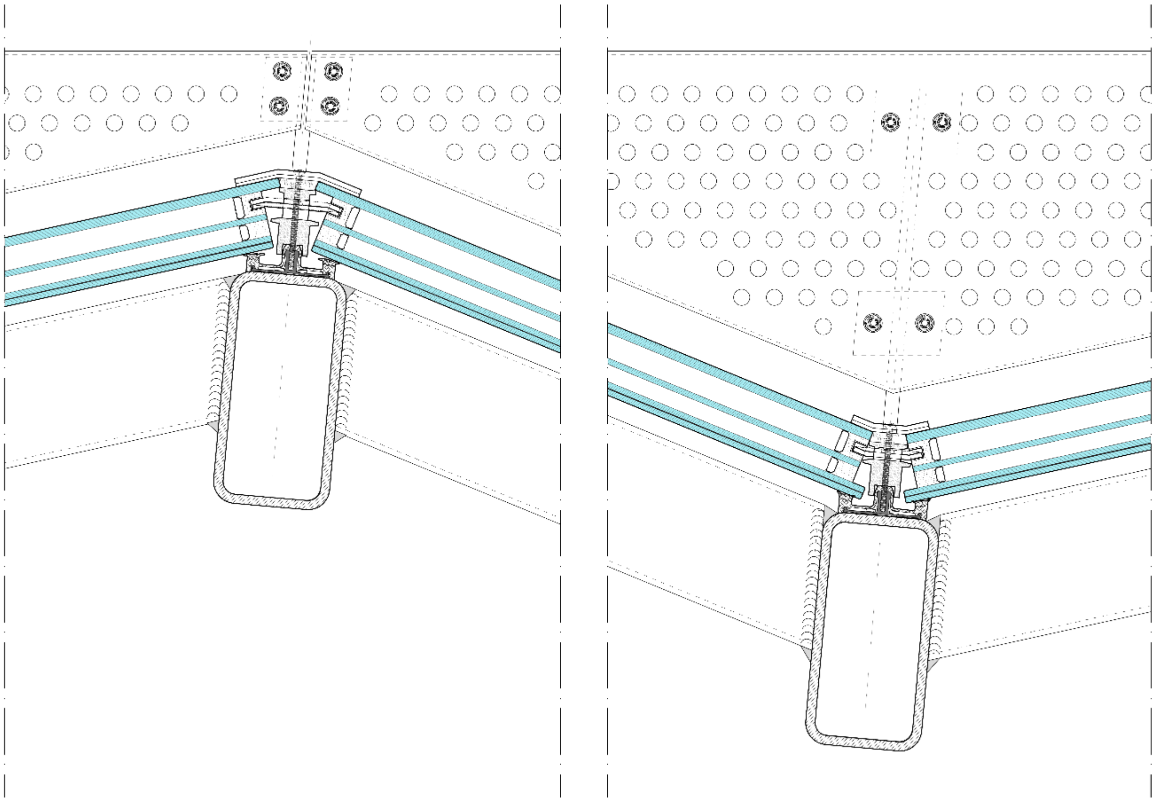

Fig. 7: 2D horizontal section detail of glass façade system (knippershelbig).

Realizing this complex geometry was a major challenge on the construction site. To do so, the façade was prefabricated as ladder elements of ca. 3.000 mm x 6.000 mm in dimensions with intermediate transoms on every other grid bay. These intermediate transoms were installed on site which allowed for tolerance accommodation in the connection details. After installation and positioning of the steel members, the gasket system and glazing units were installed with the use of different glazing blocks to achieve the required geometry and keep even joint widths. After sealing the façade and securing the glasses against horizontal loads, the shading panels were mounted last.

Due to the changing shadows of the metal panels and glass reflections throughout the day, a dynamic play of light is created on the outside as well as the inside of the building. The same light play is adapted on the metal clad walls, where the sunlight creates different colour shades and shadow patterns throughout the day - creating a vivid façade resembling the ever-changing light and shadow patterns of the mountains around it.

3. Gaining structural performance from the facades' geometry

The architectural concept is fully integrated in the structural resisting scheme: the high performance and slenderness of the façade is enhanced by the folded geometry, which increase the structural height of the façade. The serrated façade creates a sort of 3D Vierendeel-truss, in which the external mullions (on the ridges) are compressed, and the internal mullions (in the valleys) are in tension, or vice versa. The parametric 3D geometry model is used as a basis for structural design studies defining the perfect balance between visual appearance and structural optimisation.

To avoid the visual impact of an expansion joint, the mullions of the façade are designed as continuous beams. At each intermediate floor it is introduced a connection capable of transferring horizontal and lateral load (global direction X and Y) but free to move in the vertical direction (global Z) via a slot hole. This degree of freedom allows the cantilevering concrete slab to move vertically without generating imposed displacements on the façade.

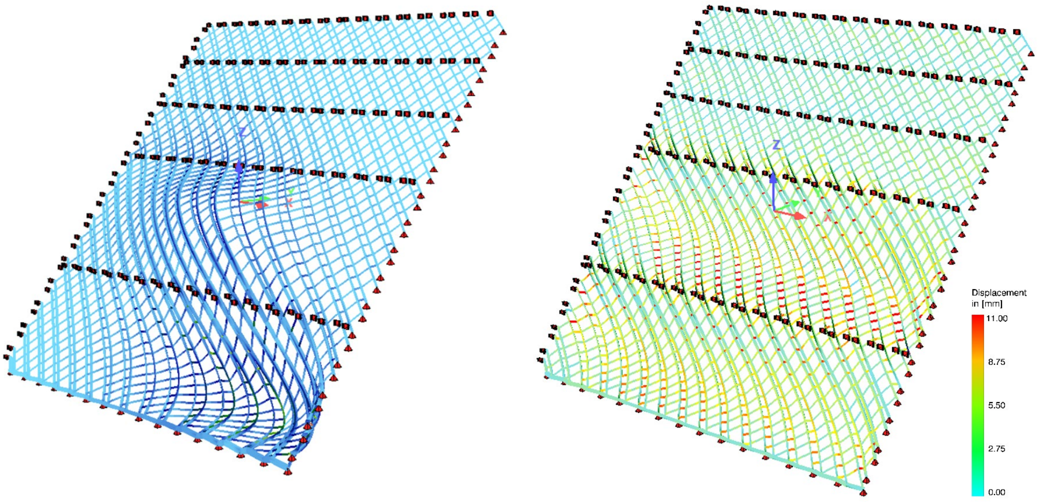

Fig. 8: a) Qualitative shape of the initial imperfections considered in the analysis (left).
b) Incremented deformed shape of the façade under horizontal loads (right). (knippershelbig).

Since the local axial direction of the mullion is not oriented along with the slot-hole direction but rotated in both local directions (local Y and local Z), the mullion is not free to expand, and thermal loads generate axial forces. Due to the inclination of the mullion, compression is also induced by permanent vertical load and variable horizontal load (wind, live load, and snow). The mullions are subjected to a considerable compression, especially at the first floors, where they span over 10m to allow for the mezzanine floor and the spacious volume of the atrium. To ensure a safe design and avoid buckling phenomena the Ultimate Limit State analysis is carried out considering non-linear second order theory (P-Delta) and high initial imperfections in the order of span/100. With this scheme the large spans are realized with rectangular hollow steel sections of 200 mm x 100 mm as mullions and of 120 mm x 80 mm as transoms, while limiting deflections to ca. 11 mm and yield stresses to ca. 305 MPa.

4. Summary and Discussion

The façade design aims to intertwine the architectural concept with the technical performance of the facades. A serrated geometry with triangular metal shading panels on the one hand resembles the nearby alpine mountains and creates a dynamic play of light in the building and on the façade. On the other hand, it is used as a passive shading system to fulfil strict energy requirements and is utilized structurally to reduce material in the facades profile system.

While a passive, fixed shading system as the one described within this article is advantageous in a high design flexibility, avoidance of energy consumption in the use phase and a high durability against external loads, disadvantages are its missing adaptability for users and a permanent view barrier.

In the context of the challenges of climate change, the approach described in this paper tries to reduce carbon emissions by utilizing façade geometry to meet high energy requirements and minimize energy consumption during the use phase with only passive shading systems. It aims to optimize material usage by structurally activating the facades' geometry and to create a long-lasting building enclosure with a durable construction and an appearance that is both timeless and well-integrated into the surroundings.

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