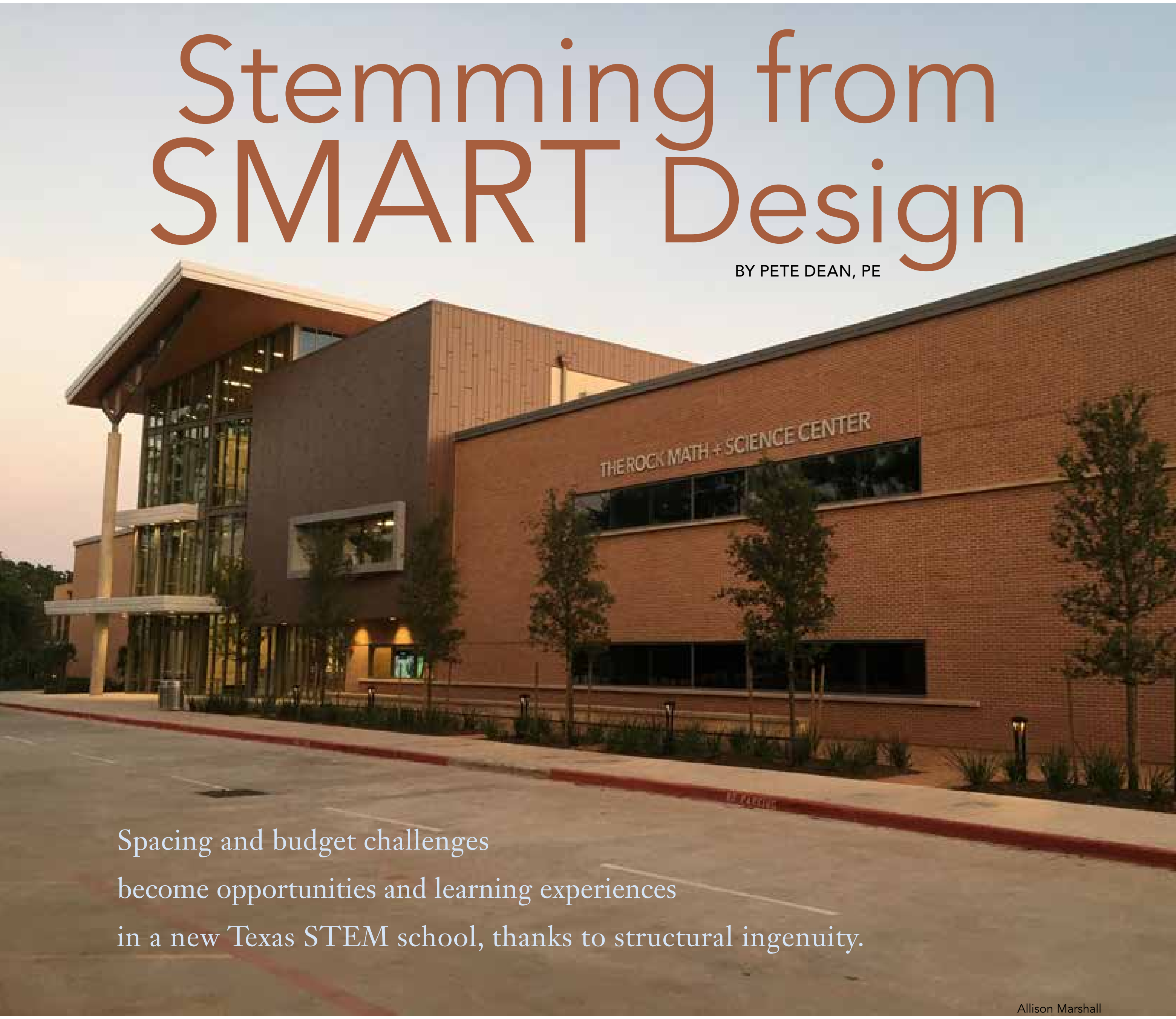
Stemming from SMART Design

BY PETE DEAN, PE



Spacing and budget challenges become opportunities and learning experiences in a new Texas STEM school, thanks to structural ingenuity.

Allison Marshall

Pete Dean (**pd@pinnaclestructural.com**) is a senior project manager with Pinnacle Structural Engineers in Houston.

THE NEW ROCK MATH AND SCIENCE CENTER at John Cooper School in The Woodlands, Texas, is a state-of-the-art new STEM school—but it could almost be called a STEAM school.

That's because in addition to focusing on STEM—science, technology, engineering and mathematics—the facility exposes students to these concepts through its architecture.

To encourage curiosity in the built environment, the 56,000-sq.-ft, $16.9 million building showcases rather than hides the structure, which was designed by Pinnacle Structural Engineers (PSE). Every element became an important architectural feature as the design progressed, pushing the limits of engineering possibilities at every turn. Learning spaces are programmed to do double duty as both a classroom and an innovative laboratory environment, with collab-

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► The three-story open "forum" connects classrooms and serves as an interactive experimentation space that can be observed by students throughout the day.

▼ The engineer ran three complete design iterations using varying composite slab thicknesses in order to optimize the steel and concrete costs while maintaining vibration standards well above those recommended for this building type.

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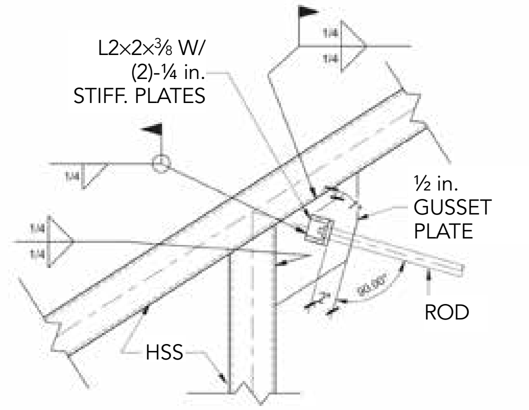
orative elements that tie the experiences together. As students move between classrooms, they are exposed to the building's epicenter, a three-story open "forum" that concurrently connects classrooms and serves as an interactive experimentation space that can be observed by students throughout the day.

Triangular Truss, Hidden Lesson

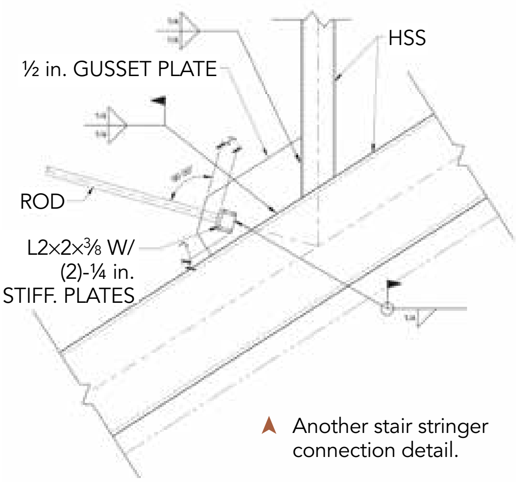
The forum roof clear spans 36 ft and is supported by six sloping triangular trusses constructed of exposed wide-flange members (W12×40 truss top chords, W10×33 web members and W8×48 bottom chords). Each roof truss balances on a 40-ft-tall unbraced concrete column that remains exposed through the forum space, and the three-story glass walls anchoring this space span gracefully between exposed wide-flange columns and beam supports. The two exterior trusses were hot-dip galvanized and use galvanized paint at the welds.

A series of 20- and 25-ft-long cantilevered beams create the uncommon geometry of the column-free second and third-floor interactive environment. Keeping with the theme of pressing the boundaries of engineering, the structural team refined the second floor's composite framing design to perform the delicate balancing act of both safely supporting these long beam cantilevers while also providing a visually impressive floor depth of only 3 ft from the top of the finished floor to the bottom of the ceiling.

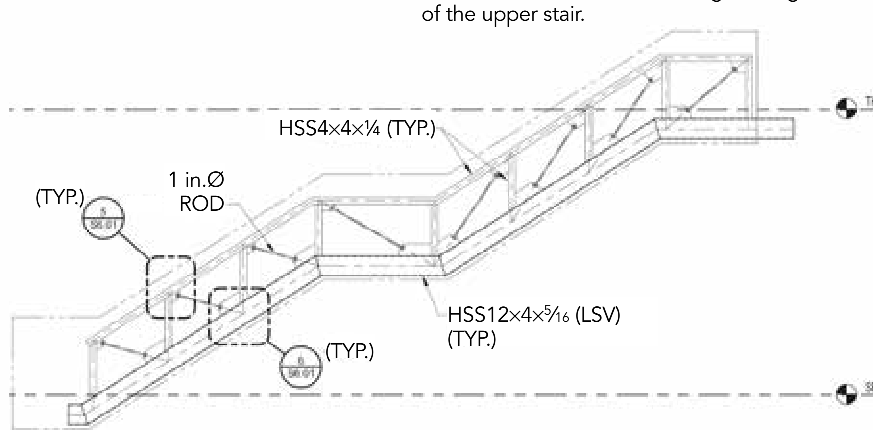
Each roof truss balances on a 40-ft-tall exposed, unbraced concrete column.



Rod connection detail for the right stringer of the upper stair.



Another stair stringer connection detail.



Right stringer for the upper stair.

The roof trusses at each end of the sloping forum roof are located outside of the building envelope. As a result, they are not able to simple-span from the circular concrete columns across the lobby to the columns on the opposing low roof and instead taper down to a 12-in. depth at the corner of the roof, with no visible support at that end. The final product is what appear to be 36-ft-long triangular trusses, each supported by only the concrete columns.

The effect is striking and is intended to engage the students in STEM concepts before they even walk through the door. For the students that ask the right questions, the answer is simple: The exposed steel members behind the curtainwall are designed to support the roof, not just the glass. Shallow wide-flange beams are hidden above the wood ceiling and span from the interior roof trusses across the curtain wall support beams, and also cantilever out to support the shallow end of the exterior truss.

Opportunity Knocks

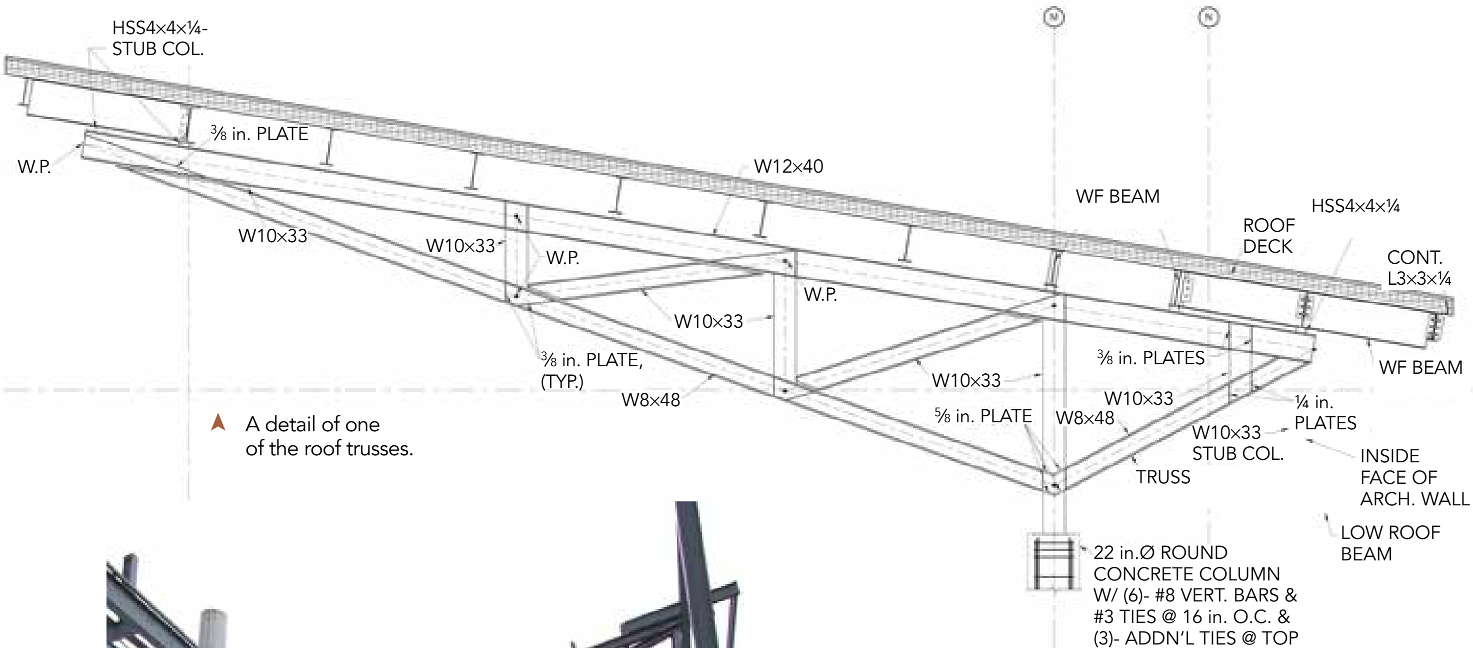
A prime opportunity to express structural design presented itself with the monument stairs in the forum. Each stair run spans up to 35 ft horizontally between supports and rises 14 ft in two runs with an intermediate landing. The design team determined a way to visually convey both load-path and tension/compression members by designing each stair as a truss, using the stringers as the bottom chord and the top of the hand rail as the top chord, and combining hollow structural section (HSS) vertical web members with threaded-rod diagonal members for the compression and tension elements, respectively. Not only was the result a visually stunning truss, but it also resulted in a stringer width that did not exceed 4 in.

The savings in cost and structure on the stair also provided an opportunity for the architect and school to get creative with the handrail design. Their collaboration highlighted the slender design and open space of the stair by installing a backlit metal panel engraved with math and science equations on both sides of the stair. This eye-catching panel is now one of the building's signature elements.

Another signature element, on the third floor, is the budding roof garden, which is artfully framed with exposed, galvanized wide-flange steel members. The garden structure cantilevers 15 ft off the face of the building, connecting it seamlessly with the landscaping and open spaces of the central green space 30 ft below. The floor of the garden is supported by W24×68 and W21×44 beams, and the exposed (and galvanized) roof trellis is made with W12×19 beams.

Functionality

Beyond aesthetics, the project must function as the state-of-the-art facility that it is. PSE ran three complete design iterations using varying composite slab thicknesses in order to optimize the steel and concrete costs while maintaining vibration standards well above those recommended for this building type. Throughout the design process, serviceability concerns were paramount to the designers—e.g., strict requirements on typical beam deflections or complete vibrational isolation of the second-floor chiller slab from the rest of the building. In one instance, ceiling height limitations in a theater-style lecture hall limited the beam depth



▲ A detail of one of the roof trusses.

◀ ▼ The complicated geometry of the building, both in the 2D floor plans and in the multiple roof elevations and slopes, made this project an ideal candidate for using structural steel and a BIM workflow.

to 16 in. to achieve a 56-ft free span. The design team engineered tightly spaced (less than 7 ft on center) W16×89 beams with 100% composite action and stringently controlled camber specifications in order to achieve a cost-effective solution that exceeded strength, deflection and vibration requirements.

A combination of HSS diagonal braces and wide-flange moment frames was used for the main wind force resisting system. To overcome the challenges of the nine different roof planes at varying elevations and slopes, as well as the lack of continuity between floor diaphragms at the forum, the engineering team analyzed semi-rigid diaphragms at both the composite floors and the roofs. By carefully assessing known assumptions for concrete cracking factors and modulus of elasticity values for un-topped roof deck, PSE was able to engineer an envelope of forces at each lateral resisting element and confirm sufficient diaphragm capacity for the load transfers. In comparison to more common simplified diaphragm analyses, the in-depth semi-rigid analysis technique provided smaller moment frames and larger diagonal braces while also reducing building drift, resulting in cost savings and a reduction in field labor and testing.

The complicated geometry of the building, both in the 2D floor plans and in the multiple roof elevations and slopes, made this project an ideal candidate for using structural steel and a building information modeling (BIM) workflow incorporating RAM Structural System, RAM Elements and Revit. Biweekly model sharing between the architect and structural engineer and the use of almost solely "live" details eliminated clash issues and reduced construction conflicts. For example, the slab on grade in the aforementioned 56-ft span was for the auditorium, so it sloped/stepped down toward the front of the classroom. Project architect Ziegler

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▲ The eye-catching stair panel is one of the building's signature elements.

▼ The building is the most significant improvement to the campus since John Cooper opened its Upper School in 1993.


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Cooper wanted to maintain a particular head height, but identifying the exact elevation of the slab at each slope/step relative to the beam supporting the second floor above would have been difficult in CAD. But using Revit, the structural team was able to cut a section through the area in question, test some dimensions and determine exactly what beam depth would be required to make the architect's vision work.

Incorporating 428 tons of structural steel in all, the building is the most significant improvement made on John Cooper's campus since the school opened its Upper School in 1993 and enhances its already sterling reputation as a premier educational facility in the greater Houston area. And by putting its significant structural elements on display, it also enhances and illustrates the STEM curriculum it was built to teach. ■

Owner
The John Cooper School, The Woodlands, Texas

General Contractor
Brookstone General Contractors, Houston

Architect
Ziegler Cooper Architects, Houston

Structural Engineer
Pinnacle Structural Engineers, Houston

Steel Team

Fabricator
VSF, Inc., Dba The Troubleshooters, Houston

Erector
Empire Acero, Humble, Texas