Columbia University Northwest Corner Building Structure

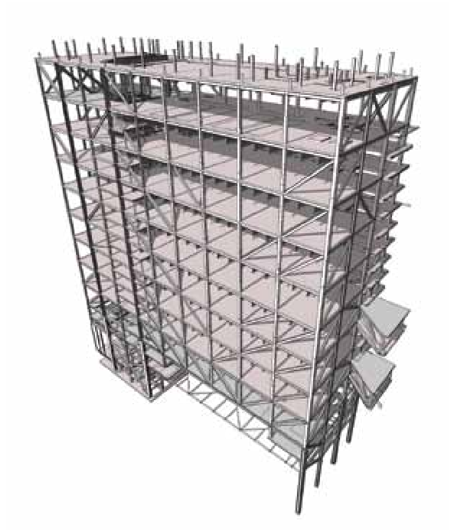
A building built as a bridge, framed with structural steel, spans 120 feet to straddle an existing gymnasium.

WHEN IT COMES TO THE IVY LEAGUE, NEW YORK CITY HAS A major feather in its cap: Columbia University. As with any top-of-the-heap institution, Columbia is always using peer schools as measuring sticks to make sure it continues to make the grade. Back in 2002, that watermark showed the university in danger of falling behind in one key area—it had no cutting-edge, 21st-century laboratory facility that could match what the Harvards and Princetons of the world were erecting. To close the gap, Columbia hired famous Spanish architect José Rafael Moneo to design a contemporary laboratory building on the last remaining major unbuilt plot of the original McKim, Meade, and White campus—the northwest corner. The site, however, came at a price. Whatever was to be built there would have to share its footprint with the existing Dodge Physical Fitness Center—notably its basketball facility, home to Columbia's Division One Lions. "The basic challenge was to come up with a structure that would span 120 feet over the existing gym, and to facilitate construction while the gym was closed," explains Dan Brodkin of Arup, whose firm collaborated with Moneo on the design. "We experimented with many possibilities, and decided to create a building like a bridge." The New York City Department of Buildings requires that two floors be completed before a space below can be occupied. Columbia wanted the gym to be open in time for the Lions to begin daily practices so construction had to move at a rapid pace. With long spans and narrow timeline the choice of structural material came easily: The building would be framed out of structural steel to cover the long span and keep the building light.

At 14 stories and 188,000 gross square feet, the Northwest Corner Building, as it is now known, packs a lot onto its 65-foot-wide site. To keep all of this space stable and immune to live loading—lab buildings are adverse to vibration and sway—Arup decided to use the whole height of the building as the truss. In other words, the engineers filled each of the perimeter framing bays with diagonal bracing elements, and put one giant chevron—a big V—through the center of the elevation. "There's a pay off to this approach," continues Brodkin. "There are more bits and pieces, but it's deeper and stronger." The internal system runs longitudinally north-south through the building, sandwiched between the corridor and offices of the east side and the laboratories of the west side. Framed with mid-range W14 wide flange sections fabricated from Grade 50 A992 steel, the big V cuts the span of the truss in half, while its easily understood, rational load pattern makes it simpler to thread mechanical systems through the building.

The expected loads did not call for bracing elements in every perimeter bay, so the engineers had the freedom to decide which would be braced and which wouldn't. Arup came up with a computerized force-weighted random structure generator that began by assuming mathematically that every space between column and beams would have an X brace. This model was then analyzed and the engineers deleted every bracing element in compression while maintaining every element in tension. Then they analyzed it again, grouping the diagonal members based on their force level—600 to 900 kips were grouped as high force, 300 to 600 kips as medium force, and 50 to 300 kips as low force. With these groupings in place, the team set up an algorithm that they applied to each group, allowing the computer to randomly delete 70 percent of low tension members, 40 percent of moderate tension members, and 10 percent of high tension members.

Arup then began to play with its numbers, sometimes deleting more



Above The building acts as one large truss in order to bridge the gymnasium below.

Right The 14-story building sits on a 65-foot-wide site and includes seven research lab floors, a column-free science library, a lecture hall, and a café.

Turner Construction; facing: Arup

Davis Brody Bond Aedas

Turner Construction

Facing The building was constructed using Building Information Modeling (BIM). Lab floors are framed with 5-foot-deep castellated beams to allow 18-foot floor-to-ceiling heights that make room for office mezzanine levels. A unique tower crane design with a bumped-out base made room for truss assembly atop a heavy construction shed.

Above Because jumbo trusses were too large to be brought to the site on trucks and lift into place by cranes, the building team assembles them on a heavy shed above the sidewalk, then slid them into place with hydraulic rams.

hard working members, sometimes more non-hard working members. Each time, a different load pattern emerged. When hard working members were deleted the pattern became weird and unexpected, but when non-hard working members were deleted the pattern was more rational. This process became an integral part of the final look of the exterior and Moneo was a willing collaborator. He gravitated more toward the rational expressions generated by deleting the low force members, and Arup ran the program playing with the numbers until they found one that he liked. In the final assembly, the bays and diagonals are framed with a variety of mid-range W14 wide flange sections fabricated from Grade 50 structural steel.

While mathematically this building-as-truss system functioned fine as a means to carry the structure over the 120-foot span of the gymnasium without bearing on it, the design assumed that the entire assembly appeared magically in place and did not take into account the step-by-step, bottom-up nature of the construction process. To manage this essential procedure a system would have to be developed to shoulder the building's massive dead loads while it was being built. In answer, Arup devised a system of three, full-floor-height jumbo trusses that would span across the gym and serve as a launch pad for the rest of the structure. It would handle dead loads during construction, and help to manage live loads once the erection was complete. These trusses, approximately 400 to 500 tons each, were constructed from massive W14x730 wide flange sections reinforced with 4-inch-thick steel plates welded across the webs. The trusses tie into eight similarly hefty columns—W14x730 wide flange sections reinforced with 4-inch-thick steel plates—five on the north side of the building, three on the south,

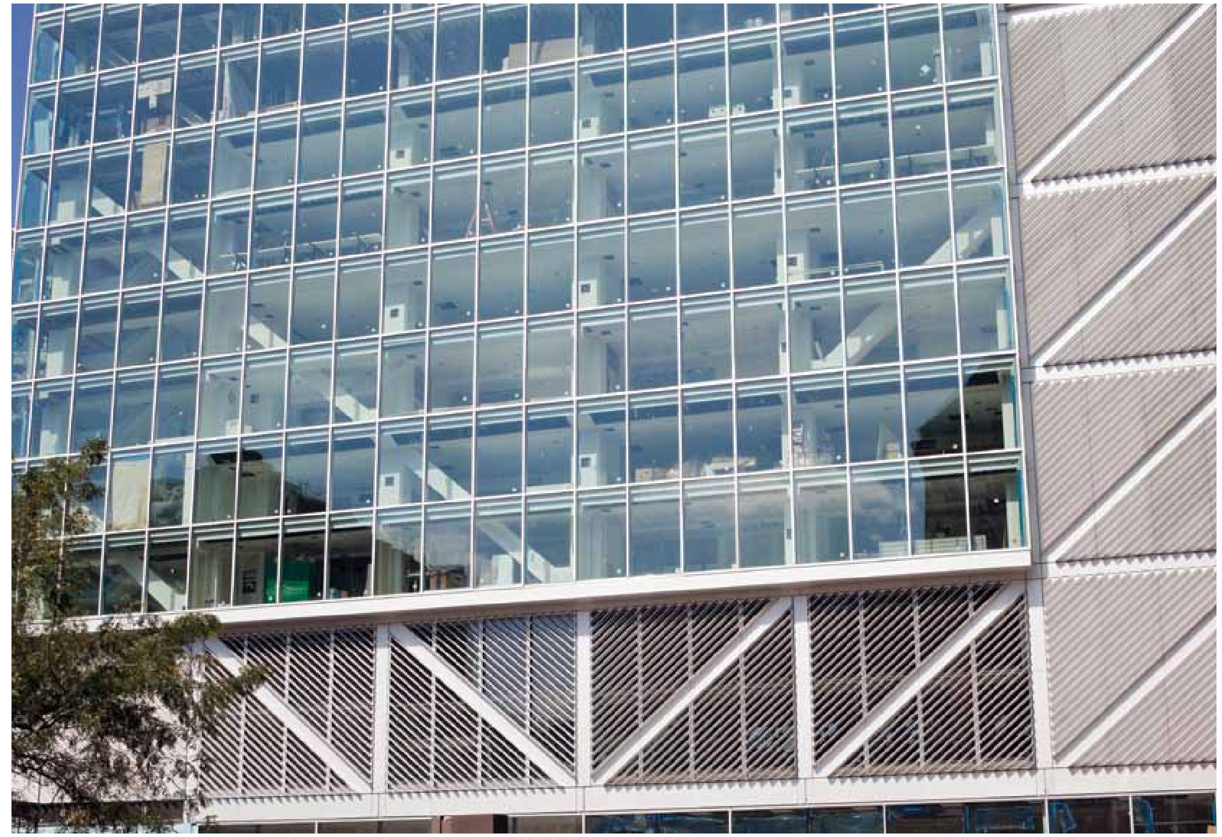
that transfer the gravity load down to bedrock.

However, these jumbo trusses were too large to fabricate off site and then truck in. They were also too heavy to lift into place with a crane, or to assemble while bearing on the roof of the gym. Working out a plan with erector DCM, Turner Construction assembled the components on a heavy construction shed above the sidewalk on Broadway, connecting them with complete joint penetration welds. Because the location of the tower crane would have interfered with the area needed for this work, its base was bumped out from the building to provide room for assembly of the trusses. Once assembled, they set up temporary steel beams spanning the roof of the gym, greased them liberally with lubricant, and slid the trusses into place with hydraulic rams.

The remainder of the steel structure is relatively straightforward, excepting the laboratory bays with their 40-foot clear spans and 18-foot floor-to-floor heights. Moneo and executive architect Davis Brody Bond Aedas set up these wide-open spaces to create greater flexibility within the facility, allowing for different scientific disciplines to augment any floor to its needs, a move that will keep the building relevant well into the future. Castellated beams frame these bays, allowing mechanical systems to be run through the web openings. The double height floors allowed mezzanine levels to be set up on the east side of the building, a literal beehive of faculty offices and student breakout space. But without structural steel, some 4,000 tons of which were used in the project, few if any of these innovative design decisions would have been possible. ■

Above top Trusses weighing between 400 and 500 tons each are slid into place.
Above bottom Each perimeter framing bay is filled with diagonal bracing elements, creating giant chevrons through the center of the elevation.

Turner Construction



Adam Friedberg

Above The campus-facing east side exposes the building's open spaces, which create greater flexibility for students and faculty.

COLUMBIA UNIVERSITY NORTHWEST CORNER BUILDING STRUCTURE

Location: **Broadway and West 120th Street, New York, NY**
Owner: **Columbia University**, *New York, NY*
Design Architect: **Rafael Moneo Valles Arquitecto**,
Moneo Brock Studio, *Madrid, Spain*
Architect of Record: **Davis Brody Bond Aedas**, *New York, NY*
Structural Engineer: **Ove Arup & Partners Consulting Engineers, PC**, *New York, NY*
Mechanical Engineer: **Ove Arup & Partners Consulting Engineers, PC**, *New York, NY*
Construction Manager: **Turner Construction Company**, *New York, NY*
Curtain Wall Consultant: **R.A. Heintges & Associates**, *New York, NY*
Structural Steel Erector: **DCM Erectors, Inc.**, *New York, NY*
Miscellaneous Iron Fabricator and Erector: **Post Road Iron Works, Inc.**, *Greenwich, CT*
Ornamental Metal Fabricator and Erector: **Empire City Iron Works**, *Long Island City, NY*
Curtain Wall Fabricator: **Sota Glazing Inc.**, *Brampton, ON*
Curtain Wall Erector: **W&W Glass, LLC**, *Nanuet, NY*
Metal Deck Erector: **Solera / DCM,** *New York, NY*