

# Making Geometry Visible: Intersections of Form, Function and Fabrication

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## Abstract

The Prada façade at Ion Orchard in Singapore represents a highly engineered steel-and-glass façade system that combines free-form geometry with advanced fabrication and integrated building services. The bespoke façade covers approximately 430 sqm and consists of 571 triangular glazing units supported by a prefabricated steel grid system comprising 27 t of structural steel and 6 t of aluminium components. The façade incorporates flat, curved, J-shaped and kinked glass geometries, creating a multidirectional grid extending over 1,300 m of joint lines. A total of 927 m of integrated LED lighting is seamlessly embedded within the façade system. A key engineering challenge resulted from significant slab deflections, which prohibited conventional suspension strategies and led to the development of a spanning structural concept transferring loads between the primary columns. The project demonstrates how digital workflows, precision fabrication and structural innovation enable the realization of highly complex façade geometries with minimal tolerances and maximum visual refinement.

## Keywords

Glass, Steel, Free-form façades, Geometries, Printed patterns

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## 1. Introduction

The realization of geometrically complex, highly integrated glass façades in contemporary retail architecture requires a precise interplay between digital design methodologies, structural engineering and fabrication technologies. Increasingly, façade systems must not only provide transparency and enclosure, but also integrate architectural expression, structural behavior and technical systems within extremely limited construction depths.

The Prada façade at Ion Orchard in Singapore exemplifies this development through a highly customized steel-and-glass façade system that combines multidirectional geometry, advanced fabrication methods and embedded lighting technologies. The project comprises a bespoke shopfront façade with an approximate area of 430 sqm, located within one of Singapore's most prominent retail destinations.

The architectural concept is based on a triangulated, multidirectional grid system, forming a continuous and visually dynamic façade surface. This system integrates 571 individual glazing units, each geometrically unique or part of a limited repetition logic, resulting in a high degree of geometric differentiation across the façade surface.

The façade system incorporates approximately 27 t of internal structural steel and 6 t of external aluminum pressure plates and cladding components. In addition, 927 m of LED lighting is integrated into the façade, requiring a high degree of coordination between structural, architectural and electrical systems.

The realization of the façade posed significant engineering challenges. These included the combination of multidirectional free-form geometry, large slab deflections due to live loads, extremely limited installation tolerances and the integration of lighting and services within a constrained façade depth. This paper outlines the development of the façade from digital modelling to fabrication and installation, highlighting the critical relationship between geometry, structure and construction.

## 2. Architectural and Structural Concept

The façade design is defined by a triangulated grid system composed of horizontal and diagonal lines, generating a continuously varying geometric pattern across the building envelope (Fig. 1). The geometry incorporates localized curvature about a vertical axis and combines planar and non-planar elements to achieve the intended architectural expression.

A total of 571 triangular glazing panels were developed, consisting of 299 flat units and 232 curved units, complemented by 28 J-shaped and 12 kinked panels. This distribution reflects a high degree of geometric complexity, with approximately 7% of panels requiring non-standard forming processes beyond conventional flat or singly curved geometries. The variation in panel geometry necessitated individual moulds and highly controlled fabrication processes.

The glazing system consists of heat-strengthened laminated low-iron glass incorporating SGP interlayers and ceramic-printed patterns derived from Prada's design language. The structural support is provided by a unitized steel grid system composed of prefabricated elements with minimized visible face widths and reduced nodal expression (Fig. 2).

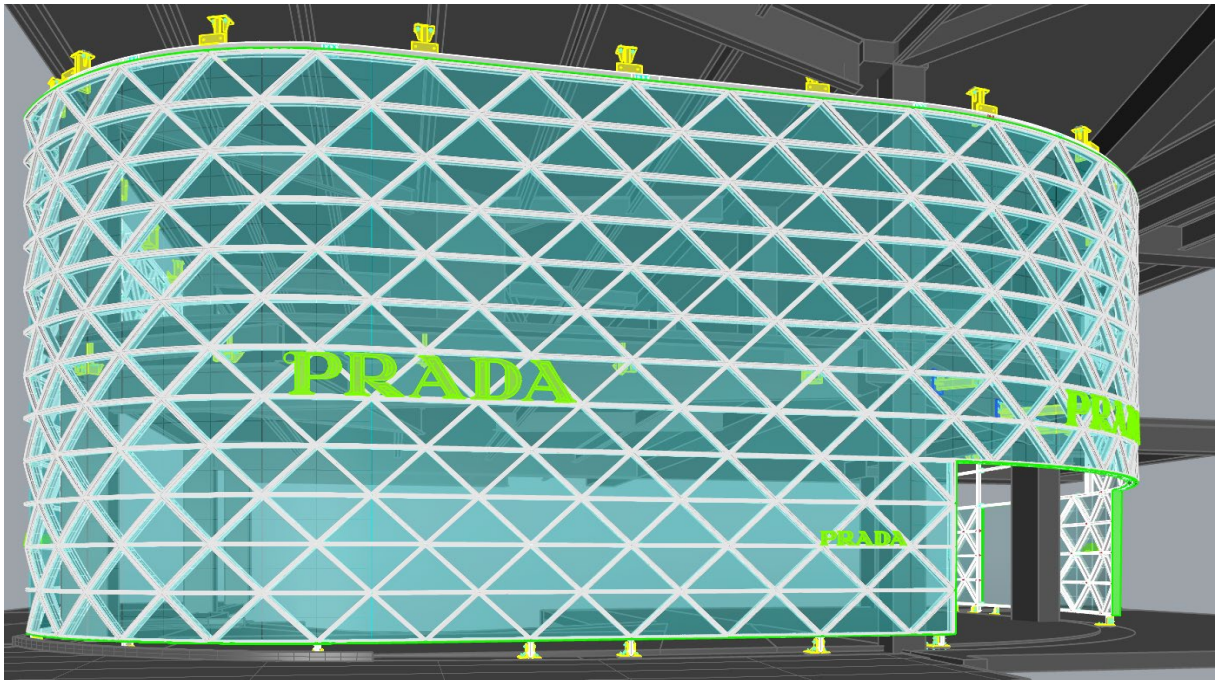


Fig. 1: Triangulated façade geometry and panel typologies.

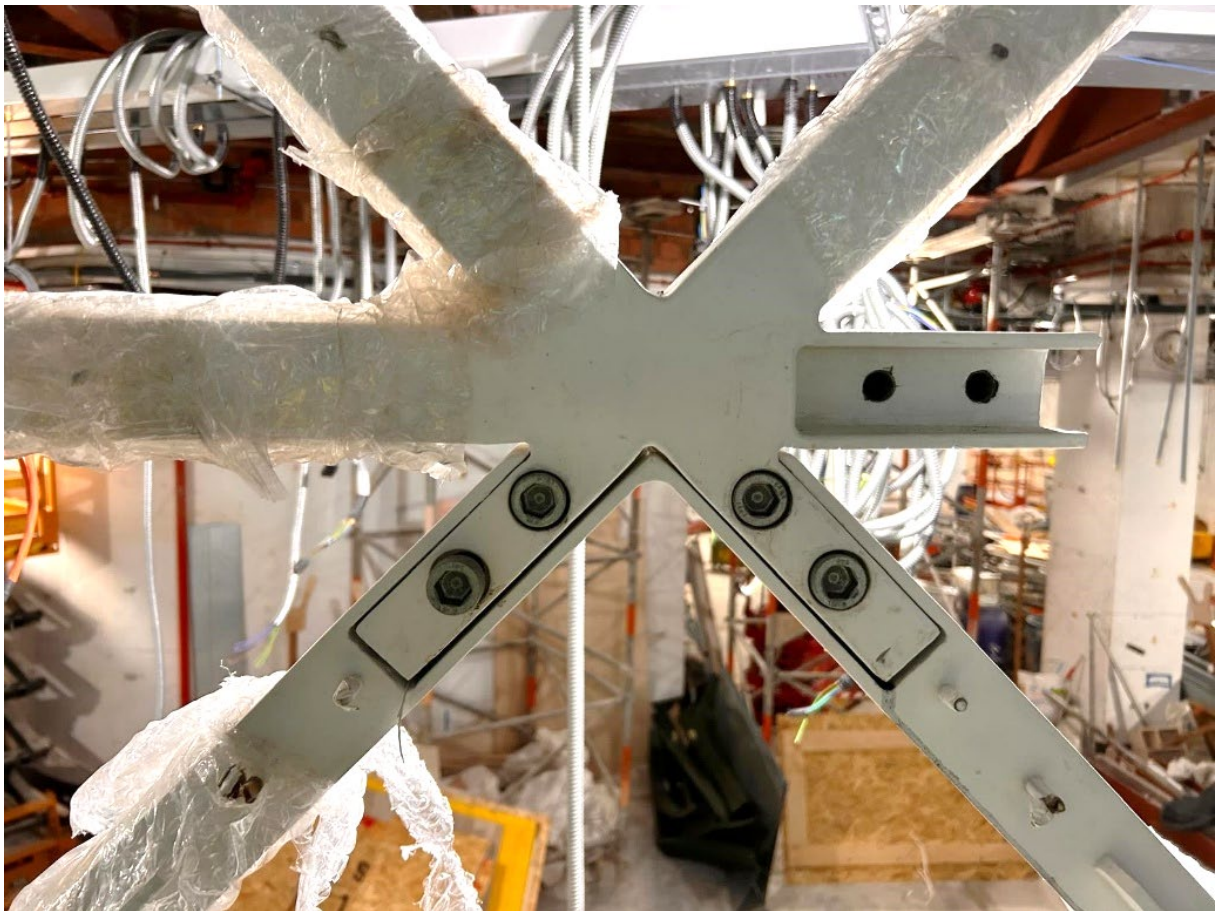


Fig. 1: Node detail and connection principle (V-splice).

A key constraint of the project resulted from the proximity of underground transport infrastructure, which required the façade to be suspended from the slab above rather than supported from below. However, structural analysis revealed significant slab deflections under live loads, exceeding the allowable limits for direct façade suspension. This condition would have resulted in excessive stresses within the façade nodes and unacceptable geometric deviations. As a consequence, the structural concept was fundamentally revised. Instead of a suspended system, the façade was designed as a spanning structure transferring loads between the building's primary columns (Fig. 3).

This bridge-like behavior significantly reduced the impact of slab deflections on the façade system and ensured that geometric tolerances could be maintained throughout the structure. The façade design is defined by a horizontal and bidirectional diagonal gridline system creating a dynamic geometric appearance across the building envelope. The geometry incorporates localized curvature around a vertical axis and combines planar and non-planar glass elements to achieve the intended architectural expression.

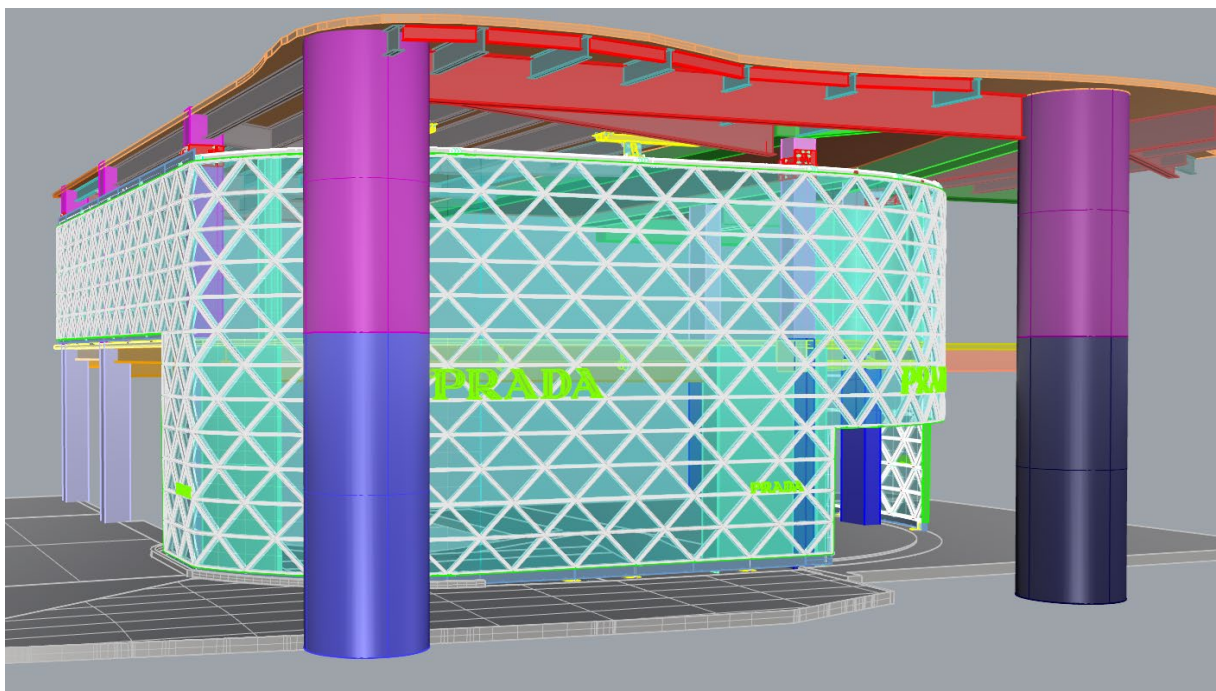


Fig. 2: Structural concept – spanning between primary columns.

### 3. Digital Geometry and Engineering Development

#### 3.1. Digital Survey and Model Development

A comprehensive 3D scanning process was carried out to capture the as-built geometry of the primary structure. The point cloud data was combined with structural design information to generate a coordinated digital model forming the basis for all subsequent engineering and fabrication processes. The digital model enabled precise geometric coordination between façade components and building interfaces. It supported the development of connection details, bracket systems and fabrication geometries, while ensuring compliance with strict tolerance requirements. Given that all façade elements were prefabricated and designed for installation without significant on-site adjustment, model accuracy was critical to the project's success.

### 3.2. Structural Development

The multidirectional geometry combined with the spanning structural concept resulted in complex load paths and interaction between façade components and the primary structure. Detailed structural models were developed to evaluate self-weight, wind loading, thermal movement, slab deflections and installation-stage conditions.

A unitized steel frame system with male-female node connections was developed to achieve structural continuity while maintaining minimal joint widths. The V-splice connection principle allowed for precise force transfer between elements but provided only limited tolerance compensation. As a result, fabrication tolerances in the order of a few millimetres became a governing parameter for both design and production. The structural concept ensured that loads were redistributed along the triangulated grid, allowing the façade to act as a continuous system rather than a series of independent elements. This approach minimized local stress concentrations and improved the overall stiffness of the façade.

## 4. Fabrication Challenges

### 4.1. Steel Fabrication

The structural system consists of 66 highly precise prefabricated steel units. Due to the geometric interdependencies between adjacent elements, components were manufactured and pre-assembled in clusters to verify fit and alignment prior to delivery.

The male-female node connections represented a critical aspect of the fabrication process. Their complex geometry and minimal tolerance allowances required a high level of precision in machining and assembly. Any deviation beyond the permitted tolerance range would have resulted in cumulative geometric errors affecting the entire façade system. Following fabrication, the steel elements were coated internally with polyurethane for corrosion protection and externally finished in white to meet architectural requirements.

### 4.2. Glass Fabrication

The glazing system required multiple production techniques due to the variety of geometries involved. Curved panels were produced using hot bending processes, while J-shaped and kinked panels were realized through gravity bending techniques. The combination of curvature, triangular geometry and ceramic printing required precise alignment between forming and printing processes. The use of low-iron glass with SGP interlayers ensured both structural performance and visual clarity. Quality control procedures were implemented throughout production to ensure compliance with strict geometric tolerances.

### 4.3. Aluminium Components

The aluminum pressure plates and cladding elements featured complex curved and twisted geometries, particularly in nodal regions. These components were produced using multi-axis machining processes and required repeated geometric verification. The interaction between aluminum components and adjacent steel and glass elements required continuous coordination. Particular challenges arose in areas where curvature and torsion were combined, necessitating iterative adjustments during the fabrication process.

## 5. Installation and Integration

### 5.1. Installation Strategy

The installation sequence began with the positioning of brackets, followed by the assembly of the steel frame and subsequent installation of glazing units. Due to the limited tolerance allowances, continuous geometric verification was required throughout the installation process. The male-female connection system enabled efficient sequencing but demanded high positional accuracy. The alignment between structural steel, aluminum framing and glazing components had to be maintained within tight tolerances to ensure proper fit and performance.

### 5.2. Integration of Lighting Systems

A total of 927m of LED lighting was integrated into the façade, forming an essential part of the architectural concept. The integration required careful consideration of cable routing, maximum cable lengths, maintenance accessibility and visual concealment. All electrical connections were routed to a single façade edge, requiring a coordinated approach to avoid visible penetrations and maintain the visual clarity of the façade. The integration of lighting within the limited façade depth required a high degree of interdisciplinary coordination between structural and electrical engineering disciplines.



Fig. 4: Installation.

## 6. Discussion

The Prada façade at Ion Orchard highlights how the realization of complex free-form façade systems is fundamentally governed by the interaction between geometry, structural behavior and fabrication constraints rather than geometry alone. A key insight from the project is the decisive role of structural boundary conditions in shaping the façade concept. The necessity to accommodate significant slab deflections directly led to the development of a spanning structural system, demonstrating how site-specific constraints can redefine conventional façade engineering approaches. Furthermore, the project underlines the importance of digital workflows as an enabling technology rather than a supporting tool. The integration of 3D scanning, parametric modelling and fabrication data ensured that geometric complexity could be translated into manufacturable components within strict tolerance ranges. In this context, the achievable accuracy of the digital model became a critical parameter for the overall system performance.

Another relevant observation is that façade complexity arises from the cumulative interaction of multiple parameters, including geometric variation, tolerance management, fabrication sequencing and installation logistics. The combination of these factors required a highly coordinated interdisciplinary approach, particularly in areas where structural components, glazing systems and integrated services intersected within minimal construction depths. The project therefore illustrates a shift in façade engineering from geometry-driven design towards process-driven realization, where fabrication logic, structural constraints and installation strategies play an equally decisive role in defining the final architectural outcome.

## 7. Conclusion

The Prada façade at Ion Orchard demonstrates how complex free-form glass façades can be successfully realized through the precise integration of structural design, digital workflows and fabrication processes. By transforming a conventional suspension concept into a spanning structural system, the project establishes an alternative approach for addressing building movement in constrained conditions. At the same time, it confirms that high geometric complexity can only be achieved when tolerance control, prefabrication accuracy and interdisciplinary coordination are treated as primary design drivers.

The project provides a clear example of how advanced engineering methodologies enable the practical realization of architecturally ambitious façade systems, offering valuable insight for future developments in high-complexity building envelopes.



Fig. 5: Completed façade.



Fig. 6: Prada Shop from inside out.

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