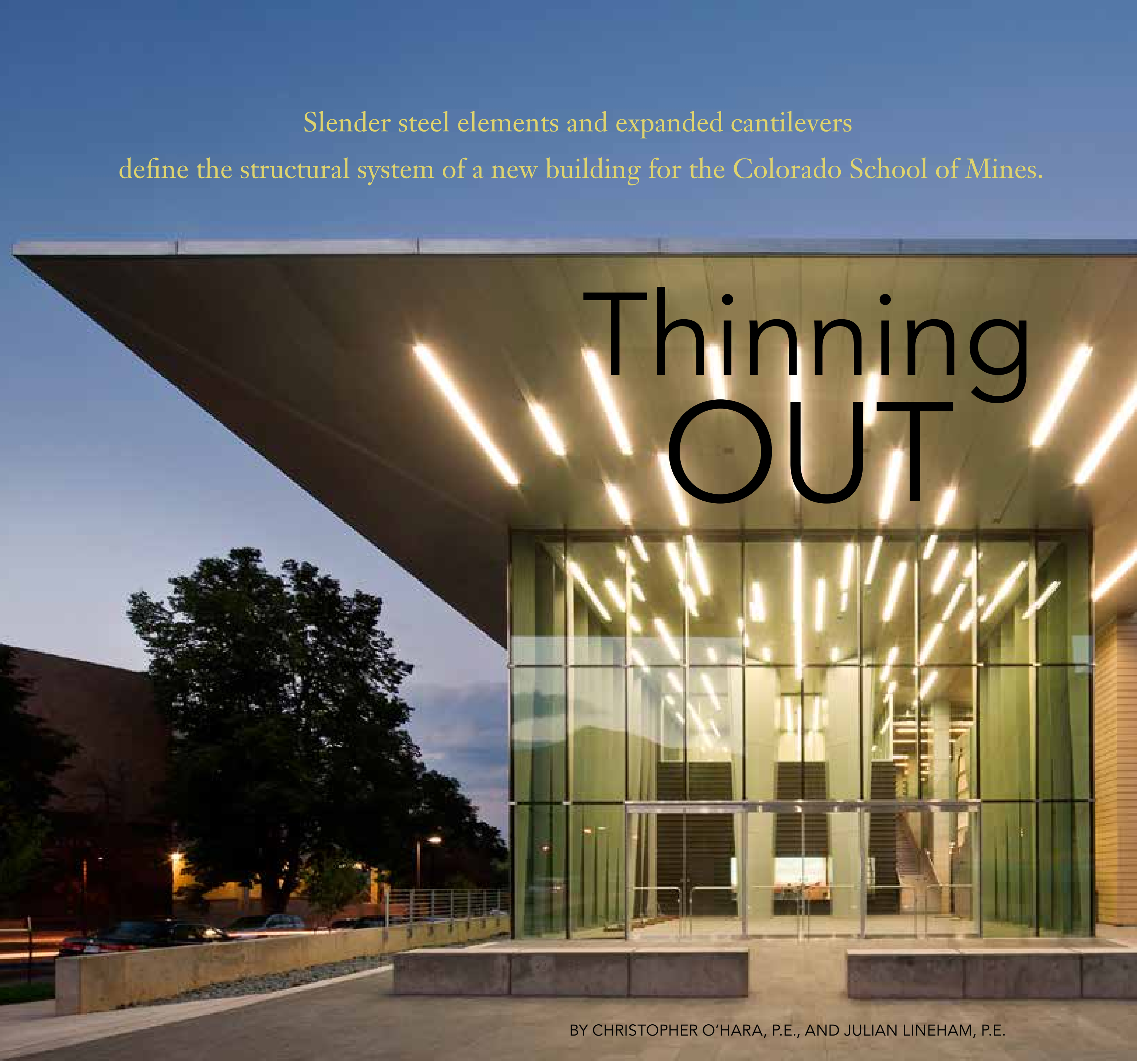
Slender steel elements and expanded cantilevers define the structural system of a new building for the Colorado School of Mines.

Thinning OUT



BY CHRISTOPHER O'HARA, P.E., AND JULIAN LINEHAM, P.E.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BUILDINGS CAN EXHIBIT not only progress and expansion, but also a shift in focus.

Marquez Hall, a new 87,000-sq.-ft facility for the Petroleum Engineering Department at the Colorado School of Mines in Golden, Colo., was designed to reflect the country's energy shift from petroleum to renewables. The building, designed by the Seattle office of Bohlin Cywinski Jackson in partnership with Denver-based Anderson Mason Dale Architects, reinforces the school's vision for the future by looking to the user, the campus and community to achieve an aesthetic reflective of the school's nationally recognized engineering programs and innovative applied science research. The structural steel framing system, featuring long cantilevers and architecturally exposed steel, was chosen to help achieve a dynamic vision for the building and address the basic structural need of supporting gravity and lateral loads (total steel used, including miscellaneous, was 773 tons). Vibration requirements for the laboratories contained within also required a high degree of sensitivity.

Nic Lehoux

Nic Lehoux

▲ Steel fins in the lobby.

◄ The west elevation of Marquez Hall.

▼ Box girder-to-column construction.

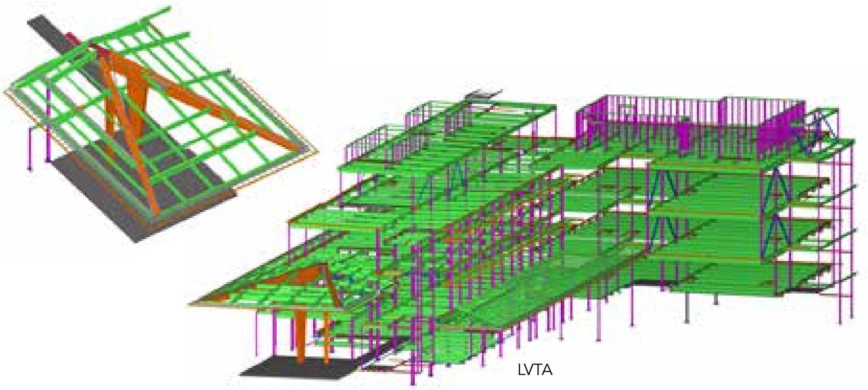
Kari Rogne

Two overriding themes can be found throughout the design of the building's structure: the varied use of cantilevers (for visual effect in some areas and to develop efficiencies of material and cost savings in others) and the use of slender elements throughout the primary structure and cladding systems.

In terms of layout, two parallel, linear programmatic bars, as well as a wing to the southeast, allow users to easily understand and navigate the facility's varied program of public, semi-public and private spaces. Functionally, the building forms one edge of the pedestrian walkway that connects the campus' two main quadrangles, thus opening its interior spaces to the area's extraordinary Front Range mountain views. Its L-shaped plan divides the building into two bars while defining a new courtyard featuring custom seating to encourage interaction. The northern bar houses a combination of graduate and undergraduate laboratories, a 4D visualization classroom and a drilling simulator room. The southern bar holds offices and laboratory support spaces, and the southeastern wing includes a lecture hall as well as four levels of smart classrooms and seminar rooms.

Cantilevers

On the southeastern wing, full-story cantilevered trusses take their cues from staggered truss concepts and are reconfigured to create a cost-effective 20-ft cantilever for the third and fourth levels. Diagonal ties applied in the cavity inside the solid walls—similar to a cable-stayed bridge—suspend the building's extension over the campus quad below. While this feature provides refuge for people entering and exiting the building and a sense of closure to the end of the quad, the driving force for this design move was cost savings, as providing additional foundations and traditional columns would have been more expensive than the diagonal framing. Additionally, the building is



Tekla models of the structure.

supported on deep-drilled pier foundations because of the area's poor soils, and the structure of the surrounding floor plates is arranged to bear on the backspan of the story-high trusses, thus eliminating the possibility of a net uplift on columns and foundations.

The laboratories of the northern wing, separated from campus offices by a primary circulation corridor, have been designed to strict laboratory vibration criteria through the use of steel composite beams and girders. The structural framing is oriented to minimize footfall-induced and corridor vibrations from being transmitted into the laboratories. Beams within the laboratory run north-south, while the remaining beams span east-west, parallel to and independent of the laboratories' girders. The girders feature a double-cantilevered design to help maintain deflection criteria in the presence of shallower beams that permit significant mechanical duct runs to cross the girder line.

Slenderness

Along the south façade of the northern bar is the building's primary entry point from the quad. Because the design team was not satisfied with the cost and finish quality of intumescent paint for application on the heavily loaded south-side columns, a solution beyond a fireproofed, wrapped column was pursued. This lead the team to investigate and discover fire-rated composite columns (as per Appendix 4 of ANSI/AISC 360-05), allowing the architects to use a high-quality Tnemec paint, eliminate column covers and avoid a costly solution known for its inferior finish.

The use of slender steel elements was most notable in areas outside of the primary structure. While plate stringer stairs are quite common and are used throughout Marquez Hall, the feature stair joining the west lobby with the laboratory and office bars of the building took it a step further. Here the balustrade and stringer are all one element with ½-in.-thick by 48-in.-deep plates spanning more than 40 ft. Fabricator Zimkor used software to locate the center of gravity so it could design and locate lifting lugs that could be rigged to lift the stair at its installed pitch. Shipping bracing incorporated in the lifting lugs braced the stair sides to avoid bending them during hoisting. The balustrades around the stair opening are constructed using ½-in.-thick plates cantilevered from the floor structure. The steel was left natural with a simple oiled finish (and sealed) to make it clear that all of the slender elements are indeed raw steel.

The west façade of the lobby.

Slender Cantilevers

The main feature of the building, the west lobby, is at the end of the northern wing. It serves as a focal point and assembly space for entertaining potential donors. This transparent exhibition and lobby space marks a potent position on the campus's main thoroughfare and serves as the building's main entrance. Since the lobby is primarily glass, a long roof extension was required to shade it from the region's plentiful sunlight. To solve this from a structural standpoint, glazed glass walls hang from a 60-ft cantilevered roof via a pair of tapered box girders that extend out from the east side of the lobby.

Because the at-grade perspectives do not permit an angle sufficient to see the roof's slope, the tapered girders maintain a flat bottom flange with a sloped top flange to create the illusion of a thin structure. To help maintain the cantilever, the building's mass is oriented to bear on a story-high truss at the end of the cantilever's backspan. This significant mass acts as ballast for Colorado's snow loads, and

The facility uses 773 tons of steel in all.

Looking in at the steel fins.

Steel sunshades on the south end of the building.

the harsh 116-mph wind speeds prevalent along Colorado's Rocky Mountain Front Range. The girders and their supporting columns vary in depth from 24-in. at the tip to 84 in. deep at the column girder intersection, and 12-in.-deep steel beams spring from them to extend the cantilever a bit further. Finally, the perimeter gutter system truncates down to just 6 in. using angle ribs with gage thickness plate to form the gutter.

To achieve the architect's goal of a transparent façade while maintaining a responsible budget, a structural steel fin system was used to support the façade. The fins replace the traditional aluminum mullion and steel wind girt system that would typically be required for this 30-ft span under the building's wind loads. By hanging the system and directly mounting the double-insulated glass panels to the structure, the fins are essentially pre-stressed to feel as though they are in tension. The system does not have any horizontal steel members. The localized load due to seismic loading on the weak axis of the fin is resisted using the glass panels as "shear walls." The fins vary in depth but are only ½ in. thick. Structural steel bearing plates extend from the fins to eliminate the need for costly point-fixed glazing solutions, and the glass adheres to the fins laterally with structural silicone.

Getting it Done

The Marquez Hall project required an extremely aggressive schedule, which would not have been possible without close integration of the design and construction teams. Revit models were configured with tight tolerances for cuts on exposed elements, and 3D connection elements, where critical to the design intent, were exported to the fabricator and lead detailer through an .ifc format for inclusion in the Tekla model. With an accurate Revit model, direct import into Tekla was possible, which saved critical time and decreased the possibility of misinterpretation, allowing the detailing team to meet the tight schedule.

The construction team proactively conducted meetings on-site with the design team to prereview shop drawings, discuss erection strategies for the intricate elements of the west lobby and perform coordination reviews with other trades, such as HVAC, through general contractor Adolphson and Peterson Construction's Navisworks model. Due to the size and weight of the box girders, field splices and erection were a challenge, thus two shoring towers were erected and all splices were arranged with temporary bolt splices to facilitate field welds. As the system was primarily governed by deflection, all welds were configured to use only fillet and partial penetration welds, and precise splice locations were determined by trucking limitations. The street layout in this area of the campus is quite tight, so the team needed to verify that the chosen box girder field splice locations would yield shipping lengths that wouldn't cause turning problems (and Zimkor also needed to verify that it had the hoisting capacity to lift each shipping piece in the shop).

Whether it was an exposed feature such as sunshades, façade fins, stairs or fire-rated columns, or hidden elements such as the story-high trusses of the southeastern wing/bar or tapered box girders of the west lobby, the agile capabilities of structural steel—along with the design and construction team's ingenuity—created a beautiful building that not only expands the school's capabilities, but also signals progress in terms of energy use. ■

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Adolphson and Peterson, Aurora, Colo.

Design Architect
Bohlin Cywinski Jackson, Seattle

Architect of Record
Anderson Mason Dale, Denver

Structural Engineer
Studio NYL Structural Engineers, Boulder, Colo.

Steel Team

Fabricator
Zimkor, Littleton, Colo. (AISC Member/AISC Certified Fabricator)

Detailer
Lehigh Valley Technical Associates, Northampton, Pa. (AISC Member)