

One of the world's largest charitable organizations pursues its global goals from a new headquarters campus.

Greater Good

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Sean Airhart/NBBJ

TO SAY THAT the goals of the Bill & Melinda Gates Foundation are wide-reaching is a rather large understatement.

The primary aims of the Foundation are to enhance health-care and reduce poverty on a global scale as well as the domestic expansion of educational opportunities and access to information technology.

The Foundation has been pursuing these goals from multiple leased office spaces around the Seattle area, but recently moved into the completed first phase of their new headquarters located just north of downtown. With this move, the organization will bring its more than 1,000 employees together into a state-of-the-art LEED Platinum campus. The overall master plan for the 12-acre project serves to give a physical identity to the Foundation's global mission of providing all people a chance to live healthy and productive lives while also creating a permanent, collaborative and dynamic environment for its workforce.

The new campus was originally conceived in 2005 when the Foundation purchased the surface parking lot for the adjacent Seattle Center grounds, which originally hosted the 1962 World's Fair. The first phase of the project was the construction of a 1,000-car underground parking garage on the southwest corner of the site. The subsequent phase of work includes the construction of two seven-story steel-framed office towers, totaling 400,000 sq. ft, situated over a new subgrade structure encompassing the complete site. A final phase, currently designed and permitted and to be completed in the coming years, will provide a third tower of the same size.

Design Precepts

From the outset the design team, led by the architect, NBBJ, was guided by a set of high-level design precepts developed by the Foundation. Design drivers drawn from these precepts—such as “Adaptability,” “Dynamic,” “Timeless,” “Delight” and “Daylight Access”—helped guide the program, form and technical design criteria for the buildings. The end result was a distinctive “V” shape for the buildings, which are aligned so that their “arms” point outward in different directions to symbolize the outward focus of the Foundation. In addition, the top five stories of the towers were intentionally designed to read as distinct continuous elements elevated above the lower two-story podiums. The functionality and layout of the office workplaces were critical design considerations as well, which resulted in the use of perimeter tapered soffits for daylighting, a raised access floor, connecting stairs and a relatively large 50-ft × 30-ft column module.

Each elevated composite steel floor plate is 65 ft wide and roughly 500 ft in total length measured along the “V.” A W24 × 68 section, at 10 ft on center, served as the typical beam spanning the 50 ft column module, with corresponding cantilevers off of each end. At the early stages of design Arup worked closely with the Foundation to determine a satisfactory floor vibration performance due to human walking excitation. Using an explicit finite-element modal steady-state analysis of the entire floor plate, an assessment of different walking frequencies and amplitudes, applied



▲ The new Bill & Melinda Gates Foundation headquarters consolidates the organization's 1,000-plus employees in one location.

▲ The two seven-story towers, located just north of downtown Seattle, use a total of 3,400 tons of structural steel.

at different locations on the floor—such as the breezeway corridor versus the partitioned office spaces—could be quantifiably assessed. The design guidance for this assessment used an Arup procedure that has been calibrated based on actual field measurements and considers all relevant modes and harmonics of footfall forces. The underlying principles of the procedure are based on AISC *Design Guide #11*, British Standard *BS 6472* and SCI *Publication 076*. The outcome of this assessment provided an optimally sized structural steel system that was assured of meeting the client's performance objectives for floor vibration performance.

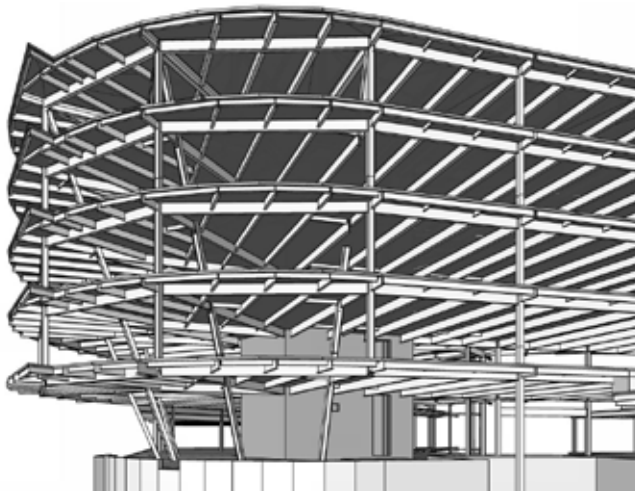
A designated breezeway concourse along the interior perimeter of each floor plate provides access into the various workplace environments. At the breezeway the tapered ceiling soffit requires a corresponding custom 8-ft tapered, cantilevered wide-flange to be used to support the breezeway floor and be precisely aligned to support the cladding mullions, which are on a 10-ft module, at its tip. To ensure efficient material use, a W30 section was cut at an angle through its web to create the tapered sections. This section depth allowed two matching tapered elements to be created from each W30 segment with a depth of 6 in. at the tip and 24 in. at the support (see the figure on page 45). A matching flange plate was shop welded to complete the section shape.

The Knuckles

At the curved “knuckle” regions, steel framing complexities are introduced due to the overall curving nature of the floor plate, the floor opening for the connecting stairs and the requirement that each cladding mullion along the interior edge be supported at a 10-ft module by a cantilevered beam. A thoughtful arrangement of the steel framing provided an efficient framing layout that could be detailed and constructed using only a handful of simple project specific typical details. (A representative example,

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- ▲ One of the "knuckles" as rendered in Revit.
- ▶ Knuckle raking columns with the shoring removed.



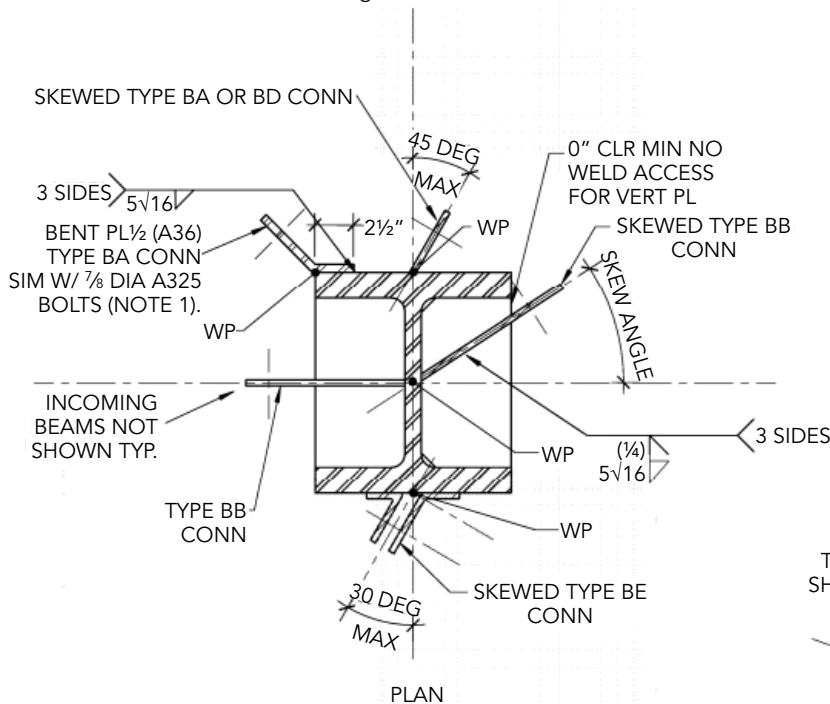
Arup

below, of this is the typical detail for wide-flange columns that support more than four incoming beams at skewed angles.) This single detail proved to be an efficient means by which to address all such conditions on the project.

In addition, at the curved knuckle conditions of the floor plate, a sequence of wide-flange hangers, columns raked at roughly 20° from vertical and associated roof-level wide-flange tension struts stabilized off of the adjacent concrete core were

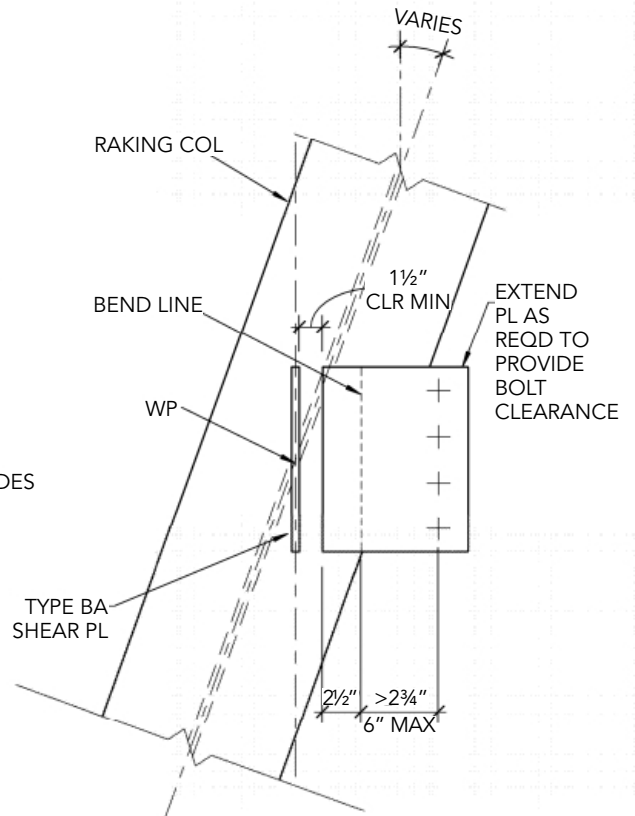
implemented. This allowed for the Level 3 and above floor plates to distinctively project and sweep outward from the two-story podium below. During construction each of the perimeter hangers were temporarily shored by the contractor from the underside of Level 3 until the complete structural system was completed. The decision to use wide-flange beams for the raked columns and hangers allowed for simplicity in beam-to-column connection detailing.

- ▼ Typical beam-to-column connection with skewed angles and more than four incoming members.



NOTES:

1. CONNECTION NOTED SHALL BE USED WHEN SKEW ANGLE IS TOO LARGE TO USE SKEWED TYPE BB CONN OR WHEN A TYPE BB CONNECTION INTO ADJACENT COLUMN WEB IS ALREADY PRESENT.



BENT PL AT RAKING COLUMN

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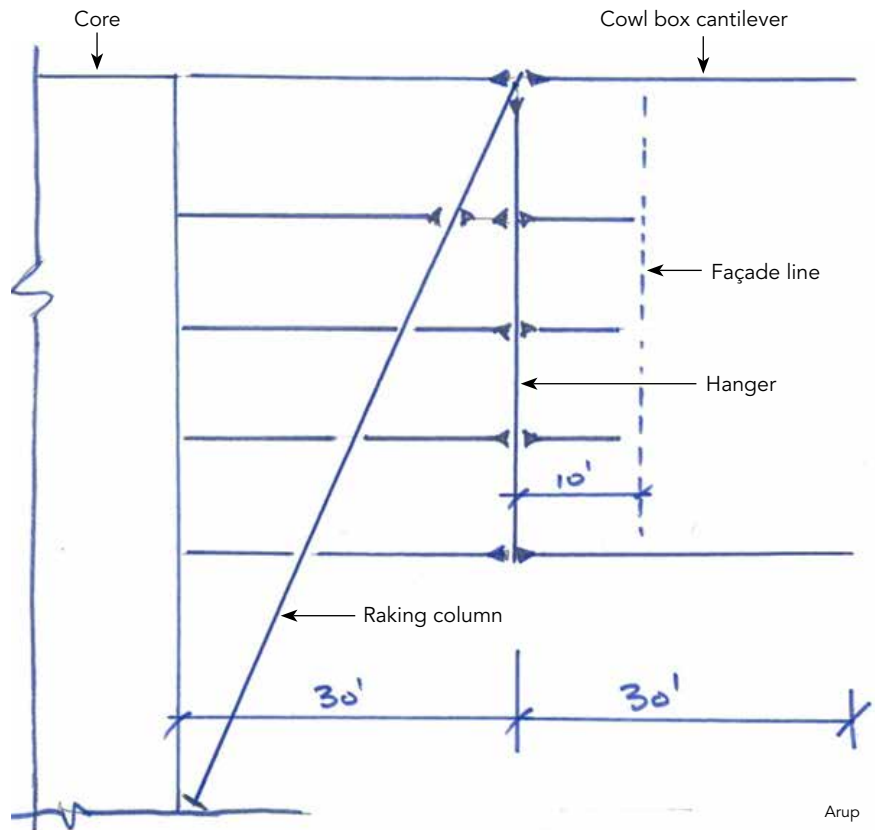
The Cowls

Projecting off the ends of both tower structures, a distinctive 60 ft, 5-story building cantilever is achieved through means of boxed steel cantilevers, hangers, raking columns and tension roof members stabilized off of the concrete cores. This structural system was closely analyzed to monitor the global deflection of the cantilever. A camber of over 2½ in. at the tips of these “cowls” was required to ensure that, upon application of the full building superimposed dead load, the steel framed structure would deflect downward yet remain contained within the exterior cladding envelope. In the same manner as the knuckle region, the hangers were temporarily shored by the contractor during construction until the full structural system was complete.

At the roof level, the wide-flange tension members supporting the cowl raking columns are not in direct alignment with the supporting concrete core. To further complicate the issue, rooftop mechanical equipment required several large roof penetrations adjacent to the core. To simplify connection details, provide a rigid load path and ensure the ceiling space within the beam depths on the floor below was not impinged, steel plates were field welded at the roof beam top flanges. A cost comparison study during design between the steel diaphragm plate option chosen versus a more conventional horizontal trussed diaphragm scheme revealed that the slight increase in tonnage for the steel diaphragm option was less than the added connection costs that would have been required for more conventional horizontal truss diagonal web members.

Cable Net Wall System

An 8,000-sq.-ft atrium provides the primary multi-purpose gathering space for the campus. The space is accentuated by having a 60-ft interior clear height with a transparent butt-glazed cable net wall located on the south and east faces. At each of the 6-ft, 8-in. glass modules a 30-mm (1.18-in.) stainless steel strand cable support spans vertically 60 ft from anchorage at the concrete plaza up to the steel-framed atrium roof. An alcove exists at the exterior building face, thus the cable on the interior face of the glass penetrates the exterior skin of the building at the bottom 15 ft. To limit the span length of the cable to 45 ft and prevent any relative movement of the cable due to wind loads at the building envelope penetration point, an L-shaped horizontal structural steel truss was integrated into the soffit.



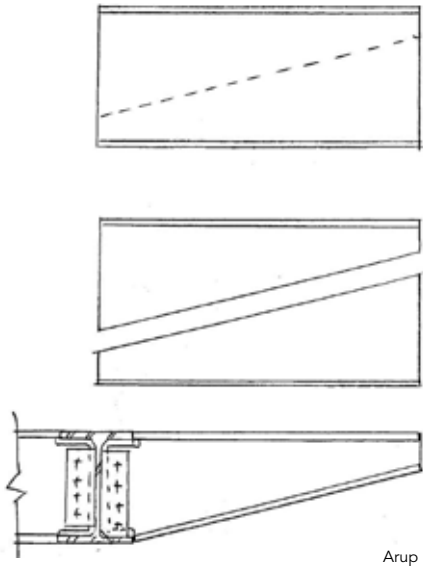
▲ A sketch of the 60-ft building cantilever at each end of both of the “V” towers.

To support wind loads applied to the glass face, each cable was sequentially pretensioned during construction to a final load 25 tons. At this level of prestress the tension stiffening effect on the cables limited the out-of-plane maximum design wind deflection of the glass wall to 12 in. outward and inward.

Although the large cable tension loads enable the glass wall transparency to be maximized, this intent had the potential to be compromised by using bulky perimeter structural columns to resist the additive tributary cable loads in compression. In the case of the atrium, nine steel HSS round columns were placed at 20 ft on center 2 ft, 6 in. inboard of the glass wall. The total factored compression load tributary to each column is on the order of 150 tons. Two additional constraints on the design were that 1) the building code required a fire resistance rating for the columns and 2) at the most highly loaded corner column, three deformation compatibility struts from the glazed wall impose horizontal wind forces along the column length that are concurrent with the large compression loading.

Despite these constraints, the objective was to use as small a column diameter as feasible. A 14-in. outside diameter round HSS column was achieved by pursuing an integrated design approach as follows. First, the horizontal soffit truss over the alcove (described above) was used as a brace point for each column. This reduced the column unbraced length to 45 ft. Second, each column was comprised of two 14-in. HSS pipes—with 10-in.-diameter round HSS sleeved inside of them—which were end plated together to make one integral column section. Prior to end plating, the inner column was intumescent coated to achieve the code required fire rating to support the tributary roof and office floor loads above.

This also enabled the outer column to be readily painted and fabricated to a high architecturally exposed structural steel (AESS) standard without need for an intumescent coating. Third, the complex combined loading on the columns introduced concurrent bending and axial loads. As it is not applicable to determine the unbraced load K for such columns using the nomographs pro-



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- ▲ A W30 section cut at an angle through its web to create two matching tapered elements with a depth of 6 in. at the tip and 24 in. at the support.

vided in the AISC *Steel Design Manual*, the Direct Analysis Method contained in the AISC 360 *Specification* was used. This methodology allows for the actual out-of-straightness of the column to be explicitly modeled with concurrent loads applied using a software package that accurately captures second order p-delta affects. This allowed for the direct load-deflection behavior of the column in combined compression and bending to be accurately assessed for the given loads so that the minimum HSS column size could be quantifiably validated.

Rooftop Enclosure

The rooftop for each tower includes a 12,000-sq.-ft mechanical equipment penthouse for the large chillers, pumps and boilers that service the buildings. The design required the penthouse to be fully enclosed to keep all equipment hidden from view. A simple and efficient hot-dip galvanized structural steel frame comprised of W12 sections, welded moment bents and steel rod bracing was used. A 1½-in. aluminum grating lid surface was supported at 7 ft, 6 in. on center. It was a key architectural driver to ensure that the grating support spacing was regular throughout and that the grating span direction was consistent. The only change in grating span direction is at the penthouse roof's mirrored bisector line.

At the side faces, a perforated and corrugated aluminum siding is supported off of a steel channel (laid flat),

sag rod and heavy-gage metal stud infill wall. The wall and roof framing are all field-bolted assemblies that allow for access to replace the mechanical equipment in the future. At the curved knuckle regions, the perimeter W12 sections supporting the wall sag rods are curved in plan and box-plated to resist combined bending and torsion loads. The curved section provides a consistent relationship with the wall and readily accommodates the simple and regular spacing of the roof framing supporting the grating.

When completed, the two towers, which use 3,400 tons of structural steel, will set the stage for the planned expansion of the campus as the Foundation expands its efforts in trying to make the world a better place. MSC

Owner

The Bill & Melinda Gates Foundation

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Structural Engineer

Arup, Seattle

General Contractor

Sellen Construction, Seattle

Steel Team

Fabricator

Canron Western Constructors, Inc., Portland, Ore. (AISC Member/AISC Certified Fabricator)

Detailer

Dowco Consultants Ltd., Surrey, B.C., Canada (AISC Member)