Yale intends to introduce its new business building with a bang.

Ivy League Steel

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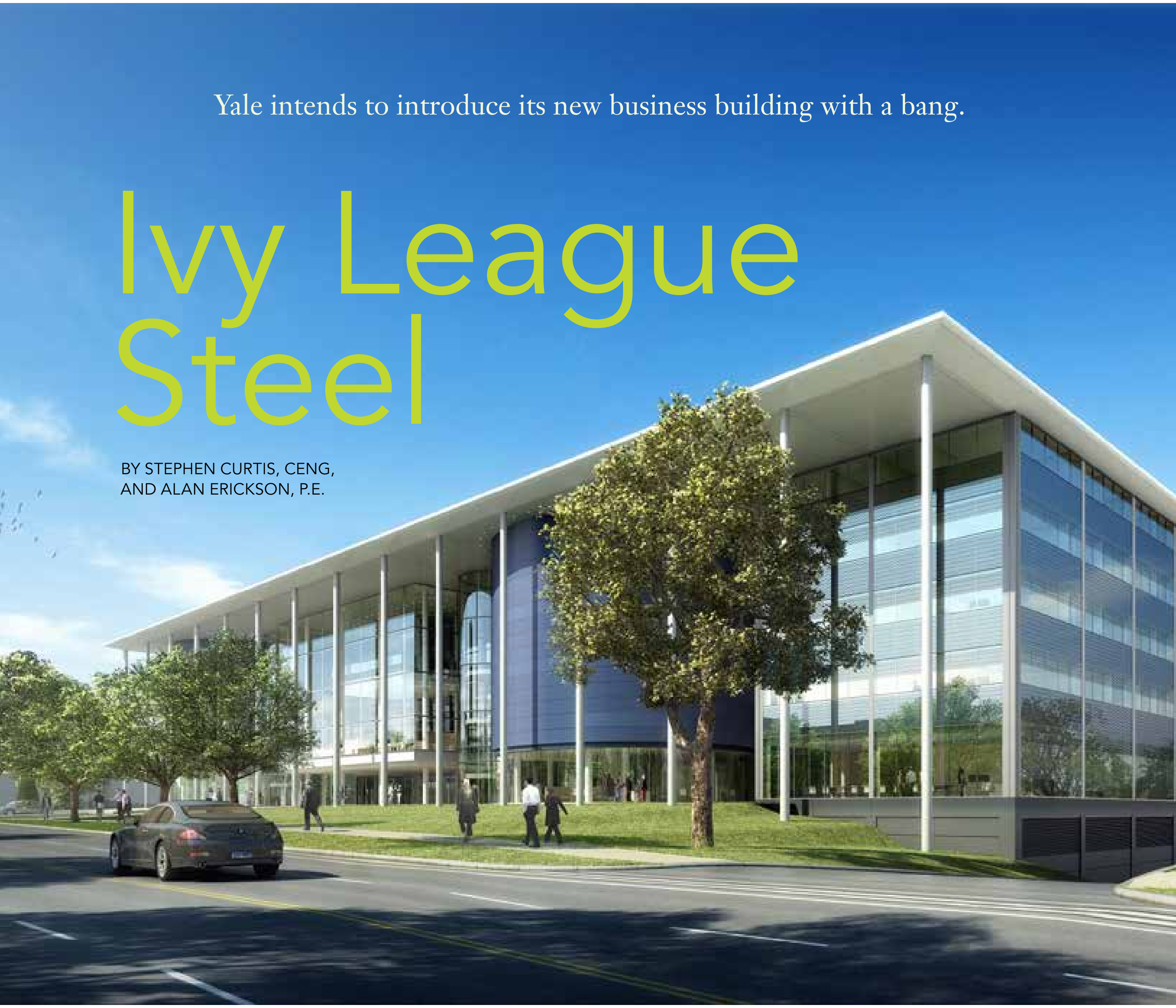


THIS COMING JANUARY, Yale University will open its new $189 million, Foster + Partners-designed Edward P. Evans Hall at the School of Management with a three-day conference attended by leaders from academia, government and business. A dramatic and complex building will welcome them. With a structural system designed by Buro Happold, the 242,000-sq.-ft facility features exposed exterior columns; a curved, four-story glass façade; slim interior vertical elements; and intricate connections, all formed using structural steel, to achieve the demanding architectural vision and provide unobstructed views, both inside and out.

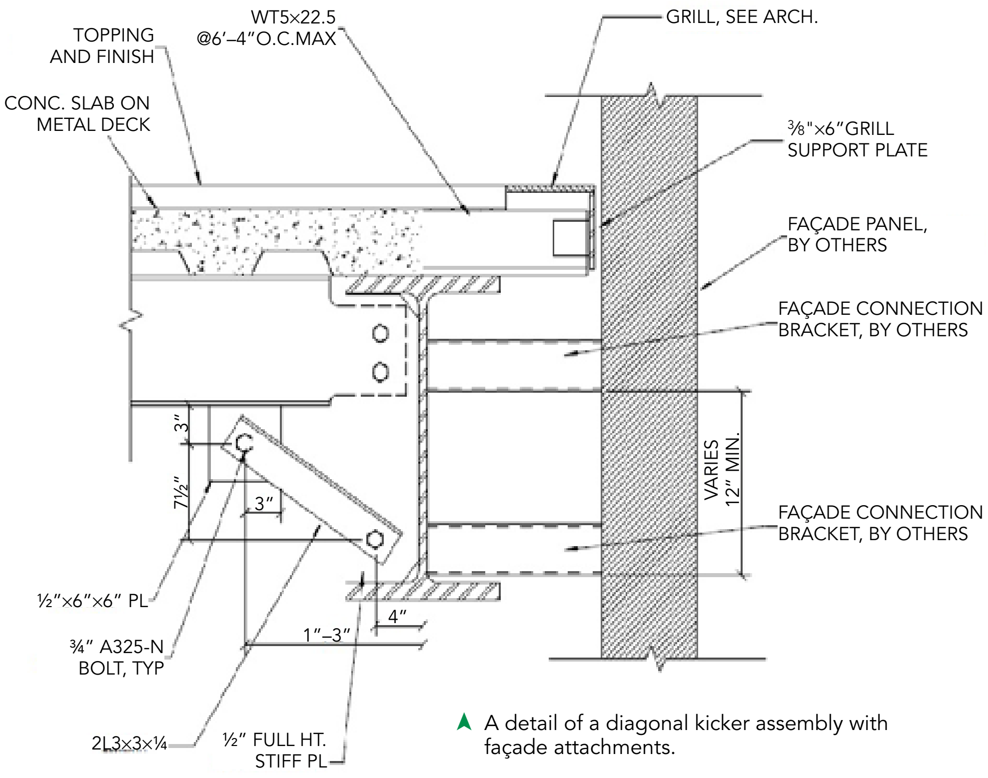
Evans Hall will double the size of the School of Management and house diverse office and classroom spaces arranged around a central, outdoor courtyard. It also includes an academic center, study areas, a 350-seat auditorium and parking for 150 vehicles. This addition to the Yale campus in New Haven, Conn., will enable the school to expand the student body and faculty, offer more community facilities and grow its executive program offerings.

An Opening for Steel

The building is comprised of five stories above grade and two stories below grade. Buro Happold used steel construction for the above-grade structure and reinforced concrete flat slab construction with drop panels spanning to cast-in-place columns for the below-grade floors. The engineering team selected steel for the above-grade portion—using more than 1,900 tons—because they considered it to be the best material with which to achieve an architectural design allowing for large, column-free areas and clear, unobstructed façades.

"There is a rich history of precast concrete across Yale's campus," said Erleen Hatfield, regional discipline leader for

The 240,000-sq.-ft Evans Hall opens on Yale's campus early next year.



A detail of a diagonal kicker assembly with façade attachments.

structural engineering in North America at Buro Happold. "So, during the early project phases we explored both cast-in-place and precast concrete as options. However, only steel could deliver such an open design and still provide the required structural support."

Foster + Partners envisioned a four-story, curved, glazed façade to serve as a prominent feature in the courtyard. The façade is supported only at its top and bottom, thereby making an atrium within the building as it bypasses the intermediate floors. To achieve this long vertical span without needing large structural members that would interrupt the view, the design team decided to hang the façade's weight entirely from the roof with the bottom support used only for lateral bracing. Buro Happold designed custom steel sleeve connections to integrate the façade's vertical element with the second floor's structural steel. This allowed seamless integration and vertical movement between the second floor and the facade, even though a separate contractor provided each.

Halfway up the façade, a mezzanine extends within several feet of it but does not connect. This created a cantilever condition ranging from 10 ft to 17 ft that had to fit within the thin floor profile. To achieve this, the W27 cantilever beams were designed for strength only and 2-in.-diameter deflection control hanger rods were added at the ends of the cantilevers. As the rods were designed for deflection control only, they did not need fireproofing and therefore lessened the structure's impact on the architectural design.

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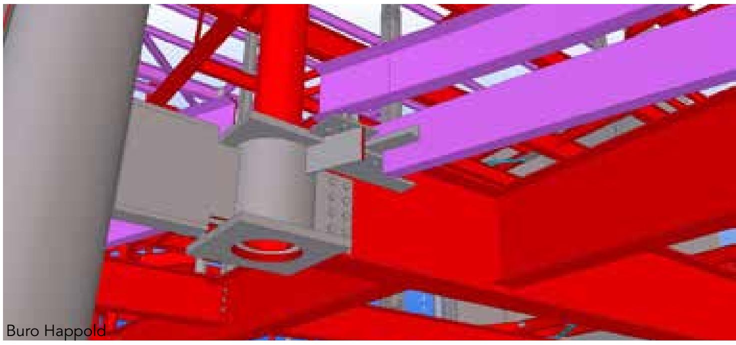

The courtyard façade hangar base as a Tekla model...

...and during construction.

Evans Hall doubles the size of Yale's School of Management and houses diverse office and classroom spaces arranged around a central outdoor courtyard.

The auditorium, located beneath a proposed entertainment/multi-function space, had strict acoustical criteria in terms of vibration and noise transfer for the structure supporting the space. To meet the vibration criteria, Buro Happold designed 49-in.-deep plate girders for the 50-ft span and also made provisions in the design of the plate girders to accommodate penetrations for the building systems, as the steel members took up all of the available ceiling space. In addition, the criteria for limiting noise transfer into the auditorium from the space above was met via a 7-in.-thick normal weight concrete-on-steel deck slab.

Exterior architecturally exposed structural steel (AESS) columns, while part of the desired aesthetic, presented several challenges. These columns would be exposed to view from both the inside and outside of the building, and the architects wanted them to feature a thin, elegant profile. They also had to be designed to incorporate thermal effects and, since the roof-hung façade was supported on the exterior columns, their design had to be coordinated with the façade contractor. The exterior HSS columns ranged up to 64 ft tall and are unbraced, yet had to support a significant portion of the floor, which created undesirable fireproofing issues. To resolve this, Buro Happold performed detailed fire engineering studies proving that these HSS18×½ columns could do a better job withstanding fire than what was anticipated by local building codes. Consequently, the engineers determined that the fireproofing on these key architectural elements could be reduced and, in some cases, eliminated.

Geometric Challenges

From the beginning of the project, it was clear that the building's success depended on the team working together to solve its geometrical complexities. The design team leveraged Revit modelling at the start of construction documents to allow real time 3D coordination of all trades. While this proved helpful, it became apparent that more advanced BIM was required on several fronts. The architects' vision left little room in the ceiling void for both the MEP and structural systems. Further complicating matters, a zoning decision had reduced the building's plan area while not allowing an increased height. An additional floor had to be added, reducing available space in the ceiling cavity. The only way to ensure successful construction was to deliver design team-coordinated models to the contractor; these models would need to be "clash-free" prior to handover. Structurally, this involved detailed modelling of complex steel geometries and connections as well as MEP system penetrations throughout the building.

"The university's clash-free requirement really challenged our design team to create a coordinated design and then demonstrate this," said Hatfield. "Using sophisticated technologies such as BIM, our engineers successfully managed this complex project and completed it to everyone's satisfaction."

Buro Happold designed the connections and completed a Tekla model with the connections already modelled prior to bidding of the steel. As they were able to use the members and connections in the model as a reference, all of the bidders came in within 1% of each other in terms of tonnage.

"Having the steel bids so close together indicated a clear understanding of the scope, reducing the risk for change order requests and improving our cost certainty," said Jon Olsen, Yale's senior project manager.

As construction progressed, the value of the models became even more apparent. The shop drawing process was streamlined for both the fabricator, Shepard Steel, and the engineers. In addition, the contractor did not need to spend time developing, submitting, revising and resubmitting complicated connection designs, which resulted in all shop drawing approvals occurring within five months and virtually no fit-up problems during erection.

"Since the drawings were so detailed, both the shop drawing process and the steel erection went very smoothly," said Joe Bolton, senior project manager with the project's general contractor, Dimeo. "The connection designs and 3D modeling done by Buro Happold really showed their value in terms of staying on schedule and budget." MSC

Owner
Yale University, New Haven, Conn.

Design Architect
Foster + Partners

Architect of Record
Gruzen Samton, New York

Structural Engineer
Buro Happold, New York

General Contractor
Dimeo Construction Company, Providence, R.I.

Steel Team

Steel Fabricator
Shepard Steel Co., Inc., Hartford, Conn. (AISC Member/ AISC Certified Fabricator)

Steel Detailer
Arcan Detailing, Inc., Windsor, Ontario, Canada (AISC Member)