Structural Stainless Steel Case Study 09

New Beijing Poly Plaza Cable-Net Wall

Beijing's Poly Plaza is the new headquarters for China Poly, a state-owned organisation with diverse responsibilities in the defence trade, real estate, cultural industries and mineral exploration. In addition to the company's headquarters, the 100,000 m^2 building comprises office space, shops and restaurants. The structure is triangular in plan, with an L-shaped office block forming two sides and the third side formed by one of the world's largest cable-net glass curtain walls. This creates a large atrium inside the structure, within which the 8 storey Poly Museum—'The lantern'—is suspended. Stainless steel cables and castings support the cable-net wall. The support fittings were cast from high strength duplex stainless steel.

Material Selection

The cable-net wall in the Poly Plaza comprises many stainless steel elements including cables, clamp fittings, connecting rods as well as the support fittings. The grades of stainless steel chosen were component-dependant, taking consideration of its function within the cable-net assembly. Accordingly, austenitic grade 1.4401 (S31600) is used for the horizontal and vertical cables whilst the cable-net intersection points are connected with high strength clamp fittings of duplex grade 1.4462 (S32205). The rods between the primary support cables and the cable-net are also austenitic grade 1.4401 (S31600) stainless steel. The support armature is cast from the high strength duplex alloy CD3MN (J92205), which is the cast version of duplex grade 1.4462.

Stainless steel was selected primarily because of its high strength and corrosion resistance. In addition, its pleasing appearance and low maintenance needs were further advantages. Beijing has a corrosive environment with high levels of industrial pollution and there has been a significant rise in the use of de-icing salt in the winter. Specification of corrosion resistant stainless steels made it possible to avoid high maintenance coatings. Additionally, the bare stainless steel is a sculptural, structural design element. Low corrosion rates of stainless steels contribute to the efficiency of the design. Furthermore, the high scrap value of stainless steel makes the building sustainable even beyond its useful life.

The material specifications included a requirement that the surface of each cable was free of defects such as soot, cracks, notches, etc. A light shot blast finish was specified for the elements made from grades 1.4401 and 1.4462.

Figure 1: Beijing Poly Plaza
(Photo: Tim Griffiths, Skidmore, Owings & Merrill LLP)

The support armature, which comprised twin armed fittings to connect the cable net intersections to the glass panels, were castings with a glass-bead blast finish. This finish was specified because, due to the complex shapes of the fittings, a directional finish was not possible. It was also specified that no metals, including alloys of the same base metal, were placed together in a manner, combination, or location that would be likely to give rise to damage by electrolytic or other corrosive action.

Design

The main building is constructed from a combination of reinforced concrete, structural steel and stainless steel elements. Like most typical buildings in China, the design life for the whole structure is 50 years. The building was designed using Chinese design standards and the cable-net façade, in particular, was designed using the Technical Code for Glass Curtain Wall Engineering [1]. US codes and standards including ASCE Standard 7: Minimum Design Loads for Buildings and Other Structures [2] and ASCE Standard 19-96: Structural Applications of Steel Cables for Buildings [3] were also used. Furthermore, German standards were used for material specification.

The main design feature of the building is the huge cable-net wall, which includes a large amount of stainless steel. Cable-net walls use planar two-way cable systems to support a glass façade through the resistance to deformation of the two-way pre-tensioned net. The glass is attached to the cable-net at intersection nodes, where the vertical and horizontal cables meet. Vertical loads are resisted through these nodes, which pass the forces into the vertical cables and, in turn, to the base of the structure. On the other hand, lateral forces due to wind or seismic events are resisted by the tendency of the cables to return to their straight line configuration between supports. Although the concepts of cable-net walls are relatively simple, it is only in recent years that they have become popular, as designers appreciate both their aesthetic and engineering attributes.

The cable-net is 90 m tall and 60 m wide, and encloses the main building which is an ‘L’ shape, creating an atrium space. Within this area, an 8-storey ‘lantern’ is suspended from the structure as shown in Figure 1. Preliminary analysis showed that the cable-net wall was too large to be economically achieved using a conventional steel-glass wall. Furthermore, as the conventional solution would involve using large trusses, the view of the city would be obstructed. Instead, an innovative solution was proposed whereby the wall is supported by four large diameter cables under significant pre-stress. These relatively stiff elements run diagonally along the surface from the roof of the lantern up to the top of the atrium in a V-shape and effectively divide the wall into three small faceted sub-sections (Figure 2). The folds act as virtual boundary conditions, effectively shortening the spans. These large primary cables were straight when installed and became curved towards the façade during tensioning of the cable-net. Using this faceted design solution, the typical horizontal and vertical cables of the cable-net wall were limited in diameter to 34 mm and 26 mm, respectively. The horizontal and vertical cables are spaced at 1333 mm and 1375 mm centres, respectively.

Figure 2: Main cable-net wall with primary ‘v cables’ (Photo: Tim Griffiths, Skidmore, Owings & Merrill LLP)

Figure 3: View of the cable-net components including support armature (Photo: Skidmore, Owings & Merrill LLP)

Figure 4: Close-up view of the connection of vertical and horizontal cables prior to erection
(Photo: Skidmore, Owings & Merrill LLP)

Figure 5: Stainless steel rods used to connect the support channel to the cable-net
(Photo: Skidmore, Owings & Merrill LLP)

The glass and stainless steel wall was also designed to withstand 100-year winds and can deflect up to 0.9 m under maximum wind load. The flexible nature of planar cable-net walls under lateral loading means that the critical design criterion is usually deflection. In this case, early design calculations indicated that much larger deflections would occur during high-wind loads, due to the movement of the cables and glass. As a result of these deflections, large glass pane-to-pane rotations would occur at the fold lines and so a hinged support channel, which allows the glass to rotate by up to 7°, was used. Stainless steel rods connect the channel to the cable-net and also hold it off the diagonal cables (as shown in Figure 5). The scale of the wall greatly exceeds those that have been built before, thereby introducing specific challenges. However, the advantages of the design are that it reduces the environmental impact on the building from the elements and also optimises the daylight inside, by having relatively small structural elements.

Another key issue in the design of the new Poly Plaza was the inter-storey drift that may occur under seismic and wind loading conditions. In this case, the diagonal large stainless steel cables act as bracing that tries to resist the forces. To limit the load levels, it was decided to decouple these primary cables from the base building structure using a ‘rocker mechanism’ based on a pulley analogy (shown in Figure 7).

The cable-net wall is provided with stiff, strong boundary conditions by reinforced concrete cores which are located at the sides of the cable-net wall. These also provide an ideal location to access the stainless steel cable anchorage points and to facilitate tensioning operations. A stiff boundary condition is provided at the top by a 3-storey structural steel truss spanning 60 m between the top of the two cores.

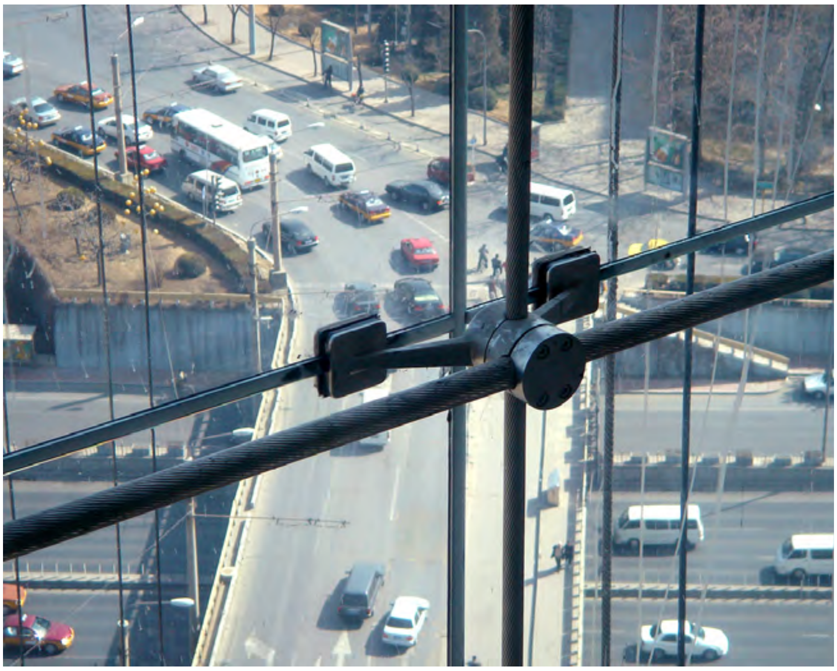

Figure 6: Stainless steel cable to glass connection
(Photo: Skidmore, Owings & Merrill LLP)

Fabrication and Erection

Although the cable-net wall structure and its components were designed and detailed on the structural engineer's construction drawings, the exterior cladding system of the building was specified such that all components (i.e. steelwork, glazing etc.) were built together. This was to achieve single source responsibility for the exterior envelope. A performance specification was thus provided. The fabrication and erection were the responsibility of the contractor who was required to meet the final dimension, finish quality and performance requirements of the contract documents.

The design of the cable-net wall required the main building structure to be topped out before any cable installation operations could occur. The main structure was constructed with the structural steel floor framing following several storeys behind the concrete cores. Once the boundary elements were in place, the installation of the rocker mechanisms and the primary V-cables began. After the main cables were installed, the smaller cables in the net were loosely installed and connected to the main cable through pin-ended connecting rods. All the final cable-net tensioning was performed by pulling the horizontal and vertical cable ends from within dedicated tensioning spaces provided in the cores at each side of the cable-net wall. After final tensioning of the cables, the cable clamp nodes at each intersection were tightened, the glass panels were installed and the joints sealed.

Figure 7: View of cast steel rocker with stainless steel cables
(Photo: Skidmore, Owings & Merrill LLP)

Information for this case study was kindly provided by Skidmore, Owings & Merrill LLP

References and Bibliography

[1] Standard of the People's Republic of China. Technical Code for Glass Curtain Wall Engineering (JGJ102-2003). Beijing, China, 2003.

[2] American Society of Civil Engineers. Minimum design loads for buildings and other structures. ASCE-7–98, 1999.

[3] American Society of Civil Engineers. Structural Applications of Steel Cables for Buildings. ASCE-19-96, 1997

Online Information Centre for Stainless Steel in Construction:
www.stainlessconstruction.com

Procurement Details

Client:	China Poly Group Corporation
Structural Engineer:	Skidmore, Owings & Merrill LLP
Main contractor:	China State Construction Engineering Corporation
Cable-net facade contractor:	Yuanda Group and ASI Advanced Structures

This series of Structural Stainless Steel Case Studies is sponsored by Team Stainless.