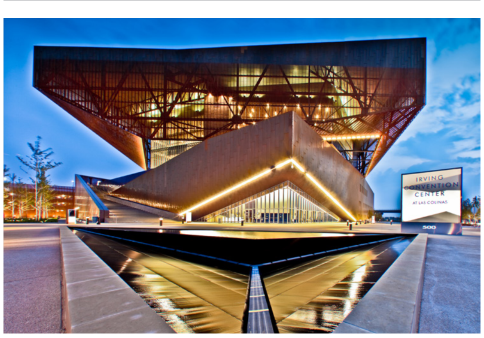
Structural Design of Convention Centers

A Guide for Architects and Engineers



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Kay Bailey Hutchison Convention Center Dallas

Datum Engineers is the structural engineer of record for the Kay Bailey Hutchison Convention Center Expansion Phase I, Phase II, Phase III and Phase IV (2002 Expansion).

Datum's continual involvement has helped mold the Dallas Convention Center into a world class facility, constructed on time and in budget.

This book is the story of Datum's involvement throughout the process. Hopefully our convention center experience can be beneficial on future projects of this type.

Thomas Taylor, PE
Principal Design Engineer of Datum Engineers

Phase IV Expansion

Design Architect: SOM Chicago

Architect of Record: HKS

The Kay Bailey Hutchison Convention Center 2002 Expansion and Renovation is the largest column free expansion space in the world, incorporating the latest technology and designs for convention centers. SOM created a unique and world class architectural design.

Datum Engineers designed Phase I, II, and III of the Dallas Convention Center and continued as structural engineers on Phase IV. The structural design team consisted of a highly experienced staff from the previous Phase III expansion.

Phase III was designed to accommodate the new Phase IV expansion. Some of the functional requirements of Phase III extended beyond the normal expansion joint locations requiring some of Phase III to be removed prior to continuing with construction to Phase IV.

Phase IV had all the same coordination problems due to spanning streets and Dart rail lines. The foundations were coordinated to miss the street, rail lines, and major known existing utilities. The contractor encountered several unknown structures buried in the site, creating conflicts with the foundations, requiring creative structural modifications.

Phase IV Expansion

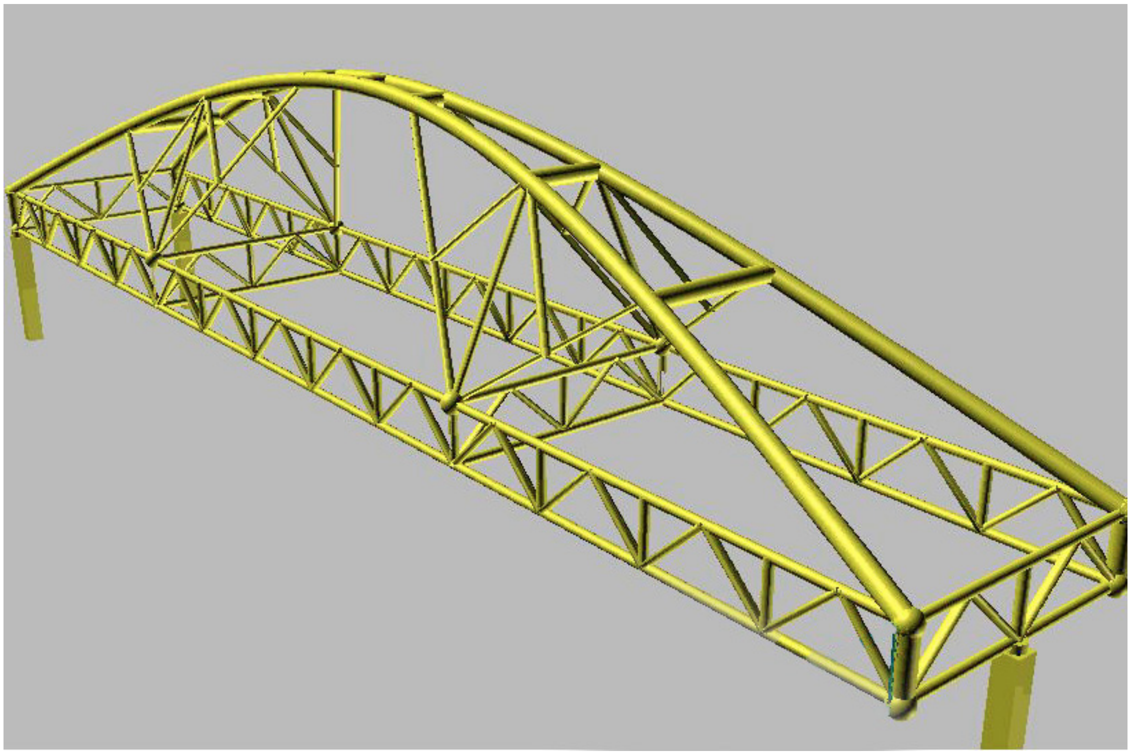
The exhibition floor is a 400' x 400' column free space design to support 350 lbs. per square foot live load. The roof is a structural steel frame hung from 2- 400' twin 50' tall parabolic arch trusses constructed from a 4'- 0" diameter x 1½" to ¾" thick pipes. At the ends of each parabolic arch is a 5'- 0" x 2" thick connection sphere tying it to the connection truss. The exhibition floor is protected from vibration from six roadways and four train lines below by spring isolators. The entry is created by a 900' long x 85' tall structural-architecturally exposed concrete wall. The wall incorporates many structural design features to control the architectural finish and to control cracking.

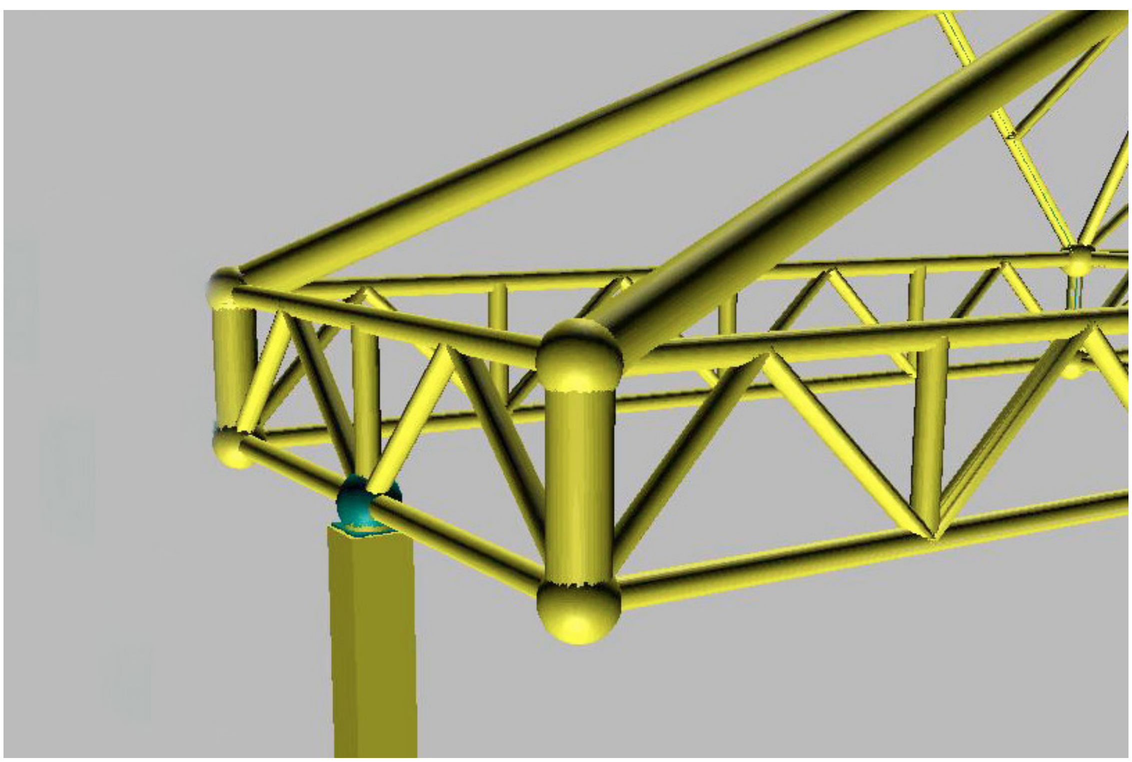
Special signature concrete wall design features include:

- Special pour sequence of the concrete
- Specific detailing of the reinforcing
- Concrete control joints to control cracking locations
- Special concrete mix designs
- Flexible foundations to release stresses in the wall

Phase IV opened in 2002 and the project was on schedule and in budget.

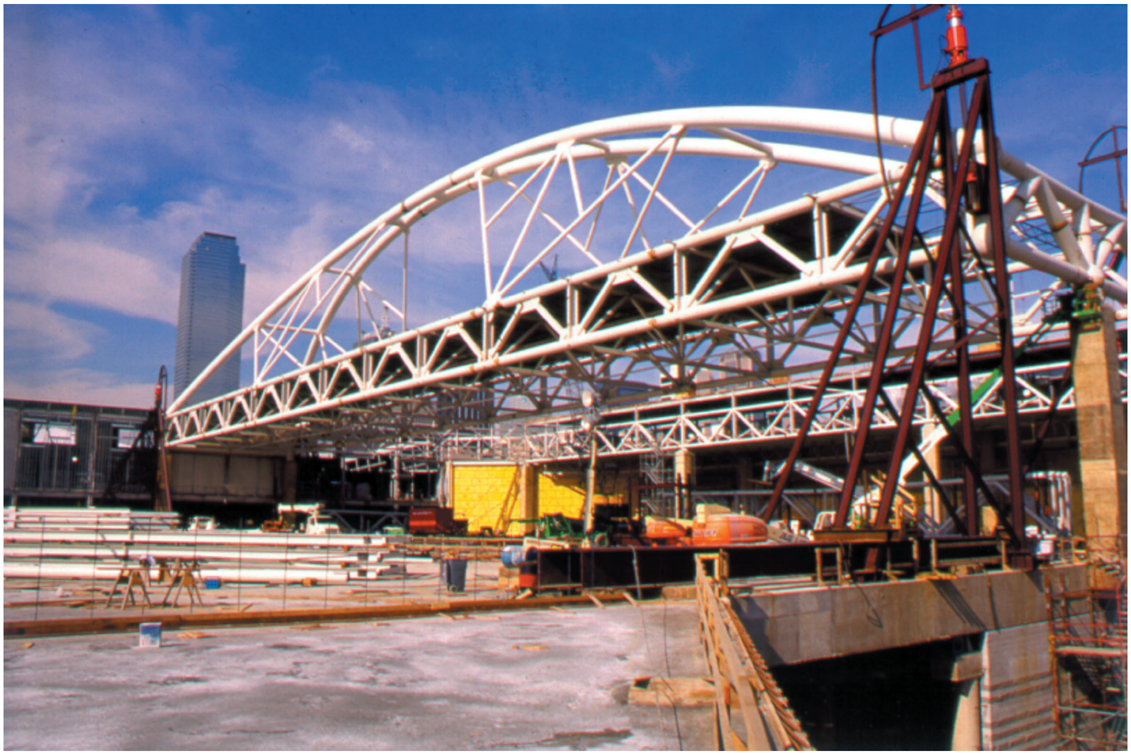
Phase IV Expansion





Structural steel roof frame hung from 2 exposed 400' twin 50' tall exposed parabolic arch trusses constructed from a 4'- 0" diameter pipes.

Phase IV Expansion



ENGINEERING AWARDS of EXCELLENCE 2003

The *Engineering Awards of Excellence* are presented annually by AISC to recognize engineering excellence and innovation in steel-framed buildings.

There are four categories, based on project cost: less than $10 million; $10 million and greater but less than $25 million; $25 million and greater but less than $100 million; and $100 million and greater.

More than one project may be submitted by the same firm and each submittal will be considered as a separate entry.

ELIGIBILITY

- A significant part of the framing system must be steel wide-flange structural shapes or hollow structural sections;
- Building construction must have been completed between January 1, 1999 and December 31, 2002; and
- Projects must be located in the U.S., Canada or Mexico.

JUDGING CRITERIA

- Creativity in response to the owner's and architect's program;
- Application of new or innovative technology in areas such as connections, gravity systems, lateral load resisting systems and fire protection;
- Structural efficiency; and
- Significance of engineering achievement.

2003 JURY

- Jon Magnusson, P.E., Hon. AIA
  Chairman/C.E.O.
  Magnusson Klemencic Associates
  Seattle
- Nancy Hamilton, P.E., S.E.
  Principal
  ARUP
  Chicago
- Robert McNamara, P.E., S.E.
  President
  McNamara/Salvia, Inc.
  Boston

AWARD WINNERS

$100M or GREATER

MERIT AWARD
THE DALLAS CONVENTION CENTER 2002 EXPANSION
DATUM ENGINEERS, INC.

Structural Engineer
Datum Engineers, Inc.
Dallas, Texas

Associate Structural Engineer
Charles Gojer and Associates, Inc.
Dallas, Texas

Architects
Skidmore, Owings & Merrill LLP
Chicago, Illinois

HKS Architects
Dallas, Texas

General Contractor
Manhattan Construction Company
Dallas, Texas

Steel Fabricator and Detailer
North Texas Steel Company
Fort Worth, Texas

Curved Pipe Manufacturer
Bend Tec
Duluth, Minnesota

Engineering Software
SAP 2000, RAM Structural System

MERIT AWARD

$100M OR GREATER

Dallas Convention Center 2002 Expansion

DALLAS, TX

JUROR COMMENTS:

The use of large scale pipe (48") for primary structure is excellent.

THE DALLAS CONVENTION CENTER 2002 EXPANSION

U.S. $100 Million or Greater

The 2002 expansion of the Dallas Convention Center included a unique feature, requiring special engineering attention that did not exist in the previous Convention Center. This expansion was planned to be the largest column-free convention center in the country at 390 feet x 600 feet. The functional criteria established for the space included a flat ceiling 40 feet above the convention center floor. The ceiling should be flat in order to attach banners, lights, and other convention function props. The 30′ x 30′ module of the ceiling grid should center over the electrical outlet boxes in the floor. The goal was for the interior ceiling structure to match the existing convention center ceiling structure while at the same time be a column-free space.

This criteria dictated locating the longspan structure above the roof grid and spanning 390 feet. The basic roof structure could then remain the same as in the present facilities. The only difference was the roof would be supported by a structure above in lieu of columns. The roof structure is composed of trusses that span 60 feet to 120 feet spaced at 30 feet on center in the longitudinal direction. These trusses have a maximum depth of 14 feet for shipping purposes. The bottom chord is horizontal, and the top chord sloped to create the drainage for the roof structure. Fourteen feet deep bracing trusses were situated in the transverse direction at 30 feet on center creating a 30′ x 30′ main truss grid. Shallow 30′ span bar joists were centered in each grid to reduce the metal deck span to 15′- 0″.

Seven concepts for spanning the 390 feet dimension and supporting the 14′-0″ deep trusses were value engineered. Two systems were developed far enough to obtain a cost estimate from the Construction Manager. The two final systems were a cable suspended system and the double pipe parabolic arch concept, which was ultimately selected as the most economical solution to the problem.

The two double pipe parabolic arches are supported on 5′ x 5′ concrete columns that are spaced 60′-0″ apart. The pipes also curve in the horizontal plane and lean against each other at mid span. The top chord is a bent 48″ diameter pipe with wall thicknesses that vary from 5/8″ to 1 1/2″. The thrust of each double arch is taken by the top chord of a 14′-0″ truss centered on the concrete column support at each end. The top and bottom chords of the tension tie trusses are 12″ diameter pipes. The 12″ diameter pipes visually contrast the tension tie trusses from the typical truss composed of wideflange members.

In order to transfer the thrust of the parabolic arch to the tension tie trusses, a 60″ diameter steel pressure vessel connection was developed. The round ball configuration allowed every member intersecting at the single point to have a plane perpendicular to the member for a connection and provided a visually attractive appearance.

Bend Tec fabricated the arches. Beasley Erection Co. erected the arches and the trusses as an assembly by jacking them from the floor deck to the final location. Gibson Construction Co. of England performed the jacking operation.

Big Bends

The entire roof-truss support system for the Dallas Convention Center was fabricated and delivered to the job site by BendTec, Inc., a pipe fabricator located in Duluth, MN that specializes in the fabrication of HSS trusses. BendTec's scope included the sizing of connections, detailing, bending of the arches, fabrication of the trusswork and delivery to the job site.

The four arches were bent from 48" OD API 5IX52 pipe using BendTec's induction pipe bending process. Pipe wall thickness varied from 0.625" to 1.5". Since the arches were parabolic, not circular, special measures were taken to guarantee the correct shape. The induction bending process utilized an electric induction coil to heat a narrow band around the pipe to a predetermined, controlled bending temperature. As the pipe was pushed through the machine at a controlled rate, a hinged arm clamped to the pipe caused it to bend. Bendtec utilized specially qualified bending procedures to control essential bending machine parameters and guarantee that required mechanical properties were maintained throughout the bend. After bending, Bendtec installed the gusset plates for the truss hangers and preassembled the arch structures in the shop to ensure correct field fit-up. Each arch was shipped to the field in nine segments ranging from 30' to 50' in length.

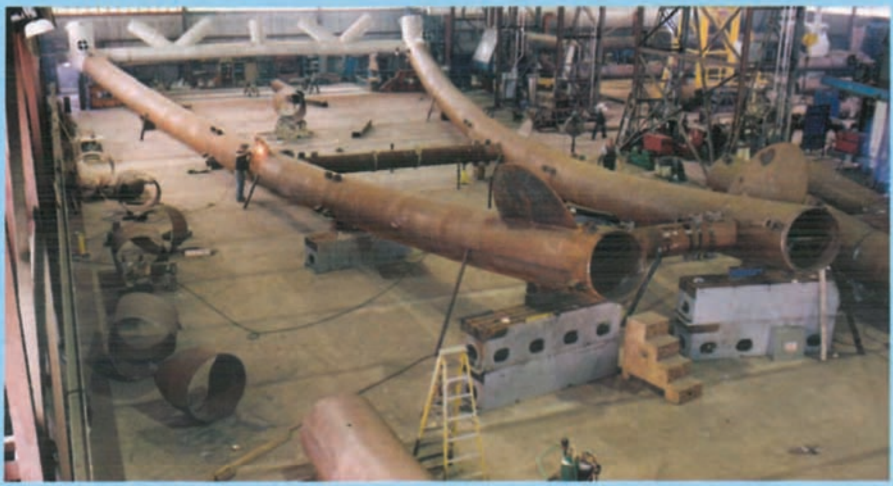
The arches were anchored to the north and south end trusses, supported by a total of only three columns (one on the south end truss at mid span, and two on the north end truss). The complex intersections at the corners of the end trusses where five to six members intersect were simplified by using 5'-diameter spheres constructed from hemispherical heads welded together by the SAW process. The spheres varied in thickness from 2" to 3".

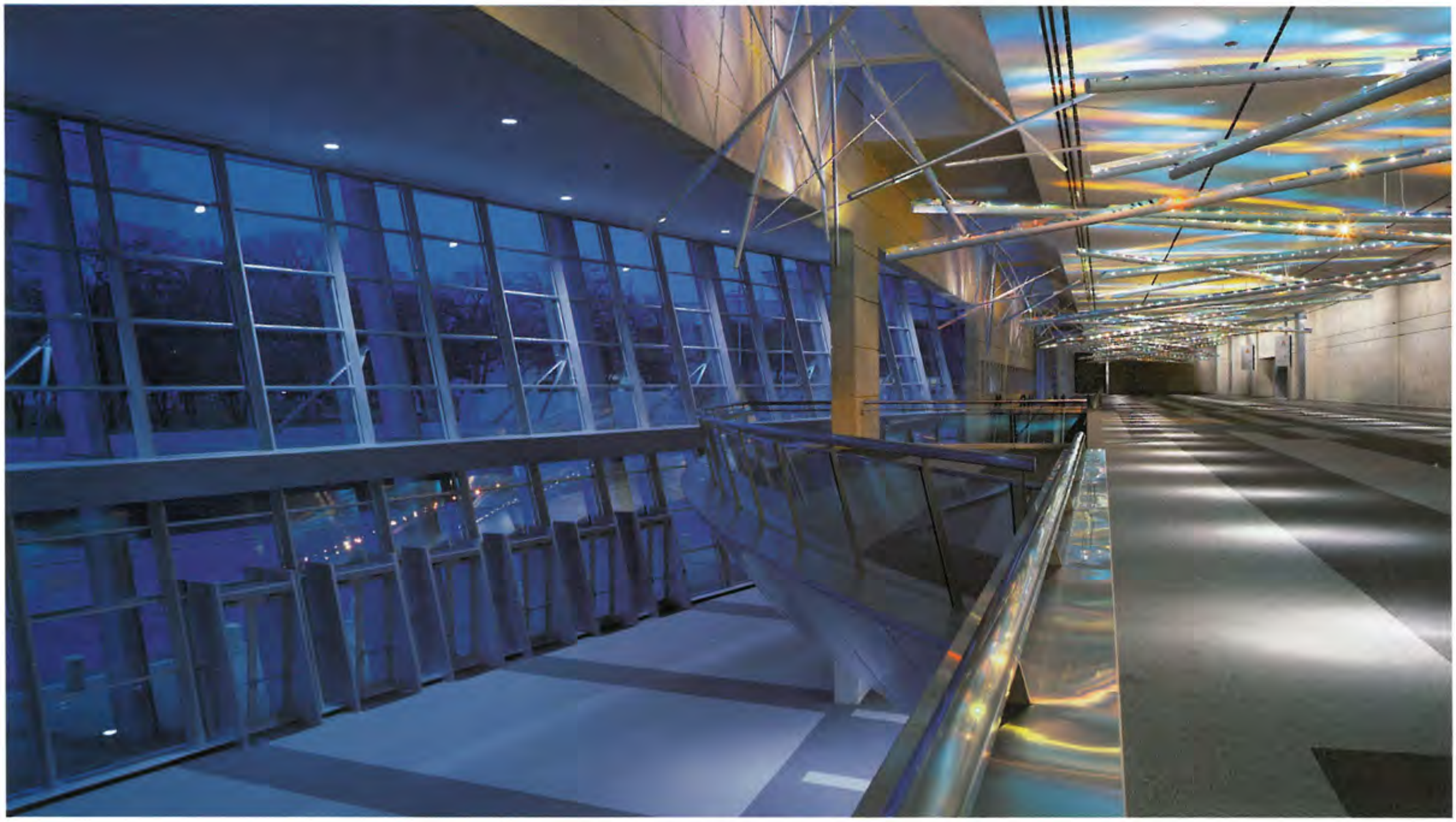
The south end truss was fabricated from 30" OD by 2"-thick API 5IX52 pipe and weighs 186,300 lb. After fabrication, this truss was split into two pieces and truck-shipped from Duluth, MN to Dallas, TX. The lighter north end truss was fabricated from 30" OD by ½" API 5IX52 pipe and was also shipped by truck in two pieces.

The side trusses, which connect to the north and south end trusses, were fabricated from 24" API 5IX52 pipe with wall thicknesses ranging from ½" to 1.25". Each truss was furnished in nine shop-fabricated segments, 14'-6" wide by 30' to 58' long.

BendTec detailed the entire project in-house, developing 140 (24" by 36") drawings. Because the arches were slanted towards the center of the truss assembly, the horizontal cross braces presented special challenges to both detailing and fit-up. By accurately drawing the entire truss assembly on CAD, these connections could be isolated and patterns made for coping the cross braces to intersect the arches.

The project involved furnishing of 1,200 tons of architecturally exposed steel for the two truss assemblies. ★





Conventional Landmark

by TOM TRENOLONE, ASSOC. AIA

THE conglomeration of buildings known as the Dallas Convention Center grew from a small civic center designed by George Dahl and built in 1957. Over the following four decades, several expansion projects have increased the convention center's total volume of exhibition and meeting space to make it one of the largest in the nation—enough air-conditioned space to cover 17 football fields. What has been missing is a visual identity for the complex to mark its presence on the Dallas skyline. A recently completed expansion project has filled the void by providing that elusive signature element in the form of two gigantic steel arches. Spanning 390 feet across a new exhibition hall and rising 55 feet above its roof, the twin arches now define the convention center and create a new landmark at the southern edge of downtown.

The project – designed by Skidmore, Owings and Merrill (SOM) of Chicago with Dallas-based HKS as architect of record – is the fourth major expansion project for the convention center within 30 years. With each of those projects, architects have had to address several significant challenges inherent with the site, particularly its location near major transportation arteries (both automobile and rail) and an east-west interior circulation defined by the original building. Like their predecessors, SOM and HKS faced similar challenges in adding two major components, a 203,000-sf exhibit hall that straddles existing rail lines and a new entrance to service the sprawling complex. (The convention center has long been without an identifiable "front door.")

The latest expansion is the first part of a construction program outlined in a 1999 master plan, also by SOM and HKS, for the convention center that calls for the eventual construction of two more large exhibit halls, two ballrooms, and a new theater, as well as the reconfiguration of all ground-level spaces into meeting rooms. The timeline for completion of the master plan is undetermined due to current economic conditions, according to City of Dallas Project

PROJECT Dallas Convention Center Expansion and Renovation, Dallas

CLIENT City of Dallas Public Works/Transportation and Events Services/Cultural Affairs

ARCHITECT OF RECORD HKS Inc.

DESIGN ARCHITECT Skidmore Owings & Merrill LLP

CONSTRUCTION MANAGER Austin Commercial

GENERAL CONTRACTOR Manhattan Construction Company

CONSULTANTS Datum Engineers (structural); Blum Consulting Engineers (mechanical and plumbing); Campos Engineering (electrical); Arredondo, Zepeda & Brunz (civil and survey); Caye Cook ASLA (landscape); Convnetional Wisdom (programming); Reginald Hough FAIA (concrete)

PHOTOGRAPHERS Ed LaCasse and Ron St. Angelo (where noted)

(previous page) "Lightstreams," an installation of kinetic lights by artist Ed Carpenter, energizes the exhibit hall concourse at the new Griffin Street entrance. (this page) The cant of the entry adds visual drama to the exterior.

As seen from a northwest perspective, the twin steel arches make Exhibit Hall F easily recognizable. Future expansion will abut the new exhibit hall's south side; photo by Ron St. Angelo. (below) The pre-function area within Exhibit Hall F is modern and efficient.

Manager Thomas Wurtz, AIA. But if eventually completed as planned, a second pair of arches will double the visual impact of the convention center's new arcing silhouette.

Completed last year, the new project is undeniably modernist and demonstrates a deliberate respect to the city's modern skyline. While the design of the new entry is not groundbreaking, the architects have shown skill and an understanding of proportion combined with function. However, it is the new Exhibit Hall F that grabs attention with technical gymnastics to create one of the world's largest column-free exhibition spaces.

The volume of Exhibit Hall F was predetermined in the Z axis, with a height restriction due to the close proximity of a heliport that serves downtown Dallas and a floor elevation that must allow both DART light rail and Union Pacific locomotives to pass underneath. This condition required columns to be modified with springs at the top to prevent vibration transfer from passing rail traffic and the need for a short stair transition adjacent to the existing Hall E.

As previously mentioned, the most distinctive design/structural element is the twin 740-ton steel arches—two arcs that extend up from perimeter columns and at their apex merge

FLOOR PLAN
1 NEW RESTAURANT
2 EXISTING BALLROOM
3 LOBBY
4 NEW PREFUNCTION
5 EXISTING ROOMS
6 EXISTING ARENA
7 EXHIBIT HALL A
8 EXHIBIT HALL B
9 EXHIBIT HALL C
10 EXHIBIT HALL D
11 REGISTRATION
12 EXHIBIT HALL F
13 EXHIBIT HALL E
14 EXISTING LOADING DOCKS
15 EXISTING THEATRE
16 NEW LOADING DOCKS

along the centerline of the bay. The strong sweeping forms have a visible efficiency, yet the arrangement of the tension members hanging from these arcs lack elegance.

Sited along the northern perimeter of the complex, the new entry is designed as a gentle curve that arcs out toward Griffin Street and Pioneer Plaza. The cant of the entry's curtain wall creates a sense of flow, but at the same time it seems to alienate the geometry of the line of punched openings that march along the exhibit hall concourse. The entry is caped by a generous overhang supported by elliptical columns that parallel the cant of the curtain wall. A braced canopy, which defines the door bank, engages the canted columns and denotes the intersection with elliptical punches that expose the front edge of the columns.

The exhibit hall concourse ceiling is defined by artist Ed Carpenter's "Lightstreams" installation, an array of kinetic lights and diffusers aligning with a multitude of vectors. "Lightstreams" projects colored lights that cycle through a fixed spectrum and introduces variations in hue. The flow of light along the ceiling is engaging, but the juxtaposition of the actual structure of the lights creates a tension with the architecture that makes it appear as if the space is not dynamic enough. This seemingly strained relationship between art and architecture is puzzling, especially considering that the installation has been part of the design since the project's schematic phases. The tension eases somewhat in the evening, but there's a slight feeling of disconnect that lingers.

Taking everything into account, the overall design is successful and has set a foundation that will allow the master plan to be realized. Conventioneers and local residents will appreciate the latest renovation of the interior spaces and the utility of the new entrance. Future expansion and renovation, as outlined in the master plan, will further improve the convention center's capacity for larger events as well as further enhancing its physical presence within the cityscape. ▪

Tom Trenolone, Assoc. AIA, works with RTKL in Dallas.

RESOURCES **UNIT PAVERS:** Pavestone; **FENCES, GATES, AND HARDWARE:** Anchor Fence; **MASONRY UNITS:** Trenwyth; **RAILINGS AND HANDRAILS:** Big D Metalworks; **WATERPROOFING AND DAMPPROOFING:** Tyvek Commercial Wrap; **WATER REPELLANTS:** Chamberlin; **BUILDING INSULATION:** Owens Corning; **EXTERIOR INSULATION AND FINISH SYSTEMS:** TEIFS; **METAL ROOFING:** AEP-Span; **INSULATED METAL WALL PANELS:** NOW Specialties; **METAL DOORS AND FRAMES:** Tex-Steel; **ENTRANCES AND STOREFRONTS:** Tepco Contract Glazing; **UNIT SKYLIGHTS:** Acralight; **DECORATIVE GLAZING:** Tepco Contract Glazing; **GLAZED CURTAINWALL:** Vistawall; **GYPSUM BOARD FRAMING AND ACCESSORIES:** Dens-Glass Gold; **ACOUSTICAL CEILINGS:** Armstrong; **METAL CEILINGS:** Chicago Metallic Planar Micro; **PAINTS:** ICI Dulux; **HIGH-PERFORMANCE COATINGS:** Sherwin-Williams

Convention Centers

DALLAS EXPANSION IS TRUSSED UP LIKE A BRIDGE TO SPAN 390 FEET

SUSPENDED Bowstring trusses will support a 200,000-sq-ft column-free space.

IT TOOK CONTRACTORS EIGHT WEEKS to assemble and only 30 minutes to jack into place the first of two 390-ft-long bowstring truss assemblies that will support the roof of a $128-million addition to the Dallas Convention Center.

The expansion will bring total exhibition space to over 1 million sq ft and includes a 200,000-sq-ft column-free exhibit space, which will be the largest of its kind in the world when the facility is complete in September, say project officials. However, the David L. Lawrence Convention Center in Pittsburgh, now more than half-complete and slated for final opening in March 2003, is set to break this record with a 250,000-sq-ft column-free exhibit space.

While the exposed tubular steel bowstrings are the most distinctive feature of the expansion to the Dallas facility, they are by no means the only challenging aspect of the project. "Nothing is cookie cutter about this job," says Thomas Wurtz, project manager for the city-owned building. With the expansion spanning two city streets and six active rail lines, columns and piers were shoe-horned between a variety of obstacles. Portions of the structure rest on spring isolators to minimize vibration from trains passing below.

After assembling the bow-string truss on the new exhibit floor, contractors last month raised the assembly into position using hydraulic jacks. The second assembly is set to be raised next month.

Each 70-ft-deep assembly consists of a pair of 55-ft-tall parabolic arch sections sitting on top of a 60-ft wide by 15-ft deep box truss with 5-ft-dia spheres forming the key connections. Arch section welded steel tubes are up to 4 ft in dia and 1.5 in. thick. "It goes together like Tinker Toys," says Roger Files, regional project manager for Austin Commercial, the local construction manager.

Both bowstring assemblies are designed to bear on three 5-ft-square concrete columns, with two columns at the north end and only one column at the south end, due to space limitations. The trusses will be lowered onto the columns after the concrete gains 85% of its compressive strength, says Files.

Designers considered at least seven alternatives for the roof support, including cable-stayed structures, but the truss system "was the most economical and efficient," says Thomas Taylor, chairman of Dallas-based Datum Engineers Inc., structural engineer.

The floor slab is designed for live loads of 350 psf, resulting in up to 8-ft-deep cast-in-place beams spaced every 60 to 80 ft. Where two light-rail lines pass beneath the floor slab, 4.5-ft-deep precast beams span nearly 60 ft. Over four freight lines, 3-ft-deep box girders span up to 78 ft. Precast concrete planks form a sound barrier beneath each set of beams and steel spring assemblies isolate the building from train-induced vibrations at the columns adjacent to rail lines.

Foundations also presented a challenge, due to the numerous obstacles and varying bedrock conditions, says Taylor. In areas above a solid 10-to-50-ft-thick limestone layer, 4-to-6-ft-dia piers are founded directly on the limestone approximately 20 ft below grade. In areas with thinner limestone overlaying weak shale, piers were driven up to 140 ft deep to provide additional skin friction.

At the north end of the project, a 900-ft-long and 80-ft-tall cast-in-place concrete wall forms a new convention center entrance. "We tried to unify the various phases with a new front door," says John Hutchings, senior vice president of local architect-of-record, HKS Inc. ❑

By Andrew G. Roe

OBSTACLES Convention center expansion spans six rail lines and two city streets.

PHOTO TOP COURTESY OF DATUM ENGINEERS. PHOTO AND IMAGE BOTTOM COURTESY OF THE CITY OF DALLAS

Phase III Expansion

In 1986, Datum was selected by JPJ and LMN Architects as the structural engineers for the Phase III expansion and an elevated vertiport. The elevated vertiport was to have a 360 foot runway that would accommodate VTOL aircraft weighing 46,300 pounds.

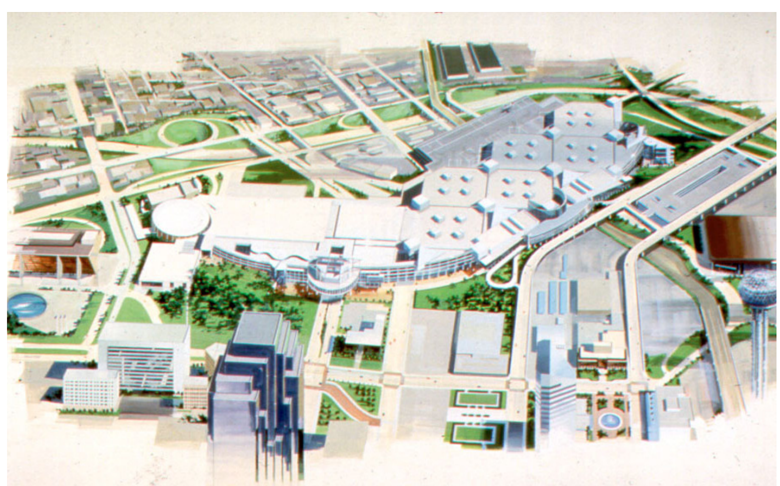
For value engineering purposes, Datum studied various loading conditions to see if the 350 psf superimposed live load on the exhibit floor could be reduced since the structure had to span long distances over existing streets. It was concluded, based on Datum's experience with checking the loading required by the AGC heavy equipment show, that 350 psf was occasionally required. The Convention Center, for competitive reasons, wanted to continue with the 350 psf live load since this seemed to be the industry standard loading.

The foundation of Phase III got more complex as the expansion proceeded westward toward the shales found in the Trinity River bottom. Therefore, the east end of the structure is supported on limestone and, as the limestone became thinner to the west, the foundations were drilled through the limestone and founded in the shale. Special testing was required to identify the exact location where it would be required to drill through the limestone.

Phase III was coordinated with a Dart station which was located below the exhibit floor. An elevator and stairs connects the Dart station to the exhibit floor and the vertiport terminal.

All of the parameters of the original Convention Center criteria were established except the flexibility of reducing the column spacing was again permitted. Also, due to the poor cracking performance of the topping slab in Phase I and II, it was decided to delete the topping slab. We should study the cracks that have occurred in the structure, but, at last check, this was a successful decision.

One of the challenges presented to the designers was to create an efficient roof system for the exhibit halls, and that is the subject of this article.



The roof system had to satisfy several constraints. Convention planners required a spacing of 120 feet between columns in the exhibit hall, and future expansion plans required these spans to be maintained at the perimeter of the building. Efficient mechanical design required a major air conditioning system to be centered on the roof of each exhibit hall. The combination of long spans and heavy loading indicated structural steel trusses for the primary structural frame.

Phase III Expansion

All roof elements, including ductwork and other building services, had to be 35 feet clear above the exhibit hall floor. To minimize the overall building height, it was desirable to run the ductwork through the trusses. Warren trusses were selected to provide adequate room for the major ducts. The Warren trusses also provide an attractive appearance for the roof structure, which is visible in the completed building.

The optimum spacing between trusses was determined to be 30 feet. Spacings of 20 feet and 40 feet (both equal divisors of 120 feet) were studied, and each resulted in increased steel tonnage. A benefit of the 30 foot spacing is that it matches the planning module for convention layouts, and corresponds to the layout of service boxes in the exhibit hall floors.

Bracing trusses are provided at a 30 foot spacing to stabilize the major roof trusses, for both gravity and wind uplift loading. These bracing trusses also support the roof joists, which are located at panel points to eliminate local bending in the truss chords. Finally, the bracing trusses resist cladding reactions at the bottom chord elevation, thereby minimizing the vertical span of the cladding.

After consulting with steel fabricators and erectors, the steel trusses were limited to 14 feet depth, to allow unrestricted highway transportation. Erection splices would allow the trusses to be transported in 60 to 75 foot sections. The top chords of the trusses are sloped to provide roof drainage, while the bottom chords are horizontal. All trusses are cambered to compensate for dead load deflections.

The final scheme consists of structural steel trusses with spans of 80 to 150 feet, and a 30 foot spacing. The trusses support 24" deep steel joists spanning 30 feet. A 3" metal deck spans 15 feet between supports, and an acoustic liner was included to control helicopter noise. This scheme is shown on the attached plan.

Design loads include the dead load weight of the building components, 20 psf roof live load, a 10 psf hanging load allowance for exhibitors, wind loads and the effects of temperature. Over the center bay of each exhibit hall is a 10,000 square foot fan room, containing all the HVAC equipment for the building. Lateral forces are resisted by the concrete columns, which act as cantilevers from the exhibit hall floor level.

Due to the long spans for the roof, we were concerned about designing the trusses as simple-span. While this solution allows the most efficient erection of the roof structure, we were concerned about the long-term effect of rotational movement at the truss supports. This lead us to study making the trusses continuous and the connections rigid. This solution makes more efficient use of materials, reduces live load deflections and eliminates rotational movement at the supports. However early analysis ruled out the use of fully continuous trusses. Chord connections at the supports would need to transfer the full axial capacities of the chord members, which were too large for economical connection detailing. Lateral stability of the bottom chords was also a concern for fully continuous trusses.

Phase III Expansion

The solution became clear. We should design the roof trusses to be simple-span for dead loads, and continuous for live loads and wind loads. The benefits of this solution are several.

1. Straightforward erection, since members are simple-span for dead loads.

2. Reduced quantity of materials, due to continuity at the supports.

3. Reduced deflections, again due to continuity under long-term loading.

4. Manageable chord forces at the support connections, since no dead load chord forces are transferred through the connections.

5. No stresses in the chord connections under long-term loading.

The final geometry of a typical truss is shown on the attached drawing. The trusses are cambered for dead load deflection, and the ends of the chords are staggered to allow for rotation due to dead loads. An elevation was drawn for every truss, and all information about truss geometry and member forces was scheduled.

Vertical forces are transferred through a bolted connection between a vertical WT in the secondary truss and a wide-flange vertical member in the primary truss. Chord forces are transferred through the connection using welded plates. The bolted connections are detailed as slip-critical.

Bolts located near the top of the connection were fastened when the truss was erected, while bolts at the bottom of the connection, along with the chord connections, were fastened after dead loads were in place on the roof.

The average weight of the roof structure (away from mechanical room area) = 9.2 lb./sq.ft., which represented a 12% reduction in tonnage of steel resulting from continuity. This weight includes primary trusses, secondary trusses, bracing trusses, OWSJ and bridging.

Detailing of the roof structure went smoothly, with clear and open communication between the fabricator's steel detailer and the structural designer. The roof structure was erected using a mobile crane operating on a grillage system on the exhibit hall floor.

The result is a convention center which satisfies all the objectives of the design. The roof structure is economical in its design and was efficient to construct.

Craig Blackmon, AIA

Craig Blackmon, AIA

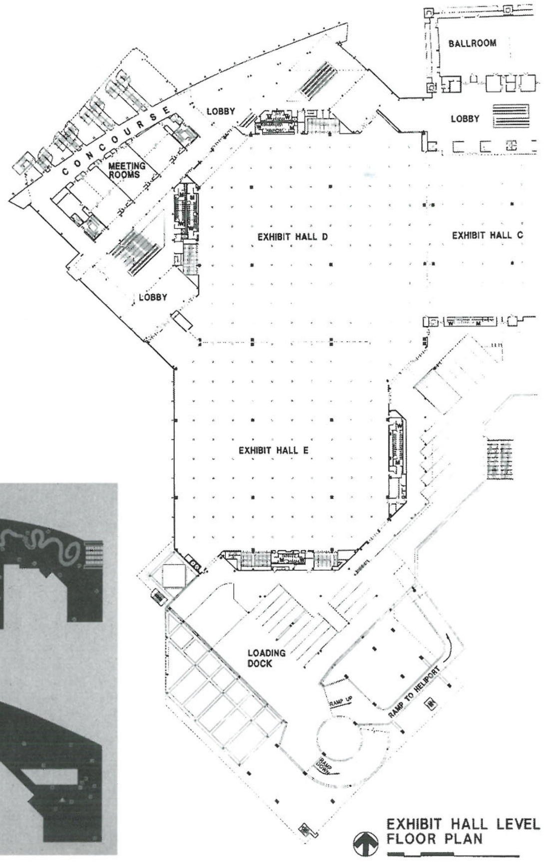
The Art of Wayfinding:
The Dallas Convention Center

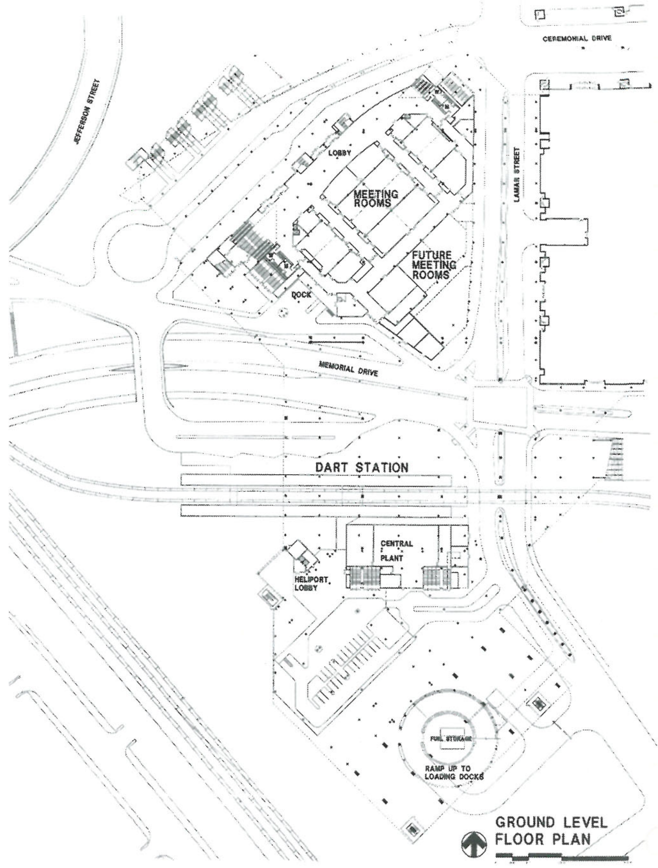
La oficina de arquitectos JPJ, artistas y artesanos trabajan juntos en la gran expansión del Centro de Convenciones de Dallas, proyecto que será completado durante los próximos diez años. A los cien mil pies cuadrados con los que cuenta esta facilidad, se le añadirán tres millónes. Para resolver el problema de los visitantes entrando, saliendo y ubicándose dentro del amplio centro, JPJ incorporó un proyecto de arte, trabajo de nueve artistas estadounidenses. La obra incluye imágenes terrestres, arquitectónicas y celestiales en un piso de terrazo. El proyecto, además de embellecer el espacio, codifica diferentes áreas del centro para facilitar la orientación del visitante.

JPJ ARCHITECTS of Dallas heads a design team that has planned a multi-phase expansion campaign for the Dallas Convention Center (see *TA*, Mar/Apr 1993, p. 61) that will enlarge the already vast meeting place to more than three million square feet, with the addition to be built out over the next decade.

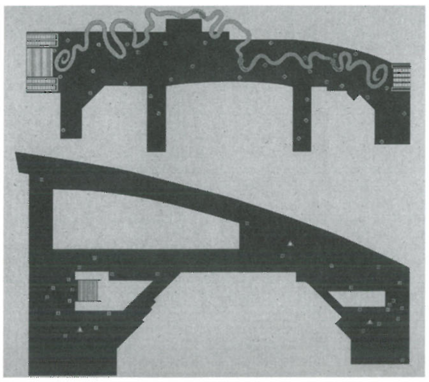
With this expansion has come the problem of helping visitors enter and leave the center and orient themselves once inside the building's several shifting volumes. To begin to solve this problem, JPJ incorporated a remarkable public art project into the first phase of the expansion, which was completed earlier this year. The art project, rendered in the beautifully crafted terrazzo floor of the expansion's circulation space, incorporates the work of nine artists from around the United States. The motifs of the art works, drawn from Dallas's natural and political history and civic aspirations, ranges from terrestrial to architectural to celestial images. The works are divided thematically, with earthly things on the exhibition-hall floor, and more abstractly rendered astronomical and mythological subjects on the upper floor.

Dallas Convention Center expansion, phase one plans: exhibit-hall level (right), and ground level (far right)





Below: plans show distribution of the art works in the expansion's public areas



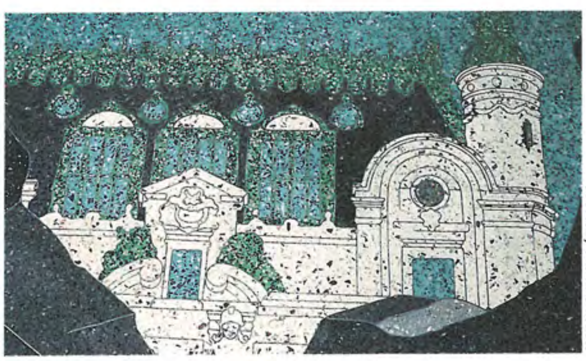
Craig Blackmon, AIA

Above: Serpentine patterns mark the main entry on the ground floor.

Right: Abstract patterns referring to solar and celestial events mark the upper level.

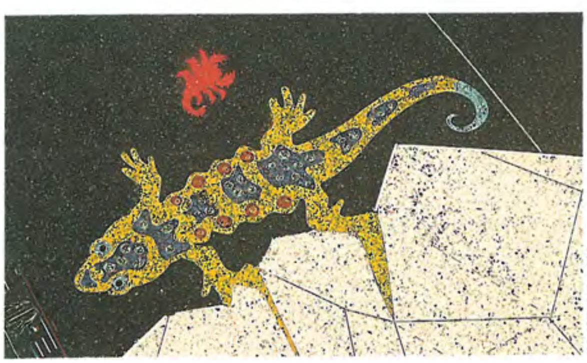
Craig Blackmon, AIA

Craig Blackman, AIA



courtesy JPJ Architects

courtesy JPJ Architects



Stewart Cohen

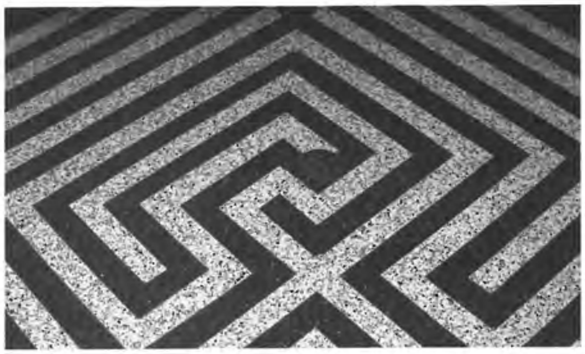
First page, top: Where the Dallas Convention Center expansion phase one faces the cityscape, the architects used a wall of high windows.

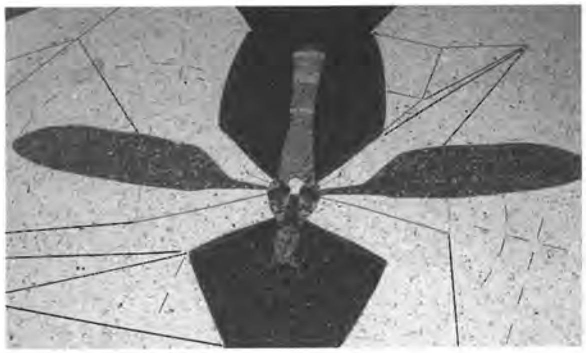
This page, top: The Convention Center expansion's new exhibit space, which turns toward an adjacent freeway, is clad in metal panels.

Motifs used in the expansion's terrazzo floors draw from civic history (above left), contributing cultures (above right), and nature (bottom left).

At the same time, the architects have shaped the rooflines of the expansion's public areas to bring light to the major junction points of the expansion, and they have opened the expansion's public areas to views of the surrounding cityscape in ways that enhance the wayfinding abilities of visitors, helping them know where they are in the center by seeing where they are in the city.

Publicity releases for the art project point out that the Dallas Convention Center forms the view of Dallas that thousands of visitors to the





Stewart Cohen

Stewart Cohen

Other motifs include (clockwise from top left) spirals, mazes, boots, and mosquitoes

SpecNotes

A new twist on an ancient technology is evident in the Dallas Convention Center expansion, where a crew of 25, working for seven months, installed 1/4-inch epoxy terrazzo over the structural floor slabs. Use of the epoxy terrazzo instead of traditional cementitious terrazzo allowed creation of the rich colors used in the center's 55 individual art pieces, according to Brent Flabiano of American Terrazzo; it also provides lighter weight, better stain and chemical resistance, and faster installation.

PROJECT *1994 Dallas Convention Center Expansion*
ARCHITECT *JPJ Architects, Inc.; Loschky Marquardt & Nesholm (associate architect); John S. Chase Architects, Inc. (associate architect)*
CLIENT *City of Dallas, Department of Public Works*
CONTRACTOR *Austin Commercial, Inc. (construction manager); Huber, Hunt & Nichols, Inc. (general contractor)*
ARTISTS *William J. Maxwell, Philip Lamb, George Moseley, Garrison Roots, Norie Sato, Brad Goldberg, and Vicki Meek*
CONSULTANTS ***Datum Engineering, Inc.****/Charles Gojer & Associates (structural engineers); Blum Consulting Engineers, Inc. and Campos Engineering, Inc. (mechanical, electrical, and plumbing engineering); Albert H. Halff Associates, Inc. (civil, surveying and topography, and environmental engineering); The SWA Group and Thompson Landscape Architects (urban design and landscape architecture); DeShazo, Starek & Tang, Inc. (traffic and transportation); Pelton Marsh Kinsella, Inc. (acoustical and audiovisual); Pamela Hull Wilson Lighting Consultant (lighting); Allen Graphics (graphics); Techcord (security); Cermak Peterka Peterson, Inc. (wind engineering)*

city take away with them each year. Working against the grain of an ever-expanding facility, JPJ and the artists and craftspeople responsible for the Dallas Convention Center expansion have created a multifaceted work that will allow visitors to return to their homes with a richer view of the city than was possible before. **TA**

INFRASTRUCTURE

Heliport bolstered for future

Roof deck strengthened for expected vertical takeoff and landing craft service

Heliport, in foreground, is built atop a large loading dock serving the Dallas Convention Center.

Dallas, looking well into the future, is constructing a rooftop helicopter landing pad that may eventually serve vertical takeoff and landing craft. When civilian versions of the Osprey military VTOL are available, Dallas will be poised to accommodate them.

The heliport and future vertiport are located on top of an extension to the Dallas Convention Center now under construction. Since only part of the planned extension is being built, only half of the rooftop heliport will be built. Nevertheless, when it opens in January, there will be two landing pads for helicopters and space for parking eight.

The Federal Aviation Administration, through its Airport Improvement Program, has contributed $13.8 million toward the cost of planning, construction and land for approach protection, says Hugh Lyon, an assistant manager in the airport division. But FAA participation is only for the heliport, not the future vertiport, he says.

Jack Shelton, assistant director of aviation for the Dallas Dept. of Aviation, says the total cost for the heliport is $20.2 million. About $14.4 million is for design and construction and $5.8 million for land.

Future. Chris Basham, a vice president with the project's airport consultant, Charles Willis & Associates, Arlington, Texas, says the heliport is equipped for future VTOL use. For example, the cans for lighting are in place and the city will only need to put in bulbs and activate the circuit. And the terminal's elevator shaft is designed to accommodate another car to carry more passengers when aircraft larger than helicopters are operating.

The heliport is an irregular hexagon, 360 ft by 340 ft on its major axes. It will double in size when Dallas builds the next phase of the convention center expansion designed by JPJ Architects Inc., Dallas.

The structure is designed for a VTOL craft weighing 46,300 lb plus a 150% increase for impact loading. Stephen Lucy, project engineer for Datum Engineering Inc., Dallas, says the roof deck is designed for three conditions: a 50,000-lb-per-wheel load that includes dead load and impact; 250-psf uniformly distributed load; and 100-psf UDL to determine the amount of post-tensioning that would result in no tension in the concrete surface. Lucy says the 250-psf loading governed for ultimate stress and the 100-psf governed from the post-tensioning standpoint.

Datum developed a pan slab deck with a 9-in.-deep slab between 20-in. by 35-in. concrete joists at 5-ft centers. Typical beams are 60 ft long and joists span 35 ft to 80 ft. All the concrete is post-tensioned.

About 40% of the roof deck is above a truck dock serving the convention center. The dock is 26 ft above grade and the underside of the roof is 65 ft above grade. There is no floor under the helicopter landing area so columns rise 65 ft without intermediate framing. Since they support 60-ft by 80-ft bays and are not post-tensioned, they required 6-ft by 4-ft sections.

Lucy says that to reduce congestion at column connections with beams and joists, the firm specified 75,000-psi steel in the columns' No. 11, 14 and 18 rebar. This reduced the area of steel by 25%. The rest of the rebar is conventional 60,000- psi steel.

Jim Davis, project manager for general contractor Huber, Hunt and Nichols Inc., Indianapolis, says the job is extraordinary because of hundreds of individual post-tensioning operations and massive concrete pours. Ten months of concrete work were completed in April.

He says almost all the pan deck pours were over 1,000 cu yd, with some as large as 1,800 cu yd. In the larger pours, workers installed 27 trailer loads of rebar. And for tall columns, Huber Hunt opted for 65-ft-high forms with two pour pockets. Davis gives credit to his subcontractors for high-quality work, noting there was no displacement in the 140,000 sq ft of deck despite part of the roof being 65 ft above grade. ▣

By Peter Green

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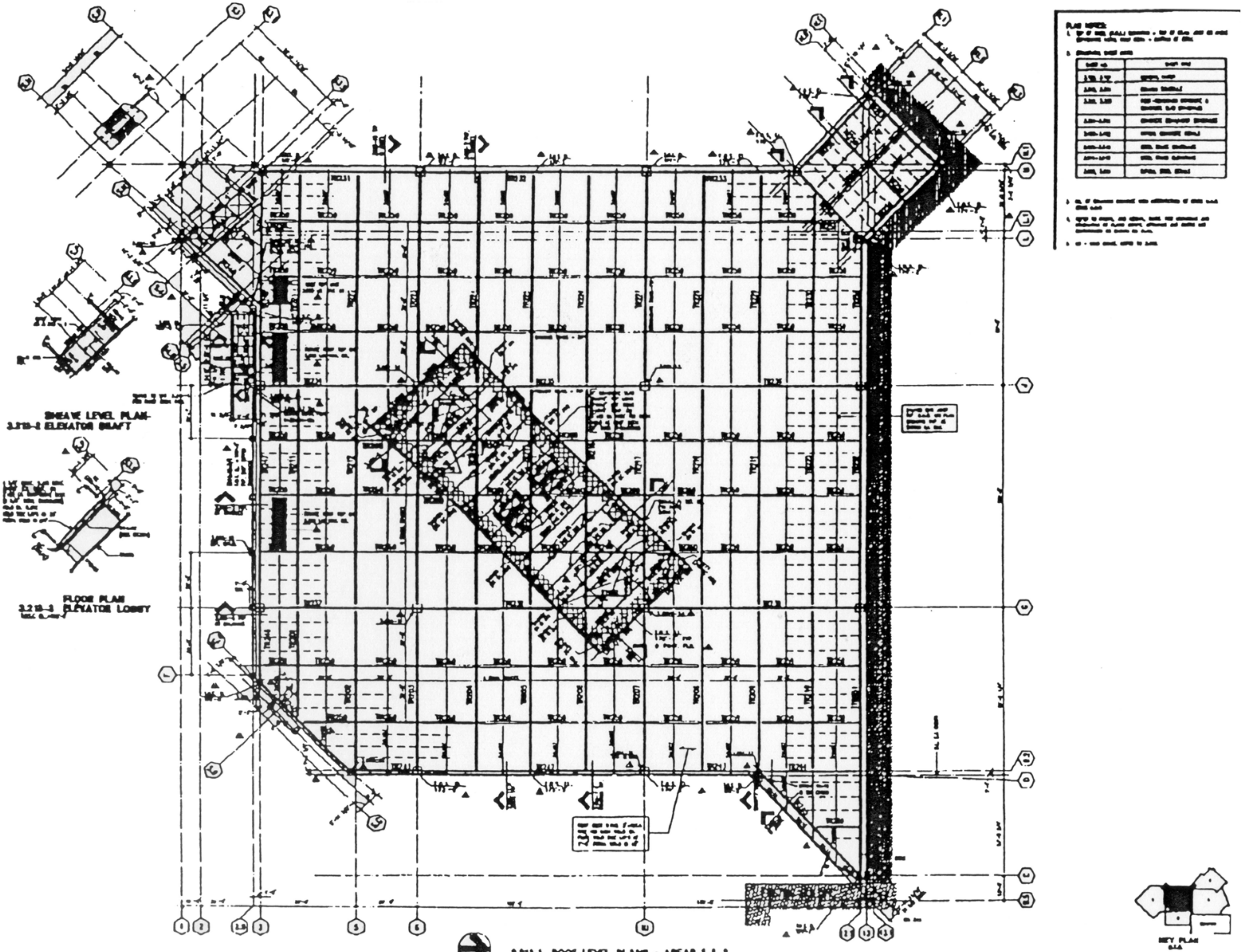
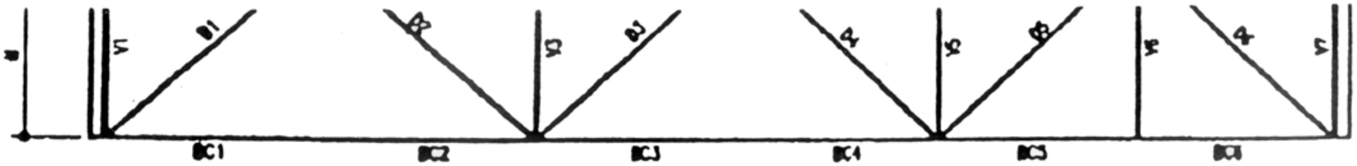


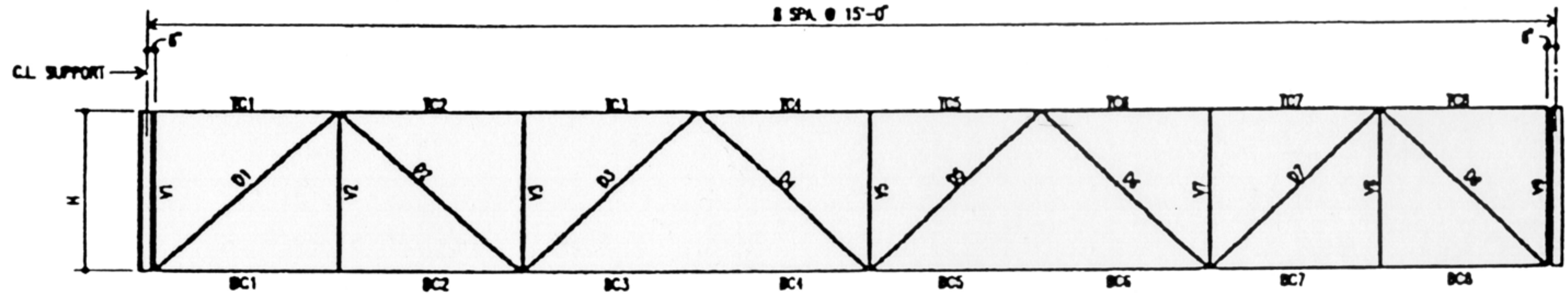
RECORD DOCUMENTS

ROOF LEVEL PLAN - AREAS 1 & 2



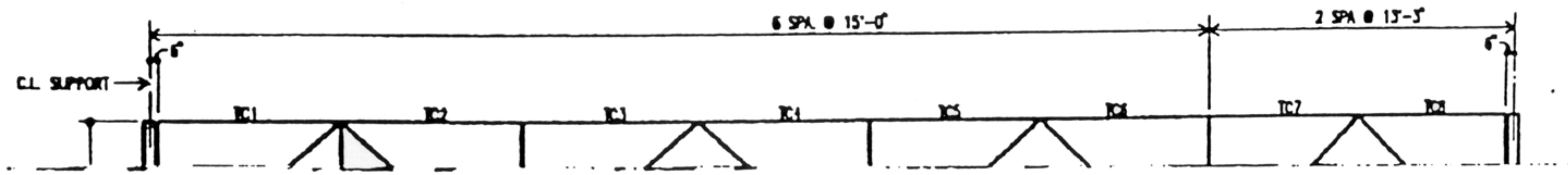
TRUSS TR202 - TR210 ELEVATION

TRUSS MARK	H OR H1	H2	H3	STAGGER	CAMBER
TR202	143.5"	–	–	1/8"	3/8"
TR203	138"	–	–	1/8"	1/2"
TR204	146"	–	–	1/8"	3/8"
TR205	156"	–	–	1/8"	3/8"
TR206	148.5"	–	–	1/4"	5/8"
TR207	141"	–	–	1/8"	1/2"
TR208	148.5"	–	–	1/8"	3/8"
TR209	156"	–	–	1/8"	3/8"
TR210	148.5"	–	–	1/8"	3/8"



TRUSS TR211 - TR220, TR247 ELEVATION

TRUSS MARK	H OR H1	H2	H3	STAGGER	CAMBER
TR211	151"	–	–	1/4"	7/8"
TR212	143.5"	–	–	3/8"	1 3/8"
TR213	138"	–	–	9/16"	2"
TR214	146"	–	–	7/16"	1 7/8"
TR215	156"	–	–	1/2"	1 7/8"
TR216	148.5"	–	–	7/16"	1 3/4"
TR217	141"	–	–	5/16"	1 3/4"
TR218	148.5"	–	–	5/16"	1 3/8"
TR219	156"	–	–	1/4"	1"
TR220	148.5"	–	–	1/4"	1"
TR247	156"	–	–	1/4"	7/8"



Phase II Expansion

In 1978, Omniplan commissioned a joint venture of Datum and Skilling, Helle, Christansen and Robertson as the structural engineer for the Phase II expansion that continued west over Griffin Street. This expansion cost $34 million and added 400,000 square feet to the Convention Center.

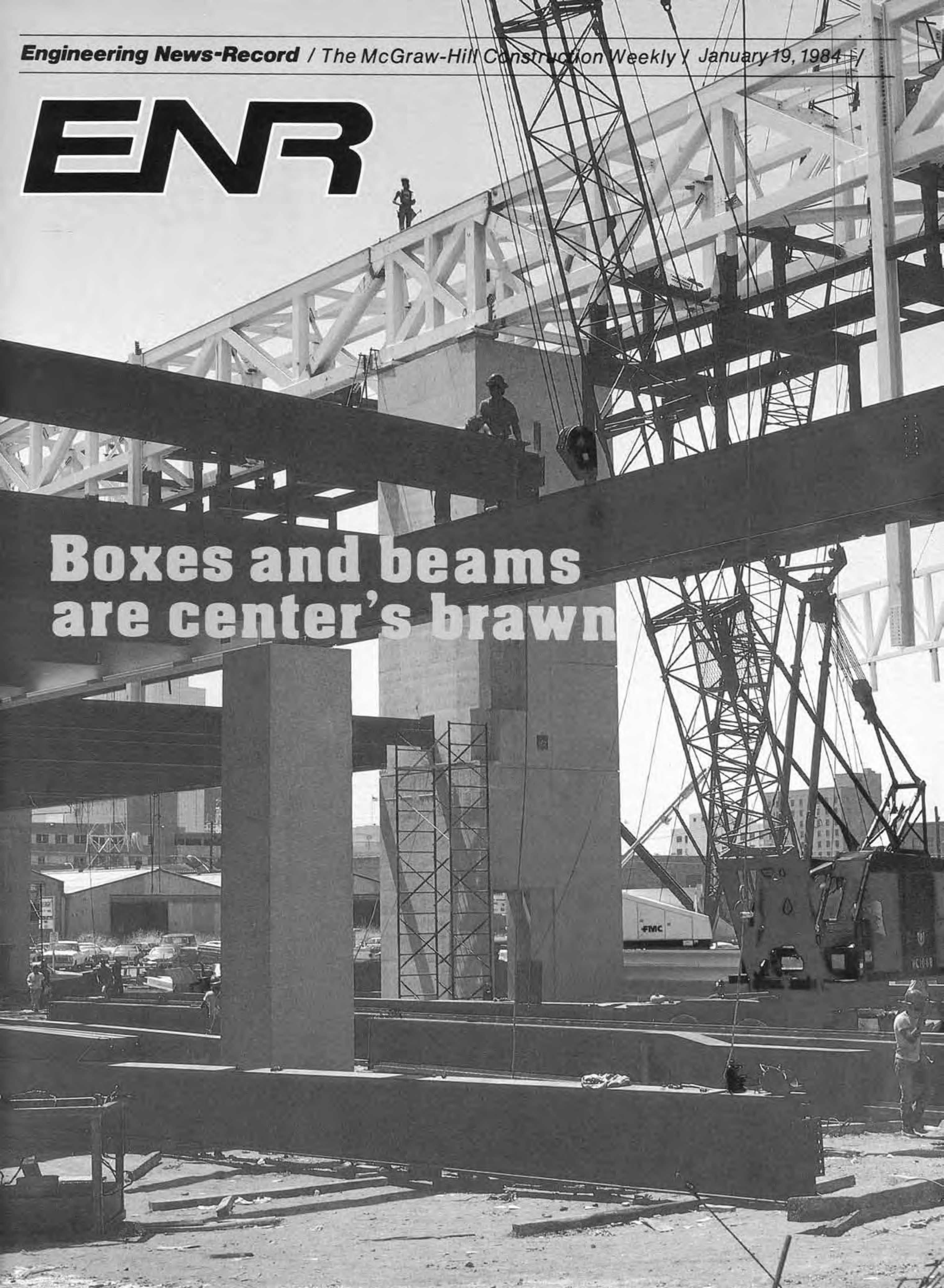
All of the basic parameters established in Phase I were established for the structural design except one. After having six years of experience operating Phase I, the Convention Center management stated that they felt they could accept a smaller column spacing than 300'-0" x 300'-0". Datum designed a box truss and bar joist roof with spans of 90 feet and 120 feet. This design was compared to the original 300 ft. x 300 ft. structural steel space truss and a savings of over $1,500,000.00 or over 4% of the total budget was realized and accepted by the Convention Center.

The 1978 expansion had several major structural considerations that the Phase I expansion did not have. The floor was still to be designed for a 350 psf live load but the structure had to span 140 feet over Griffin Street and 115 feet over Ceremonial Drive. This required major post-tensioned beams and girders to accomplish this requirement.

This project was featured on the cover of Engineering News Record and was recognized by The State Chapter of the Consulting Engineers Council as the outstanding engineering accomplishment of the year.

Engineering News-Record / The McGraw-Hill Construction Weekly / January 19, 1984 /

ENR



Boxes and beams are center's brawn

Project mixes many modes of construction

A newcomer to construction who wanted to learn how buildings are made would have to look no farther than one project for illustrations. The $34-million, 395,550-sq-ft addition to the Dallas Convention Center now under construction is virtually a construction sampler, incorporating heavy steel construction and major concrete work of both the precast and cast-in-place varieties.

The convention center will be the site of the Republican National Convention in August. The addition had to be ready four months earlier for a trade show, however. As a result, officials with the City of Dallas—the owner of the project—gave the general contractor, Del E. Webb Corp., Phoenix, only 23 months to complete it.

Because the center must span two wide streets, the designers had to come up with some outsized trusses and deep beams to handle the long spans and heavy loadings. Del E. Webb Vice President James R. Comer says the sizable beams and trusses are not the only superlatives in the building, however. "We have a big steel job, a big concrete job and a big precast job," and any one of them would be newsworthy in itself, he asserts.

The steel portion includes 3,000 tons of structural steel, 2,800 tons of reinforcing bar and 400,000 sq ft of reinforcing mesh. The cast-in-place concrete adds up to 30,000 cu yd. The precast totals 400 large panels, including some as much as 7 in. thick, 32 ft tall and 15 ft wide.

Growing complex. OMNIPLAN, Inc., Dallas, was the project architect for both this expansion and the original convention center—a $31-million, 1-million-sq-ft addition to Memorial Auditorium completed in 1973. The new buildings will include about 104,000 sq ft of exhibit space—which will increase the convention center's total by 50%. There will also be a 19,000-sq-ft ballroom, extensive meeting rooms, a two-level lobby and support facilities.

Though joined, the new exhibit hall and ballroom are essentially separate structures of different types of construction. Except for its steel roof trusses, the exhibit hall is all concrete because that suited the spans and loadings the best. The ballroom is a steel-framed structure with a precast concrete veneer.

No land was available to build the additional space next to the existing structures. Consequently, the ballroom spans 115 ft over Ceremonial Drive, which runs to the main entrance of the complex. The exhibit hall, a 110-ft pedestrian bridge and a 141-ft truck-access bridge span Griffin Street.

The 30-ft-wide truck bridge is designed for 350-psi live loads. Its deck slab is post-tensioned, poured-in-place concrete. Post-tensioned perimeter beams, 26 in. wide x 9-ft deep, take the long span.

A second-level truck dock at the end of the bridge will accommodate 10 full-size semi-trailers and a trash compactor, and ramps will allow full-size trucks direct access to the new exhibit hall. The floor of the hall, designed for 350-psi live loads, is cast-in-place concrete. Typically its beams measure 20 x 31 in., although five are as large as 48 x 84 in.

Color match. According to concrete consultant James M. Shilstone, president of Shilstone & Associates, Inc., Dallas, specifications required the contractor to match the original structure both in its color and its high-quality finish. Entirely different materials had to be used, however. Also, the two types of concrete in the addition—precast in the exterior wall

Roof of two-part addition to Dallas Convention Center is supported by steel box beams that meet at "nose cone" connections (right).

panels and poured-in-place in the massive perimeter towers—had to match.

The cement used in the existing building is no longer made. It had been combined with a reddish sand and a lightweight aggregate to get the desired color, and that had weathered badly through the years. Concrete consultant Shilstone was called in to create a satisfactory match using a different cement, sand of a different color and a limestone aggregate.

The project is also "a very tough forming job" because of extremely tight slab tolerances, Shilstone says. Slabs had to be made level 25 ft in the air with tolerances as tight as ⅛ in. in 10 ft. Adding to the complications in forming the project's concrete were five different concrete mixes in 4,000, 5,000 and 6,000-psi strengths.

Because of the difficulties, Shilstone held a two-day preconstruction training session for the architect, the contractor, some suppliers and City of Dallas Public Works Department employees involved in the construction. "We felt we needed training in concrete technology so the team started out with an understanding of what was most important and the city and architect had a good idea of the task faced by the contractor," Shilstone says.

Because of the project's accelerated construction schedule, Shilstone recommended using an in-place testing method rather than cylinder tests on about 80% of the slabs. The in-place testing method, developed in Denmark by Lok Test, Ltd., Copenhagen (ENR 6/4/81 p. 12), permits the contractor to remove forms about two days earlier than would be possible with cylinder tests.

Steel truss roofs. The roofs of the new ballroom and exhibit hall are supported by exposed steel box trusses, with spans of 90 to 120 ft. These trusses are supported by 15-ft-sq concrete towers.

OMNIPLAN designed a space frame roof for the original facility's exhibit hall. Because of budget constraints, the architect had to go to the more economical, conventional framing for the addition, says Vice President John R. Hafker. "However, to keep columns to a minimum, we used [the] large box trusses to span 90-ft and 120-ft bays, which is about the top end for this type of system," Hafker says.

One side benefit of the system, Hafker adds, was a greater clear height in the exhibit hall. Although the rooftop of the new structure is 6 ft lower than that of the existing hall, the new hall has 8 ft more in inside clear height, for a total of almost 34 ft.

"Nose cones." Inside the exhibit hall, the 10-ft-deep x 12.6-ft-wide box trusses are supported on 54-in.-sq columns. Here Datum Structures Engineering, Inc., Dallas, the project structural engineer, used an unusual connection that somehow came to be called a "nose cone." Despite the name, one engineer describes it as looking "more like a spider or children's jacks." It was "designed to make it esthetic or interesting," says Datum President Thomas W. Taylor.

The 15-ft-tall nose-cone connection supports the box trusses through eight wide-flange members that come together at one point on top of the column. According to one engineer, the nose cone "was extremely difficult to fabricate and probably involved a cost penalty."

The steel erector, Bob McCaslin Steel Erection Co., Fort Worth, used a 200-ton crane to install the trusses. To allow the crane to be located near the center of the building to set the trusses, the contractor left out 40,000 sq ft of floor decking until the trusses were erected. ■

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Phase I Expansion

Datum Engineers have been actively involved in the design and maintenance of the Dallas Convention system since the first phase was designed in 1968. The first phase was a 1,000,000 square foot $31 million addition to the Memorial Auditorium completed in 1973. Datum performed local associate work on the Phase I project for Harrell and Hamilton Architects. Datum designed the canopy of the escalator and all of the tall window mullions along with miscellaneous change order support.

During the design of the original Phase I project, several basic operational and functional decisions were made that impacted the structural design. Some of these were:

1. The floor would be designed to support 350 psf superimposed live load.

2. The building module would be 30'-0" x 30'-0".

3. Electrical conduit would be installed in the structure with a pull box at 30'-0"x 30'-0".

4. The roof was designed as a space truss with columns spaced at 300'-0" x 300'-0" to provide maximum flexibility for the users of the space.

5. The column spacing in the parking garage below the exhibit floor was established at 30'-0" x 60'-0" which moduled with the pull boxes cast in the floor at 30'-0" x 30'-0".

6. The finished floor would be a 2 ½" thick concrete topping slab.

7. The exterior walls were to be sandblasted architectural exposed concrete walls.

8. Hanging load capacity from the roof structure panel points for the exhibitors was established at 10 psf over and above the code roof live load.

Project Overview

The master site plan includes the convention center and parking garage, along with a 350-room hotel and a 190-room boutique hotel, due to complete construction in 2011, plus a future performing arts center, residential, and retail space. The site is located at the intersection of Northwest Highway and John Carpenter Freeway in the heart of Las Colinas. This is a very high-visibility location, visible from the Four Seasons Resort and Club and their Championship golf course, where the Byron Nelson Championship is played every year, immediately across the Highway.

The City of Irving wanted to take advantage of the prominent location and high visibility within the city to market the use of the facility. The owner's goals were to obtain statement architectural expression and an identifiable landmark structure with high visibility while maintaining optimal functionality of their marketable space. The building's architects, RMJM (formerly Hillier), provided a striking stacked and rotated design that accomplished the owner's goals in an exciting way.

The lower podium contains the main exhibit hall, along with office and mechanical space. The exhibit space is approximately 190 feet by 270 feet, column-free, with 35 feet of clear headroom above the exhibit floor. The office space is divided between the main floor level and a mezzanine. The mechanical space is on an additional mezzanine level above the office space.

The native soil in Las Colinas is highly expansive, with potential vertical rise (PVR) values in excess of 5 inches. However, since large areas of the exhibit floor space are open, with no sensitive finishes, partitions, or doors, Datum Gojer used a mix of foundation systems for the ground floor structure. In the large, open exhibit space, a slab-on-grade foundation over 12 feet of moisture-conditioned soils was used. This reduced the predicted heave due to expansive clay to 1" and allows the exhibit floor to economically support 350-psf live loads. In the main entry lobbies, prefunction space, first-floor office space, and other ground-floor areas with sensitive finishes and lower live-load requirements, a structured pan-joist system over a crawl space was used to isolate the floor structure from the highly expansive soils.

Project Overview

The upper building structure contains two additional floor levels. One level supports twenty meeting rooms, approximately 1,000 square feet each. Eight of the meeting rooms are created using moveable partitions, which, when opened, create a 60-foot by 120-foot junior ballroom to allow greater flexibility for use of the floor space. The top floor is primarily for the main ballroom. The ballroom is approximately 115 feet by 180 feet column-free, plus a separate prefunction area. This level also contains the kitchen space and a mechanical mezzanine. The elevated structure is rotated 20 degrees from the orthogonal podium grid, causing the corners to cantilever out beyond the lower building spaces.

In between the podium and the upper structure, an outdoor terrace level connects to the ground level below and the meeting level above via exterior stairways. This terrace level also cantilevers above the two main glass entrances in the southwest and southeast corners of the podium. An interior/exterior concrete elevator tower serves all floors and creates part of the architectural expression.

The podium and elevated structures are clad on all sides with a combination of embossed and perforated copper paneling. These perforations create a lantern effect on the south facade, causing the illuminated interior to shine through the perforations and silhouetting the exterior steel structure behind the copper panels. The perforations also create a view from the interior to the surrounding skyline.

ENGINEERING CONSIDERATIONS AND PROJECT GOALS

Two key goals were required to be met in order to make this project a success:

1. Meet the Owner's budget challenges while providing the Architect with their unique design, without sacrificing building performance or functionality.

2. Provide the building to the Owner in time for their required opening date.

Project Overview

Early in the design phase of the project, the building construction cost estimates exceeded the owner's construction budget of $85 million by 25%. The design team needed to eliminate cost from the building without impacting the function of the various building spaces and uses. During the design phase, Datum Gojer worked to economize several key areas of the structure.

Additionally, the owner wanted to begin preselling the space up to two years prior to the building opening date. This required a commitment from the entire design and construction team to meet the aggressive opening date long before construction documents were issued.

Datum Gojer worked with the owner and design team to create a strategy for achieving both of these goals, while also improving the building's performance.

SOLUTION 1: LONG-SPAN ELEVATED FLOOR STRUCTURE

The stacked-and-rotated design meant that multiple floors, plus the roof, must be supported above the column-free exhibit space on the first floor. In order to achieve this, Datum Gojer proposed a system of long-span trusses on a 30-foot module. The trusses span the 190-foot direction of the exhibit floor.

The initial pricing was based on conventional truss shapes of various depths, up to 20 feet deep. It quickly became apparent that this concept would require more steel and possibly not achieve adequate deflection and vibration performance. It would also require high-strength steel, A993 grade 65, which would need to be imported. Given the lead time for the high-strength steel and the cost associated with the extra tonnage, these conventional structural systems negatively impacted both the budget and the construction schedule. In order to make the supporting structure deeper, the building would have to grow taller vertically, which creates additional cost in copper skin and mechanical systems for heating and cooling the larger volumes.

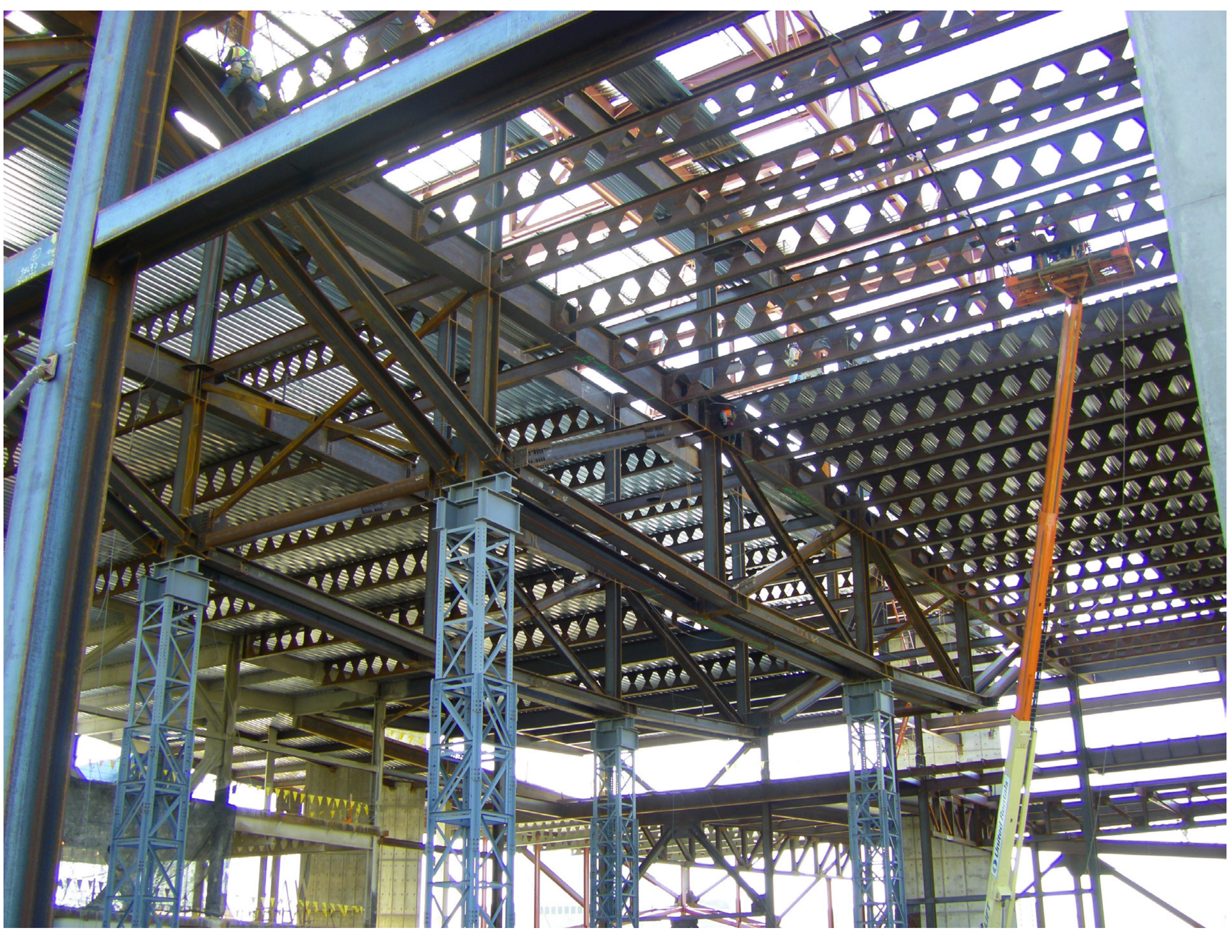
Datum Gojer began exploring structural steel options that would both eliminate the need for imported steel and reduce the tonnage. The first proposal was to use a set of segmented "catenary" trusses.

Project Overview

Rather than being limited to the space below the meeting level and above the 35-foot exhibit headroom, this proposal would extend the structural system to the ballroom level, creating a structural system that would be 35 feet deep rather than 20 feet deep. The added depth would also improve vibration and deflection performance. The primary disadvantage of this system is the disruption that the catenary chord would cause to the meeting room floor spaces, which the architect would need to work around.

The second proposal was to use arch trusses that would extend to the underside of the ballroom level, similar to the catenaries. This system had similar advantages to the catenary–similar steel tonnage required, improved deflection performance over conventional truss systems, and all domestically-produced steel. The main disadvantage was also the same–the overhead arch chord disrupts floor space on the meeting level.

The solution was to use a combination of these two truss options. The majority of the floor was supported by three catenary trusses, spaced at 30 feet to 60 feet on center, along with one arch truss at one end. The catenary truss chords were located between meeting rooms and in back-of-house spaces and away from useful floor space. This approach coordinated the structural and architectural requirements to reduce the disadvantage of the deeper catenary trusses. On the west end of the floor, the catenary would have extended outside the building; therefore, the arch was used on this end. This combined solution eliminated approximately $3 million from the construction budget and allowed the use of all domestically-available structural steel, while also improving deflection and vibration performance. In order to reduce sway due to unbalanced live loading conditions, additional diagonal bracing was provided within the truss, below the meeting room level and in the exposed exhibit ceiling space.



Project Overview

SOLUTION 2: LONG-SPAN ROOF STRUCTURE

The second challenge was to reduce the required tonnage on the four perimeter trusses clad in copper and supporting the high roof. The rotated grid at the upper structure caused the four corners of the building to cantilever beyond their supports. The layout of the occupied spaces also greatly reduced the number of support locations that extend to the ground without interrupting the various occupancies within the building. Finally, three of the four corners are upturned and all four corners cantilever, and the architectural look prevented the use of supports at the corners.

After studying column opportunities on each floor, four column locations were determined that would make the box stable. However, the southeast face of the elevated structure remained unsupported, spanning almost 300 feet. In order to reduce this span and improve deflection performance, a fifth support was needed. Datum Gojer decided to make use of the architecturally-exposed concrete elevator core. A truss is used to cantilever from an interior column, over the concrete elevator core, and out to the southeast face of the elevated structure. This cantilever truss reduces the span of the southeast truss to 190 feet.

Given the exposed nature of the exterior trusses from the interior and through the perforated copper cladding from the exterior, the architect was greatly interested in the exterior appearance of the trusses. The truss web members needed to be coordinated with the regularly-spaced copper panel joints as well as the randomly-located column supports. Over several weeks involving both architectural and structural input, a truss layout was devised that met both the structural and the architectural requirements.

Since each of the four corners cantilever, the bottom chord will be in compression. The four perimeter trusses extend below the ballroom level but not to the meeting room level. Datum Gojer located the structural bottom chord of these trusses at the same elevation as the ballroom level. The steel below this level cantilevers below the structural bottom chord. The bottom chord of the truss is pulled away from the fourth floor structure, so struts were used to brace the compression segments of the bottom chord back to the structure.

Project Overview

These trusses vary in depth from 20 feet to 62 feet, with a maximum structural depth of 42 feet. The upper box is 282 feet by 296 feet, and the longest cantilever is 117 feet. By working directly with the architect, Datum Gojer was able to reduce the structural cost by over $600,000 while keeping the building's exterior appearance intact.

SOLUTION 3: TERRACE AND MAIN ENTRIES

Early architectural renderings of the two main entries showed the entry glass spanning from the ground floor to the soffit of the terrace level without any additional structural backup. While the most economical way to frame this would have been to introduce structural columns behind the glass to create a conventional beam-and-column floor system, the added structural elements would have greatly disrupted the architectural appearance. In order to avoid the additional columns, Datum Gojer proposed to cantilever the floor structure at these two corners.

Since the longest cantilever is approximately 153 feet, the bottom chord of the truss would see a significant compression force. The bottom chord of the trusses also creates the soffit of the entry and brace the copper cladding and entry glass under wind loading. Therefore, a horizontal bracing truss was provided in the soffit behind the main bottom chord to reduce the unbraced length of the main truss cantilever bottom chord and to take the imposed wind forces. A 3" deflection joint was provided at the head of the curtain wall to isolate the glazing system from the long cantilever support structure above. This system allowed the architect to economically maintain the desired appearance at the primary front door to the building.

Project Overview

SOLUTION 4: LONG SPANS AND VIBRATION CONTROL

All of the long-span floor support conditions created a need for serious study of vibration. Datum Gojer, along with the contractor and steel fabricator, reviewed and considered several structural floor-framing systems: normal-weight vs. light-weight concrete floors, purlins spaced at 7'-6", 10'-0", and 15'-0", and conventional wide-flange vs. castellated beams. The vibration performance for the meeting room and ballroom occupancy and building uses also needed to be weighed against the costs associated with providing a stiffer structural system.

Datum proposed to use castellated beams at 15'-0" spacing with a light-weight concrete slab. This system provides improved vibration performance for the same structural cost as a similar wide-flange system (or, this system provides the same vibration performance as a much more costly wide-flange system). The light-weight concrete slab could be thinner than a normal-weight slab and still achieve the required 2-hour fire separation. This change alone resulted in significant savings to the overall project since the heavier, normal-weight floors would result in more steel tonnage and larger, deeper piers. Lastly, the increased purlin spacing reduced the number of steel pieces, decreasing fabrication and erection time while improving vibration performance.

SOLUTION 5: THE FAST TRACK PROCESS

At the end of the Design Development process, the design team met with the owner, contractor, and the steel fabricator to discuss the budget and the remaining schedule. The contractor stated that, in order to meet the owner's required opening date, the building would need to be issued for construction in 7 weeks. Given the level of completion of the design at that time, along with the complexity of the building, everyone agreed that this was an impossible task.

While brainstorming ways to meet the owner's schedule, Datum Gojer noted that certain elements of the project were time-critical. In particular, the concrete and foundation elements required only a minimal amount of time from design to construction, while structural steel procurement, fabrication, and delivery would require far more lead time. Additionally, not all of the steel would be required on the first day of construction as steel erection was scheduled to take several months. The length of time between first steel order to last steel delivery allowed the steel to be issued in multiple packages.

Project Overview

The design and construction team agreed to issue a minimum of 60% of the steel tonnage for mill order in the contractor's 7-week window. Datum Gojer worked with the steel fabricator to determine the longest-lead items for fabrication. Datum Gojer also worked to complete and provide steel based on the sequence of erection and the erection time line provided by the steel erector. Through this process, Datum Gojer was actually able to issue 90% of the steel tonnage in the first mill order package.

After the initial agreement was reached, the steel fabricator sent mill closing schedules to Datum Gojer. These schedules indicated that certain shapes would be closing well ahead of the 7-week window. In particular, column sections in the W14x90 through W14x132 group would close at the end of four weeks. The following week, W36x231 through W36x441 would close. These two early mill closings meant that design of columns and floor trusses would need to be completed after only four and five weeks, respectively.

Subsequent to the mill order package, the design team issued several other advanced bid, permit, and construction packages, including foundations, concrete, and miscellaneous metals. Datum Gojer also issued weekly detailing packages, one sequence per week, for the mill-ordered steel until the final Issued For Construction package was sent. This process allowed the steel fabricator to begin issuing shop drawings well ahead of the for-construction drawings. Approximately 15% of the steel on the project was reviewed, approved, and in fabrication prior to the final construction package.

CONCLUSION

The project is currently under construction and on schedule to be completed in January, 2011. The six solutions provided by Datum Gojer were instrumental in maintaining the Contractor's schedule. In addition, the construction cost was significantly reduced from the original construction cost estimates. The building is now well within budget, and the structural solutions played a key role in achieving these savings in addition to contributing to the owner's desire for an identifiable landmark facility.

MSC
MODERN STEEL CONSTRUCTION

Convention center's bold architectural style is supported by creative structural engineering.

One Challenge, Several Answers

BY GREG DIANA, P.E.
PHOTOS BY DATUM ENGINEERS

The 20° rotation of the upper portion of the Irving Convention Center with respect to its base creates a stunning, signature presence, leveraging its high-visibility location.

THE NEW IRVING CONVENTION CENTER at Las Colinas is at the intersection of Northwest Highway and John Carpenter Freeway in the heart of Las Colinas, Texas. It is visible from the Four Seasons Resort and Club and its championship golf course, immediately across the highway, where the Byron Nelson Championship is played every year. The city wanted to take advantage of this prominent location with its high visibility to market the use of the facility.

The owner's goals were to obtain statement architectural expression and an identifiable landmark structure with high visibility while maintaining optimal functionality of their marketable space. The building's architects, RMJM (formerly Hillier), provided a striking stacked and rotated design that accomplished the owner's goals in an exciting way.

The master site plan includes the convention center and parking garage, along with a 350-room hotel and a 190-room boutique hotel, due to complete construction in 2011, plus a future performing arts center, residential, and retail space. The lower podium contains the main exhibit hall, along with office and mechanical space. The exhibit space is approximately 190 ft by 270 ft, column-free, with 35 ft of clear headroom above the exhibit floor. The office space is divided between the main floor level and a mezzanine. The mechanical space is on an additional mezzanine level above the office space.

The native soil in Las Colinas is highly expansive, with potential vertical rise (PVR) values in excess of 5 in. However, because large areas of the exhibit floor space are open, with no sensitive finishes, partitions, or doors, engineers used a mix of foundation systems for the ground floor structure. In the large, open exhibit space, a slab-on-grade foundation over 12 ft of moisture-conditioned soils was used. This reduced the predicted heave due to expansive clay to 1 in. and allows the exhibit floor to economically support 350 psf live loads. A structured pan-joist system over a crawl space was used in the main entry lobbies, prefunction space, first floor office space, and other ground floor areas with sensitive finishes and lower live load requirements to isolate the floor structure from the highly expansive soils.

The upper building structure contains two additional floor levels. One level supports 20 meeting rooms, each approximately 1,000 sq. ft. Eight of the meeting rooms are created using moveable partitions, which, when opened, create a 60 ft by 120 ft junior ballroom to allow greater flexibility for use of the floor space. The top floor is primarily for the main ballroom. The column-free ballroom is approximately 115 ft by 180 ft, plus a separate prefunction area. This level also contains the kitchen space and a mechanical mezzanine. The elevated structure is rotated 20° from the orthogonal podium grid, causing the corners to cantilever out beyond the lower building spaces.

Between the podium and the upper structure, an outdoor terrace level connects to the ground level below and the meeting level above via exterior stairways. This terrace level also cantilevers above the two main glass entrances in the southwest and southeast corners of the podium. An interior/exterior concrete elevator tower serves all floors and creates part of the architectural expression.

The podium and elevated structures are clad on all sides with a combination of embossed and perforated copper paneling. These perforations create a lantern effect on the south facade, causing the illuminated interior to shine through the perforations and silhouetting the exterior steel structure behind the copper panels. The perforations also create a view from the interior to the surrounding skyline.

Engineering Considerations and Project Goals

Two key goals had to be met to make this project a success:

- Meet the owner's budget challenges while providing the architect's unique design, without sacrificing building performance or functionality.
- Provide the building to the owner in time for the required opening date.

Early in the design phase of the project, the building construction cost estimates exceeded the owner's construction budget of $85 million by 25%. The design team needed to eliminate cost from the building without impacting the function of the various building spaces and uses. During this phase, engineers worked to economize several key areas of the structure.

Additionally, the owner wanted to begin preselling the space up to two years prior to the building opening date. This required a commitment from the entire design and construction team to meet the aggressive opening date long before construction documents were issued.

The structural engineer worked with the owner and design team to create a strategy for achieving both of these goals, while also improving the building's performance.

Solution 1: Long-Span Elevated Floor Structure

The stacked-and-rotated design meant that multiple floors, plus the roof, would have to be supported above the column-free exhibit space on the first floor. In order to achieve this, Datum-Gojer proposed a system of long-span trusses on a 30-ft module. The trusses span the 190-ft direction of the exhibit floor.

The initial pricing was based on conventional truss shapes of various depths, up to 20 ft. It quickly became apparent that this concept would require more steel and possibly not achieve adequate deflection and vibration performance. It would also require A993 Grade 65 high-strength steel, which would need to be imported. Given the lead time for the high-strength steel and the cost associated with the extra tonnage, these conventional structural systems negatively impacted both the budget and the construction schedule. In order to make the supporting structure deeper, the building would have to grow taller vertically, which would create additional cost in copper skin and mechanical systems for heating and cooling the larger volumes.

The engineer began exploring structural steel options that would both eliminate the need for imported steel and reduce the tonnage. The first proposal was to use a set of segmented catenary trusses. Rather than being limited to the space below the meeting level and above the 35-ft exhibit headroom, this proposal would extend the structural system to the ballroom level, creating a structural system that would be 35 ft deep rather than 20 ft deep. The added depth also would improve vibration and deflection performance. The primary disadvantage of this system was the disruption that the catenary chord would cause to the meeting room floor spaces, which the architect would need to work around.

The second proposal was to use arch trusses that would extend to the underside of the ballroom level, similar to the catenaries. This system had similar advantages to the catenary—similar steel tonnage required, improved deflection performance over conventional truss systems, and all domestically-produced steel. The main disadvantage was also the same—the overhead arch chord would disrupt floor space on the meeting level.

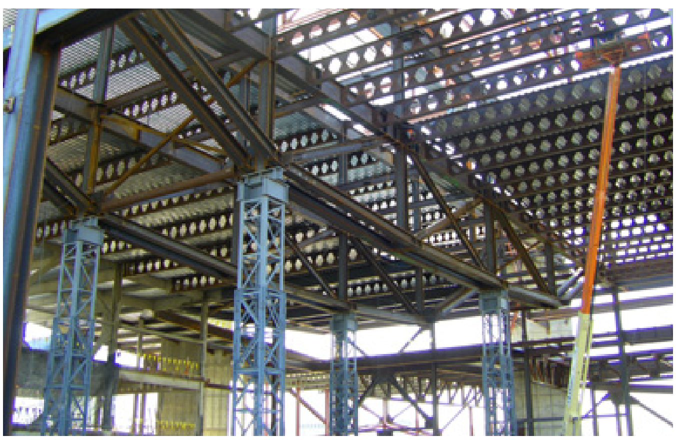
The solution was to use a combination of these two truss options. The majority of the floor is supported by three catenary trusses, spaced at 30 ft to 60 ft on center, along with one arch truss at one end. The catenary truss chords are located between meeting rooms and in back-of-house spaces and away from useful floor space. This approach coordinated the structural and architectural requirements to reduce the disadvantage of the deeper catenary trusses. On the west end of the floor, the catenary would have extended outside the building; therefore, the arch was used on this end. This combined solution eliminated approximately $3 million from the construction budget and allowed the use of all domestically available structural steel, while also improving deflection and vibration performance. In order to reduce sway due to unbalanced live loading conditions, additional diagonal bracing was provided within the truss, below the meeting room level and in the exposed exhibit ceiling space.

Solution 2: Long-Span Roof Structure

The second challenge was to reduce the required tonnage on the four perimeter trusses clad in copper and supporting the high roof.

This deep catenary-like truss is one of three spanning the 190-ft direction of the new Irving Convention Center's exhibit floor.

Three catenary trusses support the majority of the floors above the exhibit hall, with an arch truss at the end of the building where the catenary would have extended outside the building.



The rotated grid at the upper structure caused the four corners of the building to cantilever beyond their supports. The layout of the occupied spaces also greatly reduced the number of support locations that extend to the ground without interrupting the various occupancies within the building. Finally, three of the four corners are upturned and all four corners cantilever, and the architectural look prevented the use of supports at the corners.

After studying column opportunities on each floor, four column locations were identified that would make the box stable. However, the southeast face of the elevated structure remained unsupported, spanning almost 300 ft. To reduce this span and improve deflection performance, a fifth support was needed. Datum-Gojer decided to make use of the architecturally exposed concrete elevator core. Using a truss to cantilever from an interior column, over the concrete elevator core, and out to the southeast face of the elevated structure reduced the span of the southeast truss to 190 ft.

Given the exposed nature of the exterior trusses from the interior and through the perforated copper cladding from the exterior, the architect was greatly interested in the exterior appearance of the trusses. The truss web members needed to be coordinated with the regularly-spaced copper panel joints as well as the randomly located column supports. Over several weeks involving both architectural and structural input, a truss layout was devised that met both the structural and the architectural requirements.

Because each of the four corners cantilever, the bottom chord is in compression and requires midspan support. However, the four perimeter trusses extend below the ballroom level but not to the meeting room level, with the steel below that cantilevering beyond the structural bottom chord. The bottom chord of the truss is pulled away from the fourth floor structure, so struts were used to brace the compression segments of the bottom chord back to the structure.

These trusses vary in overall depth from 20 ft to 62 ft, with a maximum structural depth of 42 ft. The upper box is 282 ft by 296 ft, and the longest cantilever is 117 ft. By working directly with the architect, Datum-Gojer was able to reduce the structural cost by more than $600,000 while keeping the building's exterior appearance intact.

Solution 3: Terrace and Main Entries

Early architectural renderings of the two main entries showed the entry glass spanning from the ground floor to the soffit of the terrace level without additional structural backup. While the most economical way to frame this would have been to introduce structural columns behind the glass to create a conventional beam-and-column floor system, the added elements would have greatly disrupted the architectural appearance. To avoid the additional columns, the engineer proposed to cantilever the floor structure at these two corners.

Because the longest cantilever is approximately 153 ft, the bottom chord of the truss would see a significant compression force. The bottom chord of the trusses also creates the soffit of the entry and braces the copper cladding and entry glass under wind loading. Therefore, a horizontal bracing truss was provided in the soffit behind the main bottom chord to reduce the unbraced length of the main truss cantilever bottom chord and to take the imposed wind forces. A 3 in. deflection joint was provided at the head of the curtain wall to isolate the glazing system from the long cantilever support structure above. This system allowed the architect to economically maintain the desired appearance at the primary front door to the building.

Solution 4: Long Spans and Vibration Control

The long-span floor support conditions created a need for serious study of vibration. The engineer, along with the contractor and steel fabricator, reviewed and considered several structural floor-framing systems: normal weight versus lightweight concrete floors, purlins spaced at 7ft 6 in., 10 ft, and 15 ft, and conventional wide-flange versus castellated beams. The vibration performance for the meeting room and ballroom occupancy and building uses also needed to be weighed against the costs associated with providing a stiffer structural system.

The engineer proposed using castellated beams at 15 ft spacing with a lightweight concrete slab. This system provides improved vibration performance for the same structural cost as a similar wide-flange system. The lightweight concrete slab could be thinner than a normal weight slab and still achieve the required two-hour fire separation. This change alone resulted in significant savings to the overall project because the heavier, normal weight floors would have required more steel tonnage and larger, deeper piers. Additionally, the increased purlin spacing reduced the number of steel pieces, decreasing fabrication and erection time while improving vibration performance.

▲ The concrete elevator core provides a fifth support point on the south side of the structure, reducing the required truss span from 300 ft to just 190 ft.

▲ Cantilevering the floor structure over the two main entries allowed the area to remain column-free.

➤ Many of the convention center's steel connections, particularly in the perimeter trusses, are very complicated.

Solution 5: The Fast Track Process

At the end of the design development process, the design team met with the owner, contractor, and steel fabricator to discuss the budget and the remaining schedule. The contractor stated that to meet the owner's required opening date, the building would need to be issued for construction in just seven weeks. Given the level of completion of the design at that time, along with the complexity of the building, everyone agreed that was an impossible task.

While brainstorming ways to meet the owner's schedule, the engineer noted that certain elements of the project were time-critical. In particular, the concrete and foundation elements required only a minimal amount of time from design to construction, while structural steel procurement, fabrication, and delivery would require far more lead time. Additionally, not all of the steel would be required on the first day of construction as steel erection was scheduled to take several months. The length of time between the first steel order and the last steel delivery allowed the steel to be issued in multiple packages.

The design and construction team agreed to issue a minimum of 60% of the steel tonnage for mill order within the contractor's seven-week window. Engineers worked with the steel fabricator to determine the longest lead items for fabrication, while also working to complete and provide steel based on the sequence of erection and the erection timeline provided by the steel erector. Through this process, the engineer was able to issue 90% of the steel tonnage in the first mill order package.

The mill schedules indicated that certain shapes would be closing well ahead of the seven-week window. In particular, column sections in the W14×90 through W14×132 group would close at the end of four weeks. The following week, W36×231 through W36×441 would close. These two early mill closings meant that design of columns and floor trusses would need to be completed after only four and five weeks, respectively.

Subsequent to the mill order package, the design team issued several other advanced bid, permit, and construction packages, including foundations, concrete, and miscellaneous metals. The engineer also issued weekly detailing packages, one sequence per week, for the mill-ordered steel until the final "Issued For Construction" package was sent. This process allowed the steel fabricator to begin issuing shop drawings well ahead of the for-construction drawings. Approximately 15% of the steel on the project was reviewed, approved, and in fabrication prior to the final construction package.

Conclusion

The project is currently under construction and on schedule to be completed in January 2011. The solutions provided by Datum-Gojer were instrumental in maintaining the construction schedule. In addition, the construction cost was significantly reduced from the original construction cost estimates. The building is now well within budget, and the structural solutions played a key role in achieving the necessary savings in addition to contributing to the owner's desire for an identifiable landmark facility. MSC

Owner's Representative
Beck Group, Dallas, Texas

Architect
RMJM (formerly Hillier), Princeton, New Jersey

Structural Engineer
Datum Gojer Engineers, LLC, Dallas, Texas (Datum Engineers and Charles Gojer & Associates)

Steel Fabricators
North Texas Steel, Fort Worth, Texas (AISC Member)
W&W Steel, Oklahoma City, Oklahoma (AISC Member)

Steel Erector
Bosworth Steel Erectors, Inc., Dallas, Texas (AISC, IMPACT and SEAA Member)

Greg Diana, P.E., is a structural engineer in the Dallas office of Datum Engineers. He joined the firm in 1999 and currently serves as project manager. His project experience includes convention centers, healthcare, churches, and higher education facilities. Greg holds a bachelor's degree in civil engineering from the University of Texas at Austin.

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By Bob Kuykendall, AIA

Practice Matters | Management Lessons Learned at the Irving Convention Center

The dramatic new copper-clad Irving Convention Center, arising at the intersection of 114 and Northwest Highway in the Las Colinas Urban Center, demonstrates how a creative complex structure adds value to the client.

Certainly, its trapezoidal, twisted Rubik's Cube shape is eye-catching and memorable as it becomes a new iconic symbol for Irving; but how does a megastructure facility add value? And how can one justify the budget premiums associated with such a long-span structure with its stacked components and 120-foot double cantilevers?

The design team convinced the client that such a daring design absolutely made sense. By stacking the main components (exhibit hall, conference center, and ballrooms) vertically, they reduced the site acreage, with parking, to only 16 acres. This freed up the city's 40-acre site for additional future development.

Providing column-free, 190-foot spans over the exhibit hall increases user flexibility as well, so that indoor athletic events and large-scale gatherings can be held. The mega-trusses spanning the exhibit hall at the ground floor carry the substantial loading from the conference center and ballrooms above.

So, as an architect, what lessons can you learn from the development of a megastructure like this? Here are some of the things we gained from the process:

Plan Collaboratively: Datum Engineers, Beck, RMJM/Hillier, Austin Commercial, North Texas Steel, and Bosworth Erectors holed up in a conference room for the entire month of August in 2008 to plan how this building could best be designed and made more efficient. Ideas by the fabricator and erector also influenced the final design.

Schedule on the Fast-Track: To meet a rolling date for major shapes, the mill order was developed using design-development drawings. This put the cart before the horse, as the structural drawings had to be advanced ahead of the architectural floor plans. This was risky, but thanks to the cooperative efforts of the team, it will allow the owner to achieve earlier completion, just in time for next year's Super Bowl festivities.

Plan for Challenges: Using a double cantilever spanning the entryway caused special considerations. The glazing on the floor above could not be started until the decking was poured out to allow for the dead-load deflection from the weight of the concrete. That's not unusual, but with an L/360 projected live load, the head- and sill-curtainwall conditions had to be modified to allow for up to two inches of potential movement. Standard glazing details could not be used. ■

Bob Kuykendall, AIA, is a senior development officer with The Beck Group.

Convention Centers / Civic Centers

Kay Bailey Hutchison Convention Center Improvement Program
Dallas, Texas
Design Architect: HKS
Improvements and upgrades to the existing facility including expanded meeting room and assembly space, 5000 sq.ft. addition for a new kitchen and storage space, renovating the existing spaces, mechanical and electrical systems renovations and operational improvements. Services also include a Facility Assessment Survey and a Photovoltaic Feasibility Study.
$55 Million
2012

Irving Convention Center
Irving, Texas
Design Architect: RMJM Hillier
LEED Silver
Longspan and cantilever steel structure.
The lower box, or podium, contains the main exhibit hall, along with office and mechanical space. The exhibit space is approximately 190 feet by 270 feet, column-free, with 35 feet of clear headroom above the exhibit floor. The upper box is rotated 20 degrees, and contains a large ballroom. The clear span of the exhibit space is created by four 35'-deep catenary or arched trusses that reside in the two-story office and mechanical space between the exhibit space and ballroom. The 300' x 300' upper box was only able to be supported by 5 column locations and is framed with four perimeter trusses that span up to 300' and cantilever up to 120' to the corners.
$133 Million
275,000 Sq. Ft.
2011

Dallas Theater Center
Additions and Renovations
Dallas, Texas
Design Architect: Booziotis & Company
2009

Austin City Hall
Austin, Texas
Design Architect: Antoine Predock
LEED Gold
2005

Kay Bailey Hutchison Convention Center Expansion & Renovation
Dallas, Texas
Design Architect: SOM Chicago
Architect of Record: HKS
$110M, 203,000 sq. ft. hall addition
World's largest column-free exhibit space with two 400' clear span double arches.
2002

Kay Bailey Hutchison Convention Center Phase 2 Expansion
Dallas, Texas
$34M, 400,000 Sq. Ft. Datum designed a box truss and bar joist roof with spans of 90 feet and 120 feet for comparison versus a 300-foot clear span space truss structure. This design was compared to the original long-span space truss and a savings of over $1,500,000.00 or over 4% of the total budget was realized and accepted by the Owner
Design Architect: LMN
Architect of Record: HLM Design
1999

Kay Bailey Hutchison Convention Center Expansion/Vertiport
Dallas, Texas
The elevated vertiport was to have a 360-foot runway that would accommodate VTOL aircraft weighing 46,300 pounds. The challenge to create an efficient roof system for the exhibit halls was met by designing bracing trusses at a 30-foot spacing to stabilize the major roof trusses, for both gravity and wind uplift loading. These bracing trusses also support the roof joists, which are located at panel points to eliminate local bending in the truss chords.
Design Architect: HLM Design
1994

Kay Bailey Hutchison Convention Center Expansion
Dallas, Texas
Design Architect: Omniplan
3 Stories; 240,000 Sq. Ft.
1983

Plano Civic Center
Plano, Texas
Design Architect: HOK
1990

Convention Centers / Civic Centers

Lewisville Municipal Center
Lewisville, Texas
Design Architect: Dale Selzer Associates
1988

Fair Park Music Hall
Dallas, Texas
Design Architect: HLM Design

Carrollton City Hall
Carrollton, Texas
Design Architect: Oglesby Greene
1987

The Eisemann Center
Richardson, Texas
Design Architect: RTKL
2001

Irving Performing Arts Center
Irving, Texas
Design Architect: SmithGroup
1988

Patty Granville Arts Center
Garland, Texas
Design Architect: Clutts & Parker
1982

Zachary Scott Theatre
Austin, Texas
Design Architect: Steven Holl

Majestic Theater Modifications
Dallas, Texas
Design Architect: Oglesby Greene

The Art of
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6516 Forest Park Road   Dallas, Texas 75235   214.358.0174
8140 N Mopac Expressway, Building One, Suite 120   Austin, Texas 78759   512.469.9490
311 Sixth Street   San Antonio, Texas 78215   210.858.2880

datumengineers.com