UNITED STEEL DECK, INC.  
DECK DESIGN DATA SHEET  
No. 19

DEEP DECK – 6" and 7.5" H

32' Maximum piece length.

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SINGLE SPAN TOTAL LOADS, PSF

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Notes: Loads controlled by 3" end bearing are underlined. Loads controlled by deflection (L/240) are shown in italics. All other loads are controlled by bending. 10 psf has been added to deflection loads to account for roofing dead load. The designer is urged to check the fastener uplift resistance.

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The breathtaking Galleria at BCE Place in Toronto is an example of public art at its best. The city required the developers to spend 1% of their construction budget on public art and the developer opted to add those funds to the cost of a needed atrium and create an incredibly beautiful space. Photo courtesy of Robert Burley/Design Archive

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Structure As Sculpture

After attending a ball game at the Skydome in Toronto last week, I took a quick walk over to BCE Place. As I've previously mentioned, during the past few years I've become a bit of a steel "groupie" and it's not unusual for me to stop and gawk at just about any bit of exposed structure. But this time, I wasn't alone. As I stood at one end, I watched a procession of people walking through the Galleria with their necks bent back to provide a better view of the towering space. And it dawned on me that the designers of the Galleria and Heritage Square had successfully transcended from architecture to pure art. The steel frame had gone from structure to sculpture. (To get an idea of what these people were looking at, check out this month's cover and then turn to page 22).

The Holocaust Memorial and Museum in Washington, DC (page 14) also echoes the theme of structure as sculpture, though in this case the architect was not attempting to create beauty. Rather than creating an uplifting place, the museum's architect used such techniques as skewing the frame to create a feeling of unease befitting its exhibits. The third story in this issue (page 30) provides an interesting juxtaposition to the Holocaust Museum. While the Museum's structure creates a feeling of darkness, the brightly painted steel at the Universal CityWalk Complex is designed to create a feeling of joyous freedom.

Before leaving BCE Place, I stopped and chatted with John Zanutel, one of the center's security guards. He mentioned that the Galleria is actually becoming a bit of a tourist attraction, with many European visitors actually adding it to their agenda.

In our hurried world, it's quite rare to see people stopping to look at a structure. Usually, when people look at a building, their eyes are attracted either to its sheer size or to some ornamental feature. Bridges sometimes reach a level of structural beauty that seizes the human eye, but completed buildings rarely do. And that's a shame.

I suppose it's a question of economics. Creating a beautiful structure typically adds to the cost of the project. Some speculative developers can justify that cost by using a building's beauty to help attract tenants. Others, such as BCE Place, are forced by municipalities to create public art. And corporate entities often desire showcases.

But there can be another payback, too. As I watched people gazing admiringly at the arched roof of the Galleria and the complex majesty of Heritage Square I noticed a common expression—happiness. SM
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The following responses to questions from previous Steel Interchange columns have been received:

**What fatigue category is a full penetration weld between a tube column and a base plate?**

Although a particular weld detail is not exactly covered in the latest AISC and AASHTO specifications at my disposal, I would feel safe to utilize and classify it as fatigue Category C or D, depending on the conditions summarized below. For high fatigue (versus static) stresses, I would specify geometrical weld details and fabrication procedures that assure Category C performance. For lower fatigue-vs-static stresses, I would specify conditions that assure Category D performance. For both choices, all geometrical weld details and welding procedures must clearly be specified by the designer and carefully be followed by the fabricator.

First, to obtain a full penetration butt (or groove) weld, a continuous backup bar (say 1" by 1/4") that tightly fits to the inside of the chosen column tube needs to be formed and tack welded to the base plate. The tack welds should be placed on the outside of the backup bar so that they will later on be embedded in the butt weld. For some selected column tubes, a 1-inch-long section of the next smaller standard tube size may be used if it fits tightly to the inside of the selected tube column.

Second, all sides of the lower column tube end must be beveled (30°), including the four corners, before the tube is slipped over the backup bar. After the AWS-required gap between the bottom edge of the column tube and the top of the base plate is assured, the weld material for the butt weld and the fillet can be put in place.

Third, a concave fillet must be specified to obtain a smooth transition to the base plate. A convex fillet would increase the stress concentration factor associated with this type of weld. If inspection after welding finds severe undercuts and/or overlays, touch-up welding and/or grinding may be required to provide a smooth contour for the transition between the outer face of the tube and the base plate.

Fourth, a non-destructive inspection of the butt/fillet weld must be conducted. The most economical procedure for this structural detail would be ultrasonic inspection. X-ray inspection is considered meaningless, especially for the corner regions of the column.

In my opinion, the above conditions would qualify the connection to fall under fatigue Category C. Currently, full penetration butt welds for plates and shapes covered in the AISC and AASHTO specifications fall under fatigue Category C when the weld reinforcement (weld excess) of the full-penetration butt weld is left in place. However, the weld excess for such welds is expected to cause a smaller stress concentration factor than a butt weld with a concave fillet, and definitely with a convex fillet. Therefore, a concave fillet must be used and carefully contoured. These conditions are considered necessary for safety reasons even though they may be costly.

But what if the fatigue stresses in the subject connection are relatively low by comparison with the static stresses? In that case it would seem more cost efficient to designate the joint as fatigue Category D. This would allow elimination of costly grinding and non-destructive testing.

**Karl H. Klippstein, P.E.**

Structural Engineering Consultant

Pittsburgh, PA

**Comments on weld considerations discussed in the April 1993 Steel Interchange:**

After reviewing the weld detail in the April 1993 issue, I have two comments.

The first has to do with the way that the welds are called out in the weld detail. It appears to me that the all around call out is incorrect, especially if weld "d" is then called out separately. Weld symbols are the link between design and fabrication and if the weld call out is incorrect, how can the designer expect the fabrication to be correct. Weld symbols don’t get...
Steel Interchange

enough respect. I see plans where the engineer calls out welds incorrectly on the structural plans and then approves fabrication plans with different but equally incorrect weld symbols. I think that more care should be taken in calling out welds. Both the AISC and AWS codes are pretty specific in describing the proper way to show weld symbols.

My second comment concerns question B: If weld "d" is used to develop the strength of the connection, are there restrictions or parameters that must be placed on the weld (i.e., placement, size, etc.)? The AWS does place restrictions on fillet welds on opposite sides of a plate and states that the weld should not be continuous to both sides of the plate. It appears to me that if weld "d" is used it should stop short of the edges of the member so that the weld is not continuous to both sides of the element.

Matthew Beck, P.E.
Wardsboro, VT

The figure accompanying the Steel Interchange discussion on weld considerations (reprinted here) contains one of the most common Code (AWS D1.1-92) violations we find on structural drawings. First, the welding symbol pointing to the hidden side of the joint is redundant with the welding symbol shown to be all-around. More importantly, however, is the fact that the all-around supplementary symbol would require a Code violation of the requirement stated in paragraph 8.8.5. Specifically, such a weld symbol would require an uninterrupted deposit of weld on the opposite sides of a common plane of contact between two parts, which is prohibited. While welds (a), (b), and (c) may be continuous with each other, the code requires that the weld must be interrupted at the corners common to (a) and (d) and to (b) and (d). This is due to the deleterious effects of the resulting weld profile on the weldment.

In regard to the strength of a welded angle-to-gusset plate connection, since there is no provision in the Code which would disallow the use of weld (d), it may be used. However, there are several other Code provisions which should be considered.

While welds (a) and (b) would appear to provide the optimum efficiency in transferring reactions between the elements, weld (c), or plug welds, may be necessary to avoid the potential shear lag effects of using only welds (a) and (b). This consideration is the rationale behind the provision of paragraph 8.8.1 of the Code. Although this paragraph refers specifically to flat bars, it would be prudent to satisfy those provisions for angle shapes as well.

A Code requirement which can easily be misapplied in this situation is paragraph 8.8.6.1. While this paragraph may appear to require returns at the (c) end of welds (a) and (b), paragraph C8.9 of the commentary explains this is not the case.

Richard W. Mudd, P.E., C.W.I.
Standard Testing
Oklahoma City, OK

New Questions

Listed below questions that we would like the readers to answer or discuss.

If you have an answer or suggestion please send it to the Steel Interchange Editor, Modern Steel Construction, One East Wacker Dr., Suite 3100, Chicago, IL 60601-2001.

Questions and responses will be printed in future editions of Steel Interchange. Also, if you have a question or problem that readers might help solve, send these to the Steel Interchange Editor.

Some Building Codes permit a reduction in NDT for welders with less than a 5% rejection rate. How big a sample is used to get the 5%?

Bill Schindler
Herrick Corp.
Pleasanton, CA
The National Symposium on Steel Bridge Construction

November 11-12, 1993
Atlanta Airport Hilton, Atlanta, Georgia

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- Painting Strategies for Maximum Economy and Useful Life
- Weathering Steel - Success Stories Worth Hearing
- Cost Effective Design and Details
- Seismic Design
- Bridge Research Leading the Way to the Future
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ST EEL CALENDAR

After a short summer vacation, the AISC Lecture Series is scheduled to resume next month. The seminars have been an overwhelming success so far, often attracting more than 100 participants and very positive reactions.

"I was surprised that so many people wanted to here about such advanced subjects, but the response has been very positive," according to Charles Carter, an AISC Staff Engineer.

The seminars present information on eccentrically braced frames, partially restrained connections, low-rise buildings, and connection design. Registration is only $60 ($45 for AISC members). Included as part of the registration fee is a meal and more than a dozen handouts and publications, including: AISC Design Guide 5: Low & Medium Rise Buildings (a $16 value); ASD Simple Shear Connections (a $16 value); LRFD Simple Shear Connections (a $16 value); Seismic Provisions for Structural Steel (a $5 value). And pre-registrants also receive the other five AISC design guides (an $80 value).

The seminars are scheduled for:

- Birmingham, AL .......... 9/9
- Miami ...................... 9/14
- Orlando ................... 9/16
- Rochester, NY ........... 9/22
- Albany, NY .............. 9/23
- Atlanta .................... 9/28
- Richmond, VA ......... 9/30
- Cleveland ............... 10/19
- Columbus, OH .......... 10/20
- Cincinnati ............ 10/21
- El Paso .................. 11/16
- Oklahoma City .......... 11/18

For more information, contact: American Institute of Steel Construction, Inc., One East Wacker Dr., Suite 3100, Chicago, IL 60601-2001; (312) 670-5400; fax: 312/670-5403.

National Symposium on Steel Bridge Construction (November 11-12 in Atlanta). Symposium topics include: state plans for implementing metric; painting strategies for maximizing economy & useful life; weathering steel; cost effective design & details; and seismic design. The symposium also includes an international panel on innovative designs. For information, contact: AISC, One East Wacker Dr., Suite 3100, Chicago, IL 60601-2001; (312) 670-5407; fax 312/670-5403.

Amoco Building Recladding—Lessons Learned (November 11 in Chicago). All-day seminar discussing entire renovation project from design to the final recladding. Sponsored by Chicago Committee on High-Rise Buildings. For more information, contact: Ian Chin (312) 372-0555; fax: 312/372-0873.
The 3,950 foot Paris Landing Bridge in Tennessee includes the first application of new USS COR-TEN B-QT Steel (ASTM A-852), quenched and tempered to provide 70 ksi (480 MPa) minimum yield strength. It was developed by U.S. Steel to close the gap between the 100 ksi, and 50 ksi yield strength steels used in bridge construction. The new structure is a multiple span plate girder bridge, replacing an existing steel truss design.

COR-TEN B-QT was selected for the flanges of the main beams in areas of high stress. The increased yield strength of COR-TEN B-QT achieves the required strength, allows a constant web design, and avoids the expense of haunch girders. COR-TEN B-QT is weldable utilizing shop and field methods similar to those required by 50 ksi COR-TEN B Steel (ASTM A-588, Grade A). COR-TEN B-QT is a weathering steel with greater atmospheric corrosion resistance than carbon steel. By following the FHWA guidelines for the use of uncoated weathering steel, it virtually eliminates the need for painting with possible significant cost savings.

U.S. Steel has led the industry with structural steel innovations like COR-TEN B-QT. You will be seeing more from U.S. Steel to confirm steel's cost and functional advantages in bridge construction.
The Holocaust Memorial Museum reflects the industrial style of architecture common in 1930s Europe—but with a twist. For example, the bridges stretching over the skylit roofs recall those over the Warsaw ghetto. Also, the skylights' steel frames are skewed to present a "twisted" image. Photo at right by Jou Min Lin, Pei Cobb Freed & Partners; photo far right courtesy of Pei Cobb Freed & Partners.

In April, the nation's newest monument was unveiled in Washington, DC. The U.S. Holocaust Memorial Museum has the difficult mission of educating visitors about the enslavement and extermination of millions of lives in Europe before and during the Second World War.

To fulfill that mission, architect James Ingo Freed of Pei Cobb Freed & Partners, New York City, designed a structure that, rather than standing simply as a container for exhibits, would be part of the exhibition itself. The building uses materials lifted from industrial architecture of 1930s Europe—the same architecture used in the concentration camps. But Freed goes a step further and evokes symbolism from structural elements. For ex-

Monument To Horror
The new Holocaust Memorial Museum is designed to be visually disruptive

By Leo Argiris, P.E.
ample, bridges recall those over the Warsaw ghetto, and towers echo those that guarded concentration camps. In addition, architecturally exposed steel, reminiscent of 1930s construction, appears throughout the building.

The 245,000-sq.-ft. Museum is organized around the Hall of Witness, a long, three-story-high space topped with a skewed skylight and four bridges. Two rows of five-story towers—four on each side—line two sides of the hall. Adjacent and connected to this building stands the Hall of Remembrance, a 60'-high, 6,000-sq.-ft., six-sided structure. While much of the structure is constructed of concrete, large areas of structural steel were employed to satisfy architectural requirements.

**1930s Industrial Architecture**

The Museum posed challenges unlike any faced before by the project structural engineer, Weiskopf & Pickworth, New York City.

Chief among these was the need to make the structural steel visually recall 50-year-old techniques while still satisfying modern structural codes. Specifically, the architect required the appearance of built-up riveted plates and angles, often including turnbuckles and clevises.

To recall plate and angle construction, three basic structural elements were used. Two of these elements consist of a steel plate and four equal leg angles, with one element in the form of a cruciform and the other in the form of a wide flange section with two angles forming the top and bottom flanges. The third element uses rods tied with turnbuckles and clevises to the web plates of the cruciform and I shapes.

The structural engineer first explored the possibility of actually riveting pieces of steel together. This method, long abandoned in the U.S., might have been possible if it was needed on only a small scale. At the Museum, however, 487 tons of steel were required—eliminating riveting as a viable option.

Instead, we decided—in collaboration with the architects—that members would be bolted together at an 8" spacing to closely resemble riveting. We also used groove welds, ground smooth, in key loca-
tions to ensure the continuity of the members while still providing a smooth look.

Precise detailing and fabrication of the steel members and connections were of paramount importance. The architect developed full-scale models of the connections and actually sent photographs of these models, rather than drawings, to W&P during the development of our structural details.

To ensure that the design intent was carried out and erection schedules were met, the architect, structural engineer and steel fabricator—AISC-member The Rome Iron Group—labored together through each connection. Rome Iron produced full-scale mock-ups of the key connections to perfect the fabrication process before assembling the actual members.

**Hall Of Witness Skylight**

The Museum’s centerpiece is the 7,500-sq.-ft. Hall of Witness topped by a 152'-long by 48'-wide skylight. The skylight makes its statement not only through the replication of exposed steel plates and angles, but also through its skewed or twisted glass surface. A peaked hat, or “monitor” cuts diagonally across the length of the skylight.

While developing schemes for...
the structural framing of the skylight with its monitor shape, we experimented with a number of structural forms including folded beams, tied arches and steel trusses. Architecturally, the truss scheme worked the best.

To minimize the thermal contractions and expansions in the long dimension of the skylight, we divided the skylight into four independent modules. Each module is flanked by two trusses spaced 32' apart spanning the width of the 48'-wide atrium. Within the 8' spacing between modules, thermal movements are accommodated for a 32' segment rather than the full 152' length.

To frame the monitor, two diagonal trusses connect the end trusses of each module while rafters and purlins complete the framing. The "skew" is created as the monitor truss cuts across the skylight. Remaining at the same elevation, the monitor starts in one corner at one end of the room and arrives in the opposite corner at the opposite side of the room. As its location between the hall's side walls changes, the monitor meets the top chord of the 48' truss in a different place at each truss. Therefore, each top chord of the truss takes on a different angle as it reaches up to
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Each module required a three-dimensional analysis to determine the distribution of forces between the various truss members. At the same time, each rafter and truss segment required an individual evaluation to determine the precise geometry of the elements for fabrication.

In keeping with the vocabulary of the exposed structural steel, we designed the top and bottom chords of the trusses as I-shaped members built from \( \frac{3}{4} '' \) plates with equal leg angles. The vertical members of the trusses are cruciform-shaped plates and angles, while the diagonals are tie rods. The main skylight trusses called for chords and verticals to be assembled with \( \frac{1}{2} '' \) web plates. Instead of making individual members, Rome Iron eliminated a substantial amount of welding by starting with a \( 50' \times 10' \times \frac{1}{2} '' \) plate and cut the outline of the entire truss in one piece. This minimized many of the defects and distortions likely with a welded assembly. Angles were then bolted onto this plate to form the I- and cruciform-shaped members.

Footbridges

Four glass and exposed steel pedestrian bridges span the Hall of
Shown at left is a night view of the Holocaust Memorial Museum. At right is an image of the Hall of Witness skylight showing the skewed steel designed to create the illusion of twisted, damaged metal. Photos by Jou Min Lin, Pei Cobb Freed & Partners. Shown above is another view of the skewed skylight (photo courtesy of Pei Cobb Freed & Partners).

Witness at the Museum’s fifth floor. A fifth bi-level bridge spans between the towers at the third and fourth floors. Designed to evoke the ambiguity of near transparency, the bridges feature a walking surface of glass block laid between steel tee sections. People will “walk on air” while visitors in the Hall of Witness below will see shadowy, ghost-like images overhead. Transparent window walls located within the exterior steel construction form the sides and provide a view of the skylight below. Only the roof is constructed of cast-in-place concrete.

We designed the bridges as two 32”-deep box girders at the roof level, which support all of the gravity load of each bridge. In addition to supporting the cast-in-place roof and the bridge below, the girders double as a staging platform for window cleaning for the Hall of Witness skylight below.

The box girders, composed of 1/2” vertical steel plates and 3/4” horizontal plates provide the lateral and torsional stiffness to serve both functions effectively. A row of hangers, spaced 5'-4" on center and shop assembled in a cruciform shape, support the vertical loads. To provide the lateral wind bracing of the deck, a secondary system of...
Typical Rafter to Monitor Connection

For location of tie rod centerlines, see truss elevations, Dwg. 5-5-01

- 1/2" A444 tie rod typ
- #8 clevis
- 1½" a490 bolt, finger tightened & deform threads
- ½" clevis connection R, provide full penetration welds to connecting web fl typ

Hall of Remembrance

After visitors to the Memorial Museum complete the exhibition, they enter the Hall of Remembrance, a six-sided, 60'-tall, 6,000-sq.-ft. room. While the Hall of Witness and exhibit spaces are dark and confining, the Hall of Remembrance is open and light-filled. And just as the architecture is different, so too were the structural challenges.

We selected a structural steel frame for the Hall of Remembrance for a number of reasons. Since the floor of the Hall is the ceiling over a below-grade theater, steel allowed us to easily clearspan 72'. Using a steel frame also accommodated the Hall's sloped ceiling and offset columns. And finally, the steel frame eliminated the need for shoring concrete formwork in the 60'-tall space.

The steel frame consists of 12 columns around the perimeter of the Hall. To provide an offset in these columns at elevation 66', we introduced tension and compression rings to provide stability for sloped columns. A 70' clearspan roof is interrupted by a hexagonal skylight that rises at the center of the Hall to a peak. Once again, we used a tension ring at the base and a compression ring at three-quarter of the height of the skylight to stabilize diagonal rafter beams. Conventional rolled shapes were used in the skylight framing to minimize shadows.

Below the Hall of Remembrance, the steel columns from
Showed on the opposite page are close up views of the turnbuckle bridges and the exposed steel Hall of Witness skylight (photos courtesy of Pei Cobb Freed & Partners; drawings courtesy of Gustavo Amaris, Weiskopf & Pickworth). Shown above is a daytime view of the museum with Washington, DC, in the background (photo courtesy of Jou Min Lin, Pei Cobb Freed & Partners).

These columns above blend well with the architectural concrete forming the walls of the 414-seat Meyerhoff Theater. These columns were encased in architectural concrete prior to erection.

Structural steel also helped to provide state-of-the-art acoustics in the theater. An acoustical canopy composed of a grid of steel plates with infill glass panels was hung from the second floor framing.

The U.S. Holocaust Memorial Museum is open to the public and tickets are free. However, to ensure entrance at a specific date and time, visitors are encouraged to call TICKETMASTER at (800) 551-7328 to reserve tickets for a service charge of $3.50.

Leo Argiris, P.E., is an Associate of Weiskopf & Pickworth, a New York City-based structural engineering firm.
A Country Road
In Steel

Branching, sloped steel columns topped with a trellis-like space frame create an urban interpretation of an old country road.

If the breathtaking Galleria and Heritage Square project is any indication of the success possible when a city requires developers to create public art, then every U.S. municipality should quickly follow Toronto's example.

"In Toronto, 1% of a project's construction budget must be devoted to public art," explained Tonu Altosaar, a partner with Bregman + Hamann Architects in Toronto. "The question is, in a major project, where do you put public art?" In the case of BCE Place, a 5.4-acre, $1.2 billion mixed-use complex that includes more than 2.4 million sq. ft. of office space as well as 65,000 sq. ft. of retail, the designers opted to create a huge sculptural atrium.

A design competition was held, and the winner was Spanish architect Santiago Calatrava, who envisioned a network of steel arches and latticework. "The design is essentially sculpture," according to Altosaar. "The concept was to create a country road with maple trees on either side." Calatrava's interpretation features rows of "trees" that branch twice, once at 24' and the second time at 48'. The tree columns then support a trellis-like structure of arched trusses, with the top of the galleria rising 90'. When the sun shines through the glass roof, the resulting shadows are indeed reminiscent of a wooded path.

The atrium connects the various buildings that make up BCE Place, including the 57-story Canada Trust Tower and 47-story Bay-Wellington Tower. The complex also includes 12 additional buildings.

The steel columns and trusses at the Galleria in Toronto's BCE Place are designed to be symbolic of a country path surrounded by maple trees. Photos by Robert Burley/Design Archive.
The Galleria's columns consist of three pieces of plate welded into a cruciform shape, while the upper trusses are made up of tee shapes. The upper arch is a slice from a 40' radius circle and stretches from building to building.

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designated as having historical or architectural value under the Ontario Heritage Act. These include the only intact grouping of late 19th century commercial buildings to have survived the fire of 1904 and their facades have been meticulously restored. According to the project’s architects, the public areas were designed to consolidate an entire downtown block into a single complex while maintaining the integrity of each of its parts. The master plan was developed by Bregman + Hamann, who also served as architects, along with Skidmore, Owings and Merrill, on the project’s two large office towers. In addition, Bregman + Hamann worked on the historical restorations and the Garden Court.

The 350'-long Galleria utilizes traditional proportions and its 90' height is slightly more than twice its 42' width. At its east end, the Galleria terminates into the 100' x 350' BCE Place Galleria Cross Section

The Galleria is part of the huge BCE Place complex, which includes more than 2.4 million sq. ft. of office space and 65,000 sq. ft. of retail space.
Computers played a large role in the project, beginning with initial design drawings. Bregman + Hamann, using Calatrava's preliminary design, created a series of AutoCAD drawings to give the owner, Brookfield Development Corporation, a better feel for the project. And computers were crucial for the structural design of the project.

**Structural Design**

As might be expected, the project was incredibly complicated. "Without computers, it would be very, very difficult to design this structure," according to Alexander Czumaczenko, a partner with Yolles Partnership, Inc., a Toronto-based structural engineering firm. To handle the project's complexity, the designers relied extensively on an in-house 3D design and analysis program.

"The basic elements are trees, with one stem coming out of the ground, and then branching into two members, and then branching again," Czumaczenko said. "The architect wanted the tree cross-section to be a cruciform shape so we created it by fillet welding three steel plates together." The sizes of the 1½"-thick plates increased or decreased depending on stresses, with 16" x 16" plate at the bottom of the tree, 32" x 32" plate at the first branching, 12" x 12" at the second branching, and 8" x 8" above that. The top and bottom chords of the trusses are 8" x 8" tees, while the lacing members are 4" x 4" tees.

"The architect wanted the built-up cruciform shape, despite its added expense," Czumaczenko said. "In Spain, labor is cheap and materials are expensive; here it's just the opposite." Steel fabricator for the project was AISC-member Canron Construction Corporation—Eastern Division.

The tree columns are spaced every 45' and primarily support the trellis-like space frame above. In addition, however, the top chords of the space-frame trusses...
Separating the Galleria from Heritage Square is a large kinetic sculpture supported on a brick-clad steel beam. The large "windows", which pivot on a diagonal steel pipe, are framed with 6" x 6" hollow structural sections while steel tees are used for the horizontal elements. Photo by Robert Burley/Design Archive.

are tied into the surrounding buildings at one end. "The top chords are fixed at one end and free at the other to accommodate building movement," Czumaczenko said. Also, some of the columns have bracing elements attached to the surrounding buildings. "There's some minimal bracing where the trees first split. We could have increased the member size instead, but the architect said the bracing was acceptable."

Because of the variety of structures surrounding the Galleria—a 48-story office building, a six-story historical facade, a garden court, and a four-story building—four separate end conditions were required for the trusses. "We had to create four separate computer models to simulate the different restraint systems," Czumaczenko added. General contractor for the project was PCL Constructors Eastern Ltd.

Equally—or perhaps even more—complex is the framing system for Heritage Square. The 100' x 100' space is defined by 12 tree columns, each of which branch into two columns as they rise. The sloping perimeter columns are attached at their base to brick-clad risers...
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Three pieces of steel plate are welded together to form the cruciform shape (opposite page) that the architect desired for the tree columns. The fabricator was allowed to use fillet welds, which reduced the project's cost compared with having to grind the welds smooth. Photo by Robert Burley/Design Archive.

that contain mechanical ductwork. In addition, the space frame roof also is supported by four interior columns that rise in four directions. Rather than utilizing the cruciform shape of the columns in the Galleria, the columns in Heritage Square are square elements made up of four welded plates. Because the rain water leaders run through the columns, one plate was designed to be removable in case repairs to the leaders are necessary.

The space frame roof trusses consist of tees similar to those used in the Galleria. Snow loading was a critical issue. Because Heritage Square is surrounded by taller buildings, the Toronto Building Code required the engineers to account for a snow load of 120 psf. Instead, we had special snow load studies conducted to obtain realistic requirements," Czumaczenko said. "The actual loads were 40 psf, except for some small areas that required 80 psf."

All of the plates—in both the Galleria and Heritage Square—are fillet welded. "We showed the architect some samples and he allowed us to leave visible welds, rather than requiring the welds to be ground smooth," Czumaczenko said.

Another interesting part of the project was a kinetic glass wall that separates the Galleria from Heritage Square. The moveable wall is located above an arched passageway and its two sections pivot on an inclined axis. The pivot point is a long hollow steel pipe set diagonally in the wall opening. The perimeter frame for these "windows" consists of 6" x 6" square tube, with tee members being used for the horizontal elements. The webs are non-uniform, with the widest point occurring where the tube extends through the web.
An exposed steel frame met the architectural requirements while also providing the needed tenant flexibility for the new Universal CityWalk Complex.

By Tom Bouquet, P.E.

The new Universal CityWalk entertainment and retail complex adjacent to Universal Studios is one of the most ambitious and exciting new structures in Los Angeles today.

The complex, a four-acre microcosm of the city’s unique pop architecture conceptually designed by the Jerde Partnership for MCA Development, consists of eight separate structures surrounding a system of pedestrian walkways. In project vocabulary, CityWalk consists of three major areas: “WestWalk,” “Center Court,” and “EastWalk.”

The WestWalk portion creates a dramatic canyon of billboards, towers, awnings, hanging planters, fins, and other elements designed to give the complex a big-city feel reminiscent of the architecture of Hollywood in its heyday. It will house offices, specialty shops, a museum, restaurants and UCLA Extension classrooms, and sport an array of specialty lighting effects that will provide all the dazzle of Sunset Boulevard at night.
Center Court will form a ring of entertainment and dining venues, tied together by pedestrian bridges high above ground and covered by an exposed steel space frame.

And finally, EastWalk consists of three tiny buildings supporting exposed steel billboards rising 80' above the pedestrian walk.

The project's designers wanted the complex to look and feel as though it had been built and lived in over many years: on opening day, visitors will see pre-grown vines, specially aged facades, and variously dated architectural elements. The individual storefronts will appear to be crowded together at odd angles, bristling with signs, fins and architectural "afterthoughts." This unique and exciting design philosophy created numerous challenges for the project's executive architects, Daniel Mann, Johnson & Mendenhall (DMJM), which also provided architectural and engineering production services.

Structural Concept

CityWalk embodies the concept of the sculptured structural steel frame—a concept made possible by the revolution in computer-aided structural design and analysis techniques. The many unique applications of steel, including the large amounts of architecturally exposed structural steel, make the project a showcase for the possibilities that now exist using these techniques.

Almost every building is irregular in both the horizontal and vertical directions and has some discontinuity in the floor diaphragm; the plans were almost devoid of 90 de-
An Ordinary Moment Resisting Space Frame was used on this project for several reasons, including the high floor-to-floor heights and the many skewed connections and flying beams.

gree angles and were irregular to the extent that the engineers were forced to abandon a regular structural grid system in most areas. Yet all of the structural analyses of the CityWalk complex, from small vibration analyses to complex three-dimensional dynamic analyses, were performed on one PC at the Los Angeles office of DMJM. The primary lateral analysis program was SPACE-V from Digital Analysis Consultants.

The lateral force-resisting structural system is an Ordinary Moment Resisting Space Frame (OMRSF), which is anything but "ordinary" for this type of project in California. However, an OMRSF was selected for several reasons:

• To maintain desired frame stiffness for the expensive exterior wall assemblies;
• Because the many skewed connections and flying beam conditions made Ductile Special Moment Resisting Space Frame
(SMRSF) detailing impractical;
- Because the high floor-to-floor heights and narrow building widths actually made the wind loads higher than Ductile Frame seismic forces in several transverse direction cases.

The steel moment frame system also was designed to give the owner and tenants maximum flexibility to change or expand the project, by adding mezzanines, changing tenant lease lines, or expanding on the structure. Many such changes were made during construction as tenantization progressed. One area even required that a concrete-framed basement be extended by about 5,000 sq. ft. below a four-level steel frame building that had already been fabricated. "We decided to frame the basement extension in steel," said Martin Lichtenstein, project structural engineer. "It was the only way to keep that area on track with the rest of the project." New steel column stubs were welded below the existing base plates to transfer seismic moment to concrete pedestals, and the floor framing was designed to transfer shear forces to both new and existing basement walls. Erection was finished only 2½ months after the design conception. Steel fabricator on the project was AISC-member The Palm Iron & Bridge Works. General contractor was Ray Wilson Company of Pasadena.

Unique Features

One unusual feature of City-Walk is the two-way sloped roof, or "CityRoof," which is faceted over several structures to give the illusion of a giant dome over the project. The top steel elevation for each column had to be calculated based on an algorithm for the shape of the dome, and each framing member had its ends cut at a slightly different angle. Vertical and horizontal control were coordinated with site data by the project civil engineers, IWA Engineering. Roof beams were skewed to provide a flat surface for the metal deck, which was warped to fit the curve. The imaginary dome peaks at about 60' above grade; only spe-

Access to various levels within the Center Court is provided by pedestrian bridges located at various heights (above). One of the interesting features in this project is the creation of large, free-standing billboards (right).
cial signs, fins, and towers extend above it. At 1 1/2 times human scale, the structure below CityRoof is only three stories at most, with some single story areas rising more than 40' above grade. Mechanical wells were provided in the City-Roof to ensure that no equipment protruded above the “dome.”

The dome roof contributed significantly to the irregularity of the structural system, with each column required to be sized for its individual unbraced length, stiffness and stress characteristics. The high walls are supported by a tubular steel girt system, so perimeter W12 and W14 columns typically had to be checked for both strong-axis seismic forces and weak-axis wind forces. Flying moment frame beams, designed primarily for drift control, jog up and down the high exterior walls to follow the pattern of windows and storefront openings.

Another interesting example of unique steel framing applications is the square braced frame “stone donut” structure. Shaped like a picture frame, this structure is clad in translucent marble, which is illuminated from within at night. The supporting steel structure had to be invisible through the cladding as well as internally accessible for changing light fixtures from the inside. Due to the large size of this feature and the sensitivity of the marble finishes, the frame had to be very stiff, but dimensional requirements for “invisibility” held steel sizes to only 2”. A three-dimensional space frame using 2” tube steel (ASTM A500 Grade C, Fy = 46 ksi) was designed to meet these requirements.

Throughout the project, engineers were encouraged to develop exposed steel framing systems consistent with the industrial, big-city image the designers wanted to convey. A major focus point of the project is a triangular courtyard surrounded by three exposed steel towers, rising 99’, 104’, and 132’ above grade. The taller two towers are partially clad in steel mesh, illuminated by specialty lighting. The third supports an eccentric needle-like spire, similar to that of Hollywood’s Capitol Records building. The spire is a vertical specialty lighting element supported on a sculpted tubular steel pedestal. The towers are purely architectural features, although the tallest encloses a spiral stair for maintenance purposes. Each was structurally designed to sit on open space frames (square, hexagonal, and circular), which in turn were integral with the building frames. Tubes, pipes, angles, channels, wide flange members and steel mesh were all used in these structures.

The Center Court structure also posed a special design challenge. In plan, the building consists of four unequal pie-shaped “wedges” set on a radial grid and enclosing a circular courtyard. These wedges are separated by large, radial pedestrian walkways at the ground level and interconnected by circumferential bridges of varying length at intermediate and roof levels. A 168’ diameter canted circular steel space frame covers the courtyard, providing a partial shade for the patios below. The space frame, designed by Pearce Structures of Chatsworth, CA, is supported by a built-up, canted steel ring beam, which in turn is supported by extensions of the building’s seismic frame columns at each of the wedges. To support the space frame and ring beam without differential seismic deflections between the wedges, it was necessary to tie all of the wedges together, using the narrow pedestrian bridges to transfer lateral forces around the courtyard in a continuous ring. Thus, the entire Center Court complex was constructed without seismic expansion joints.

When completed in the summer of 1993, CityWalk will offer the essence of LA on a pedestrian scale, while serving to interconnect the existing Universal Cineplex, Amphitheater, and Studio Tours.

Tom Bouquet, P.E., is a structural engineer with Daniel, Mann, Johnson & Mendenhall, a leading international A/E firm headquartered in Los Angeles.
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In an extreme example of fast track construction, the project team for the American Home Products corporate office in Madison, NJ, expects to complete the 450,000-sq.-ft. building in only 18 months—including both design and construction.

“It was a super fast-track project,” explained Todd Heacock, P.E., chief structural engineer with Paulus, Sokolowski & Sartor, Inc., Warren, NJ. “And the speed was client driven. They were moving out of their New York City offices and had a tight deadline.”

If it had been a large warehouse project, 18 months might not seem unreasonable. But this was not a simple project.

The building features four office “pods” connected with a central atrium spine, with some of the structure sitting on top of below-grade parking. “Height limitations were a concern, so to maximize window space we designed a series of buildings,” explained Bob Kady, project coordinator for The Hillier Group, Princeton, NJ, the project’s architects. “The atrium then ties together the entire structure.” To further complicate the project, the office pods are not set at right angles to the 60’-long spine; rather, they are skewed by 10 degrees.

Smart Planning

So how did the project team manage to meet the tight timetable? Primarily through smart planning. “The job was arranged from day one with constructability issues in mind,” according to Paul
On June 10, 1992, the American Home Products building was merely a hole in the ground. By June 17, steel erection had begun. (opposite page). Steel erection proceeded very rapidly, as the pictures at right show on June 23, July 2, and July 25.

Anderson, project manager with Paulus, Sokolowski & Sartor, the project's general contractor. "The architect, general contractor and engineer were hired at the same time, and the subcontractors were selected very early in the process." And of paramount importance was getting the steel up as soon as possible. From the start of detailing to the completion of steel erection took only 10 weeks.

"The steel was competitively bid from less than 70% complete drawings," according to Robert G. Abramson, CEO of AISC-member Interstate Iron Works. But as part of the bid, the steel fabricator was required to give the structural engineer a job standards sheet including such items as connections and base plate details. This meant that throughout the job the engineer and fabricator were always on the same page. And it meant that the engineer would be designing a structure knowing how the fabricator preferred to work.

What also helped speed the steel portion of the project was the use of state-of-the-art technology by the fabricator.

"Initially, we hoped to import design drawings from the engineer’s AutoCAD system to our CAD system," stated Abramson. Unfortunately, because almost every engineer uses different layering protocols, this data transfer was not feasible (for example, the way that Paulus, Sokolowski & Sartor defines a beam member on its CAD system is different from the way Interstate does). But this
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proved only a minor setback. Interstate began the project by entering all of the structural drawings onto their detailing system. Interstate uses a system from Geometric Dataflow, a now defunct company. Fortunately, Abramson explained, Interstate had earlier bought rights to the program's source code and has over the past few years substantially modified the system. "The beauty of a CAD system is that we were able to generate the basic frame very quickly," Abramson said.

Entering the frame into the system allowed the fabricator to quickly develop mill orders and to begin detailing the project. By working closely with Bethlehem Steel, the fabricator was able to obtain material in either cut-to-length or in multi-lengths as needed. Also, some of the material was available for immediate delivery from the Bethbeams depot, located in Bethlehem, PA.

As material was received by the fabricator, numerical information from the computerized detailing system was automatically downloaded to a sophisticated material tracking system and to automated fabrication equipment programs. This direct transfer of information saved time and eliminated the chance for error. "We're a fully automated shop," according to Abramson. "We do all our burning operations, hole making and cutting on CNC equipment."

In addition to doing their own detailing in-house, Interstate also does erection. The steel was primarily field bolted, and by using two cranes simultaneously, erection was fast and efficient. Main structural members were erected first, with detail pieces filled in later. This sequencing allowed other trades, such as mechanical, electrical, concrete, fireproofing, and waterproofing to proceed sooner.

Structural Design

"We tried to keep things as simple as possible," Heacock said. The three-to-five story office pods have mostly standard 30' x 30' steel bays, so there was a lot of repeti-
tion of elements. The columns and girders are A572 Grade 50 steel, while A36 steel was used for the infill purlins.

The structure is fully moment connected using Type 2 connections predominantly. The few exceptions occurred in the connections between the office pods and spine. Because the pods are off-center, the engineer specified bent plates. "Although it's a seismic zone 2, wind loads were slightly greater and governed the design," Heacock said.

Below-grade parking was constructed beneath a portion of the structure. To accommodate the parking structures 30' x 60' bay size, the engineer designed a 6'-deep transfer girder spanning 60'. A similar condition exists in one office pod containing a recreation area.

Lessons Learned

"Teamwork was essential in meeting the project schedule," according to Anderson. "There's a myth that quality and speed are inversely related. But we learned that if you emphasize quality, you'll automatically increase speed. If you do something right the first time, you'll save the time it takes to do something over.

"Productivity is a leadership, management and engineering problem, not a field worker problem. Make sure you start with a good design. And make sure you inspect work in the shop. If it's right there, then the field work will certainly go quicker and smoother."

For Abramson, there were two major factors involved in speeding this project. "The construction manager brought in the fabricator early, and made sure the fabricator was on the cutting edge of CAD and CNC technology," he stated. "And he chose a fabricator who does its own detailing and field erection."

Second, the fabricator had to provide a list of job standards. "A smart move that the CM made was that as part of our submitted propos we had to include our standard details." And, of course, it helped that both the engineer and fabricator were willing to work closely with each other. "There was a lot of cooperation, a lot of phone calls, and a lot of faxes."

(At the 1992 National Steel Construction Conference, Robert Abramson moderated a session titled "Tieing It All Together." One of the papers presented at that session, by James P. Stevers with Globe Iron Works is contained in the 1992 NSCC Proceedings. The paper discusses the integration of data both within an organization and throughout an entire project team. "There is a revolution brewing in the structural steel industry. The revolutions called QUALITY," Stevers wrote. Copies of the 1992 Proceedings can be purchased for $20 by contacting AISC Publications at 312/670-5400 ext. 433.

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New Release, Lower Price

Metrosoft has announced a new pricing structure along with releasing Version 1.2 of its structural analysis and design software, ROBOT V6. New, lower pricing now starts at $495, which includes 2D and 3D linear static analysis capabilities for bar, truss and plate element models. The next step up is a package with a larger model size capacity, and the addition of shell elements. The top-of-the-line version can handle 32,500 nodes, 32,500 elements and 32,500 loads and combinations. Other upgradeable features include: a moving load generator for loads along any 3D path with full animated graphic display of loads and influence lines; a steel module with a guided design process for the entire structure, groups, or individual elements; and an advanced analysis module for buckling, nonlinear, and dynamic analyses of mixed element models.

For more information, contact: Metrossoft, Inc., 322 Paterson Ave., East Rutherford, NJ 07073 (201) 438-4915.

Managing Materials Lists

A new version of E.J.E. Industries' Structural Material Manager includes a Production Control Module. Once a job is in production, this module lets the user produce both master shipping lists and shipping tickets. It automatically tracks which items have been shipped, the dates they were shipped, and which items have not been shipped. Another change is the incorporation of an External Data Interface (EDI), which allows users to import information from other software systems in an ASCII format. For example, a CAD program from CadVantage can export its bill of material directly to the Structural Material Manager's EDI format, eliminating the need to re-type material items.

For more information or a free demo kit of the software, contact: E.J.E. Industries, 287 Dewey Ave., Washington, PA 15301 (800) 321-3955.

Spray-On Fireproofing

Isolatek International has reformulated its spray-applied fireproofing product to achieve a higher density, greater bond and compressive strength, as well as a more uniform mix. A free eight-page brochure documents the physical properties and performance of CAFCO BLAZE-SHIELD II. The product is fast-drying and pneumatically applied with minimal clean-up requirements. Fire endurance tests in accordance with ASTM E119 have resulted in ratings of up to four hours. Because of its formulation, the product also is a highly efficient sound-absorbing material and also acts as a thermal insulator. It is noncombustible and certified 100% asbestos-free.

For more information or a copy of the free brochure, contact: Isolatek International, 41 Furnace St., Stanhope, NJ 07874 (201) 347-1200; fax 201/347-9170.

Finite Element Analysis

The AVANS5E program for the finite element analysis of 2D and 3D structures was developed using the new technology of Object Oriented Programming, which allows for high speed and accurate results for structures with up to 1,360 nodes, 4,080 elements, 8,160 degrees of freedom, 20 load cases, and 50 load combinations. Prices start at $250 and range up to $1,095 for a full version with many modules.

For more information or a free demo version, contact: Andrew Skwara, Engineering Bulletin Board Systems, 25439 Via Nautica, Valencia, CA 91355 (805) 259-6902; fax 805/255-7432.

Steel Bridge Grid Analysis

A new steel bridge girder design program from MDX features integrated grid analysis and girder optimization. In addition to generating and loading influence surfaces for live load forces, this grid analysis program shares data with MDX's steel bridge girder design program. The scope of application for this package includes: Allowable Stress or Load Factor Design; variable horizontal curvature; skewed supports; plate girders; box girders; rolled shapes; web haunches; stiffeners; and cover plates.

For more information or a free trial version, contact: MDX Software (314) 446-3221; fax 314/446-3278.

Floor Design Program Adds Joist Capability

Version 3.0 of Ram Analysis' RAMSTEEL program offers several new features to the fully integrated floor framing and building design software. Now, in addition to composite and non-composite rolled or built-up shape, RAMSTEEL is capable of selecting and designating steel joist based on the S.J.I. joist designations or user defined tables. In addition, more than 30 performance or design enhancements have been added to this version, including fenced in area zoom, base plate design and support for the RAMSTEEL column module.

For more information, contact: Gus Bergsma, Ram Analysis, 5315 Avenida Encinas, Suite M, Carlsbad, CA 92008 (800) 726-7789; fax 619/431-5214.
Help Wanted — Project Management/Estimating

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For more information, or to obtain an order form, contact: Ben Yousef, S.E., at (619) 236-7368 or Mehrdad Mahre, S.E., at (619) 236-7324.

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