



# AMAZING GRACE

## Structure Embodies Elegant Engineering

By Thomas Taylor, PE

It seems appropriate—and a bit ironic—that the building design of a nature and science museum would appear to defy both science and nature.

The building was created to be used as a living example of engineering, sustainability, and technology at work. The 180,000 square foot structure is 170 foot-tall building rising approximately 14 stories high. The building mass is conceived as a large cube floating over the site's landscaped plinth, or base. An acre of rolling roofscape, comprised of rock and native drought-resistant grasses, reflects Texas' indigenous landscape and demonstrates a living system that will evolve naturally over time.



The facility's interior includes five floors of public space, housing 10 exhibition galleries including a children's museum and outdoor playspace/courtyard. An expansive glass-enclosed lobby and adjacent outdoor terrace offer exceptional views of the downtown Dallas skyline. The state-of-the-art exhibition gallery is designated to host world-class traveling exhibitions. The education wing includes a large format multi-media digital cinema, seating 300. Approximately 80 percent of the building is devoted to public usage, which is remarkably high for a museum.

Architectural vision was provided by Pritzker Prize laureate Thom Mayne and his team at Morphosis Architects. Datum Engineers, in concert with John A. Martin & Associates (JAMA), made the vision a reality through complex structural engineering.

### All in the Process

Datum's design processes took the many unique architectural components and made them functional through engineering expertise. Consider that the concrete frame is a simple pan-and-joint system, stabilized with a cast-in-place concrete wall system at the building's core. That is where the "standard construction" stops and the creativity of the Datum/JAMA TEAM begins.

The team created several physical models to study and understand the complex geometry of the building. In the initial design stages, these models helped the structural team visualize and then solve difficult three-dimensional problems. As the design process matured, the physical models were replaced with 3-D computer models using Revit and other building information model software.

In particular, Datum addressed three primary challenges. This unique and dramatic 6 story (170-foot-tall), cast-in-place concrete museum has a very special precast concrete façade, an escalator on the exterior face of the building, and a low, curving, and sloping green roof constructed of structural steel over the auditorium.

On the first level, sloping concrete columns, proposed by Datum/JAMA, create more opportunity for exterior light to enter the building. The columns support an eight-foot-tall perimeter concrete transfer girder. Morphosis

envisioned an open atrium, encompassed with curving precast and large glass expanses. Long stairways crisscross through the atrium, connecting floors and mezzanines. Post-tensioned cantilevering concrete beams were used periodically to achieve the architect's vision.

"The Perot Museum of Nature and Science is a gift to the city of Dallas," says Mayne. "It is a fundamentally public building—a building that opens up, belongs to, and activates the city. It is a place of exchange. It contains knowledge, preserves information and transmits ideas; ultimately, the public is as integral to the museum as the museum is to the city."

-Thom Mayne

## Museums in the News

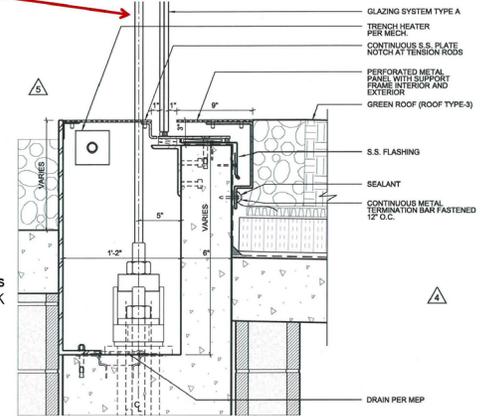
The Datum/JAMA team designed massive cantilevered and buttressed retaining walls throughout the project, and beautiful concrete lightwells on the north side of the museum. The tall glass curtain wall at the entry lobby is laterally stabilized with post-tensioned cables in lieu of standard mullions, creating a clear glass opening in the face of the building. Each cable was tensioned from 42,000 lbs to 75,000 lbs, pulling up on the first level and pulling down on the second level with great accumulative force.

The first and second floors were carefully designed to accommodate these specially imposed loads in addition to the typical museum loads. The precast concrete façade is supported by structural steel “tree columns” attached to the concrete frame. The concept was proposed by Datum to allow the precast façade to be composed of horizontal panels that allowed the horizontal slots for the escalator and windows. The precast concrete was cast on 44 different form liners and cast in eight-foot-tall panels, coordinated with slot windows.

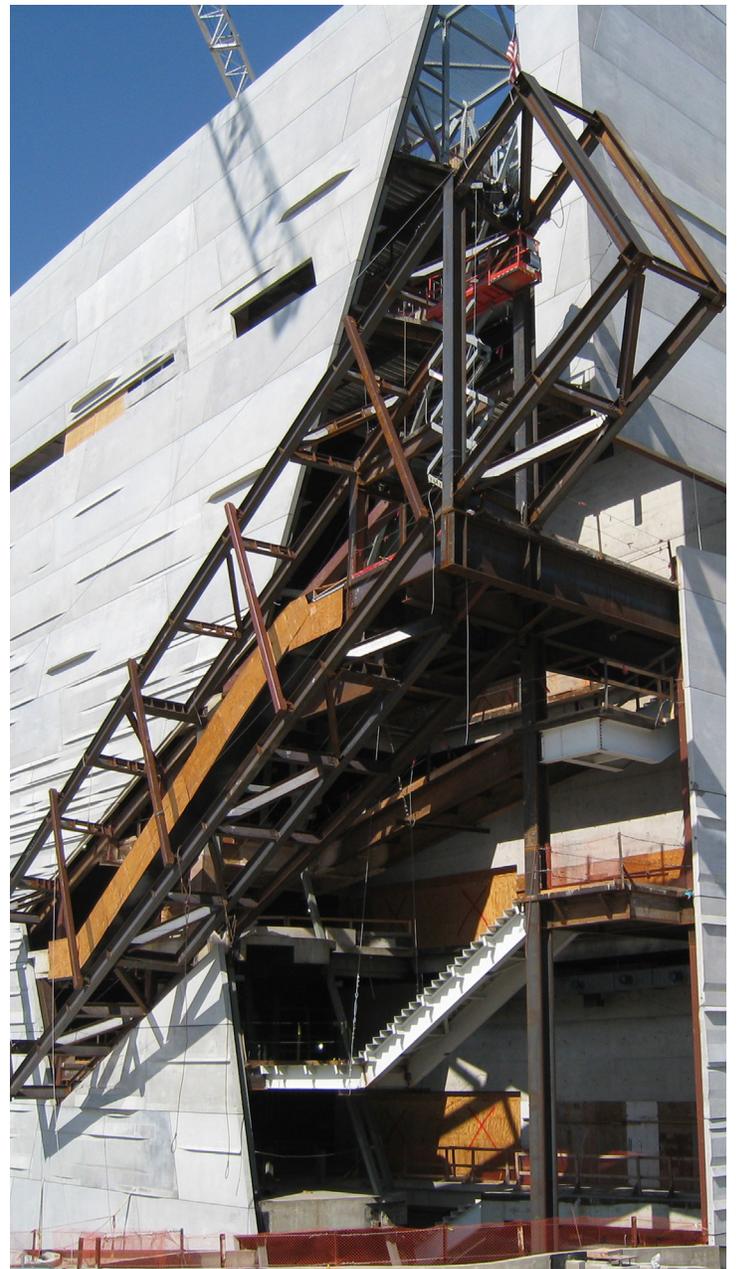
### Post-Tensioned Cable Mullion

Post-tensioned cables created almost invisible mullions to contribute even more to the open architectural expression at the ground floor.

Tension in Cables  
45-75K



**B1 WINDOW SILL @ GREEN ROOF**  
SCALE: 1 1/2"=1'-0"  
MNS-a-dtB2022-06



### Multi-Roof Design Brings Green Roof to Life

The landscape consists of an acre of rolling roofscape (covering the plinth), comprised of rock shards and native drought-resistant grasses reflecting Texas' indigenous landscape, and demonstrates a living system that evolves naturally over time. The unique lower roof is an impressive structure and an interesting engineering challenge in its own right. When the roof was first erected, it created an intricate series of steel beams, columns, and complex connections that created a spider web of framing for the future plinth roof. To further complicate the living roof, numerous underground cisterns were designed to collect rain water to be used to irrigate the landscape and to help the project ultimately achieve LEED (Leadership in Energy and Environmental Design) Gold certification from the U.S. Green Building Council (USGBC).

Modeling the curving and sloping green roof of structural steel was tedious and difficult. Datum/JAMA endeavored to make the contours of the green roof undulate like the natural flow of land in the Texas Hill Country. However, Datum/JAMA set a goal to create the curving green roof with only straight steel pieces. The use of 3D computer software helped the engineers analyze and define options. The framing and edge-of-slab drawings were defined within the software, enabling the contractor to detail and dimension the framing, though minimal dimensional information was provided on the actual framing drawings. The engineers report that the erection of this complex roof system had very few constructability issues and was finished in a minimum amount of time.

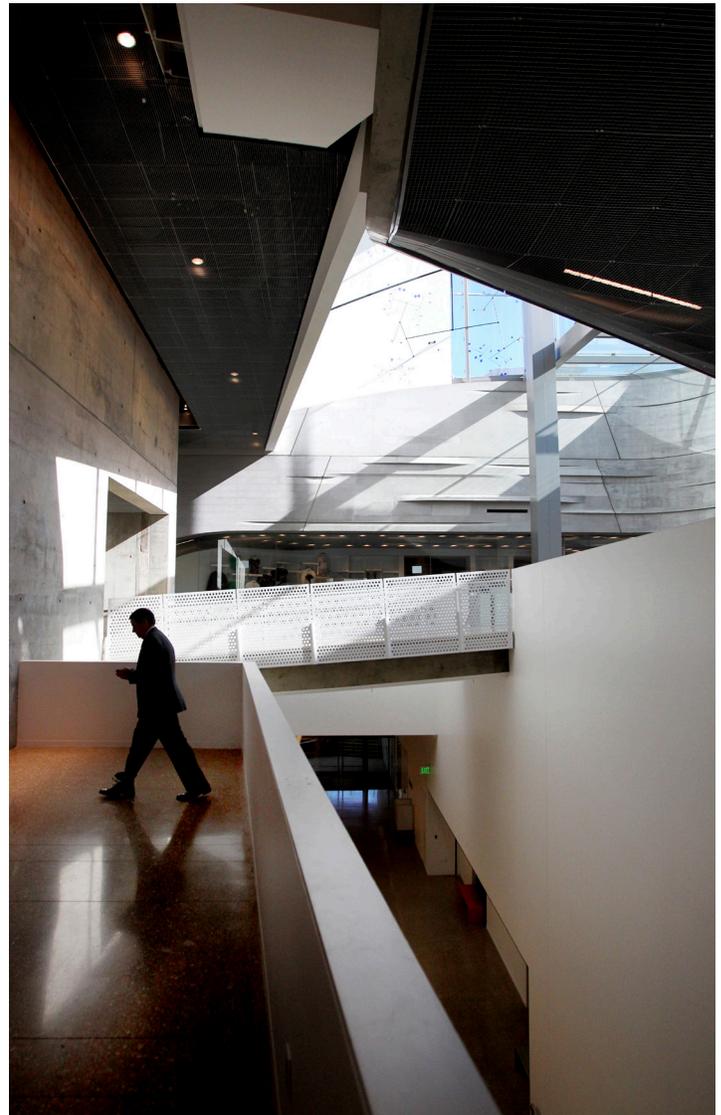
### Column-Free Solutions

To create a relatively column-free space for the dinosaur exhibit, the engineers determined that an ideal structural solution would be use post-tensioned concrete Vierendeel trusses. Unique post-tensioned concrete Vierendeel trusses, one story tall, rise between the 5th and 6th floor to create a relatively column free space on the 4th level. Its 64-foot-long, 15 foot tall concrete truss is designed to be hidden through the 5th-floor office space. The vertical elements are seen as columns.

The team also chose to have the mezzanines between the concrete floor systems constructed of structural steel to allow the concrete frame to be built without delaying construction to build a concrete mezzanine. The mezzanines were built after the frame was complete.

The Perot Museum's mission is to "inspire minds through nature and science." The engineering of the building itself is a teaching tool that provides visible and hidden examples of engineering, sustainability, and technology at work. The concrete frame was left exposed to allow the structure to be a part of the exhibit.

Thomas Taylor, PE has served as Project Manager and Principal-in-Charge for over 40 structures in the Dallas Central Business District such as the Nasher Sculpture Center, ThanksGiving Square Chapel, Dallas Police Memorial, Federal Reserve Bank, and the Dallas Convention Center.



“By using natural light and large open spaces, we’ve created an exciting environment that is friendly, accessible and easy to navigate. Our hope is that people passing by will look inside the large glass walls on the ground level – see school kids playing in the children’s museum or curators installing exhibit – and be drawn inside.”

-Past Perot Museum President and CEO, Nicole Small.