# MODERN STEEL CONSTRUCTION

August 1994

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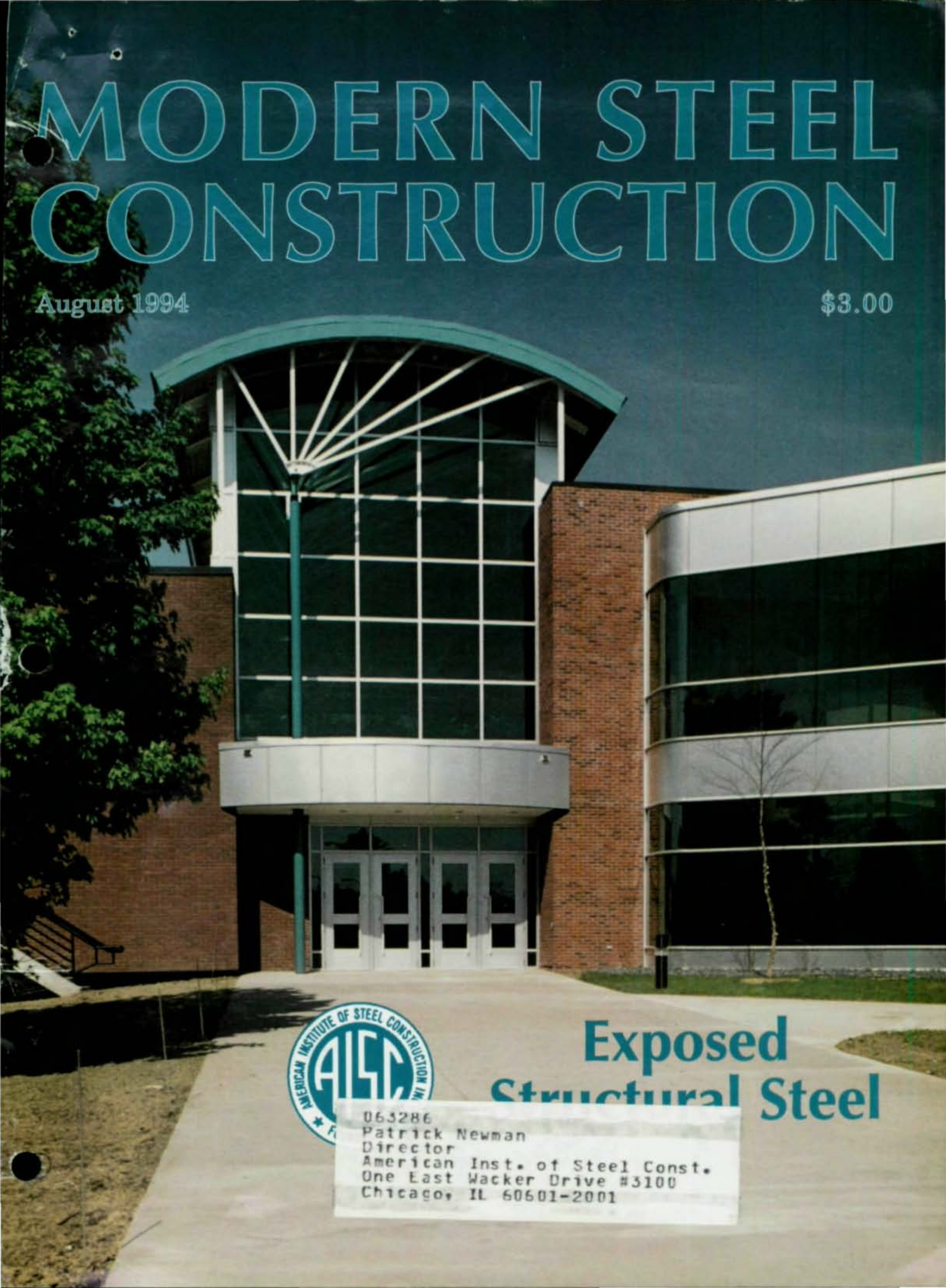

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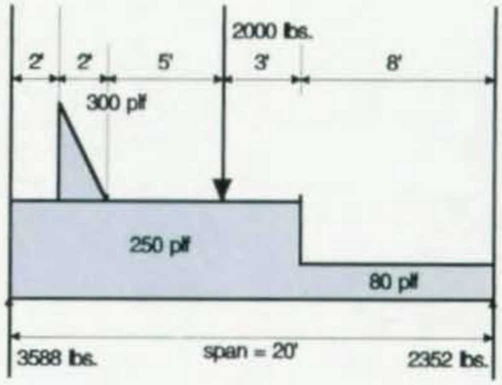
## In the past it was necessary to show special loadings, such as this example, on the structural drawings and call for a special (SP) joist.

example




maximum moment = 243 k. inch
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Now, tables for new KCS joists can be used to find a joist with sufficient moment and shear values. The new KCS joists have constant moment and shear strengths -- in the case of the illustrated example a 16KCS2 joist is found to resist a moment of 349 inch kips and a shear of 4000 pounds. By specifying this joist it is no longer necessary to call for a SP joist or show the diagram.

In addition to the tables on the new K Series KCS joists the new SJI specification contains other important revisions:

1. New bridging requirements for K, LH, and DLH joists.
2. Metric load tables.
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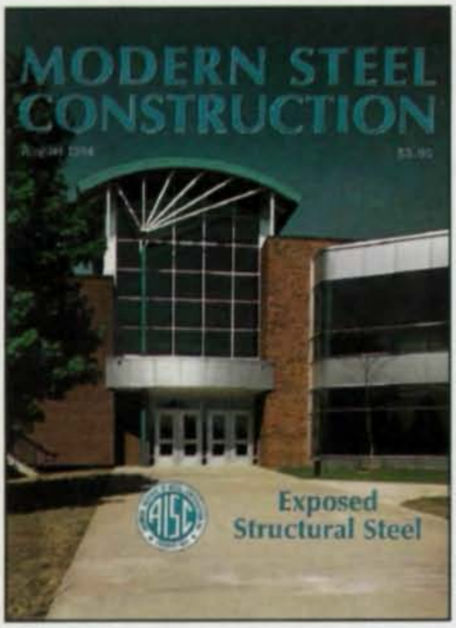
# MODERN STEEL CONSTRUCTION

Volume 34, Number 8 — August 1994


*Since Austin Community College needed an expansion, the project's designers took the opportunity to create a new main entrance, replete with a unique series of off-center trusses. The story behind this project begins on page 36.*

## FEATURES



## DEPARTMENTS

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# NOT JUST LUCK



THE STRUCTURAL STEEL CONNECTION DAMAGE FROM THE NORTHRIDGE EARTHQUAKE has received increasing publicity as the number of affected buildings in the Los Angeles area has grown (it's now estimated at more than 100). Many of the more recent headlines and commentaries are critical that an immediate research solution to the connection problem has not yet been identified. Unfortunately, there are relatively few reminders that all of these damaged buildings survived the 1994 earthquake and its aftershocks. There were no steel collapses and most remain fully functional; as in every other recent earthquake in the U.S. there was no loss of life in a steel-framed building.

The attitude in the popular press, as well as in some trade magazines, is somewhat understandable. After all, doesn't everyone love to see Notre Dame lose? Steel has for so long touted its invincibility that any crack in its armour is startling. Still, the buildings were designed to meet a life safety standard and steel's long-standing history in this area remains unscathed.

While no one could possibly suggest that these unexpected connection fractures can be attributed merely to bad luck, likewise no one should suggest that it was simply good luck that none of the buildings collapsed. Preliminary analysis after the earthquake by one nationally renowned researcher confirms the existence of quantifiable overstrength in typical steel buildings that is not accounted for in the standard design practice. This reserve strength of steel buildings from remaining connections and other elements should not be ignored nor casually dismissed.

Both the connection ductility and frame ultimate strength issues are important and inseparable. While most attention is now fixed exclusively on welded moment connections, the reassuring survivability of the entire steel framing system under overloads cannot be overlooked. Neither one of these observed seismic performance outcomes can be attributed to either bad or good luck. The only solution for future steel seismic design will result from developing technical research about these related topics—research that is currently underway and more that will follow. Both quick, short-term and longer-term answers are being pursued; research progress reports will be made periodically to keep everyone informed.

Every major earthquake has provided a valuable learning experience and the final legacy of Northridge is expected to be an even better understanding of connection and steel frame behavior.

Nestor Iwankiw

Nestor Iwankiw
AISC Director, Research & Codes

# STEEL INTERCHANGE

*Steel Interchange* is an open forum for *Modern Steel Construction* readers to exchange useful and practical professional ideas and information on all phases of steel building and bridge construction. Opinions and suggestions are welcome on any subject covered in this magazine. If you have a question or problem that your fellow readers might help you to solve, please forward it to *Modern Steel Construction*. At the same time, feel free to respond to any of the questions that you have read here. Please send them to:

**Steel Interchange**
**Modern Steel Construction**
**One East Wacker Dr., Suite 3100**
**Chicago, IL 60601-2001**

Answers and/or questions should be typewritten and double-spaced. Submittals that have been prepared by word-processing are appreciated on computer diskette (either as a Wordperfect file or in ASCII format).

The opinions expressed in *Steel Interchange* do not necessarily represent an official position of the American Institute of Steel Construction, Inc. and have not been reviewed. It is recognized that the design of structures is within the scope and expertise of a competent licensed structural engineer, architect or other licensed professional for the application of principals to a particular structure.

Information on ordering AISC publications mentioned in this article can be obtained by calling AISC at 312/670-2400 ext. 433.

***The following responses from previous Steel Interchange columns have been received:***

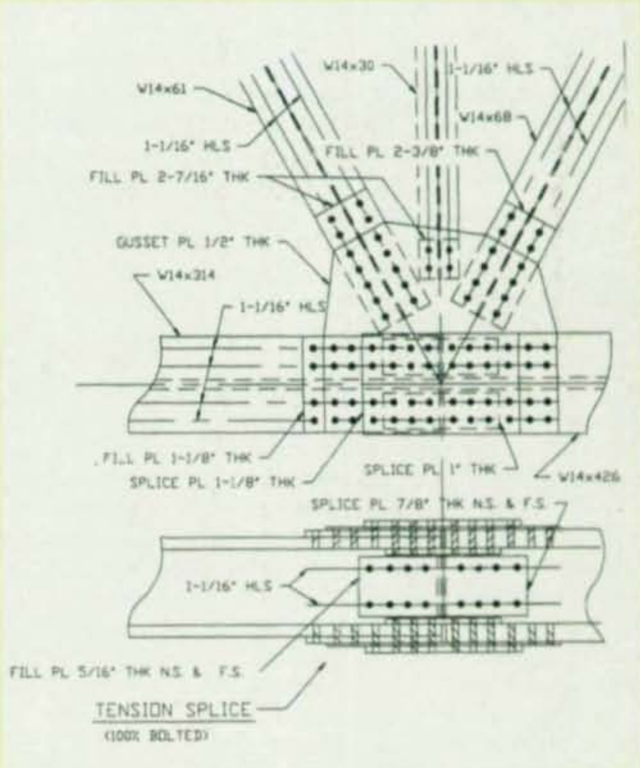
A reader wrote to state a concern regarding one of the answers in a previous Steel Interchange. His concern was that the response interpreted the AISC Specification and only the AISC Committee on Specifications can officially interpret the Specification. This observation is correct; however, *Steel Interchange* is intended to be a forum for readers to discuss ideas and information on all phases of steel construction. As stated in each month's disclaimer, the opinions expressed are not endorsed by AISC nor do they represent official opinions of AISC, but are the authors own recommendations.

**Are there any good connection details for a truss made up of all WT sections?**

We have designed and/or detailed (as we are sure that a good number of others have) many welded trusses using WT chord sections which work very well with double or single angle web members.

We would suggest, if it be desired to use WT web members, that they be welded flange to the chord web all from one side. The eccentricity effect on the truss is usually less for all welded one side than alternate sides. Of course, double WT web sections would eliminate that. Shop welding costs would also be considerably less for welding one side only.

A variation of the above question, which arises frequently, is: "Are there any good connection details for a truss made up of all W sections?" A number of good details have been developed by many engineers using field welded connections. This question was recently explored in an ASCE publication and apparently some engineers feel as we do that bolted connections are preferred for reasons of fit-up, shock resistance, and overall costs. In the case of high corrosion vulnerability, field welding may be the best choice; however:




1.Where fit-up tolerances are critical, shop prepared bolting is almost a necessity and fit-up bolting may be required, even for field welded connections.

2. Gusset plates for the heavier W sections can become unwieldy, need to be flattened or milled, or become unduly heavy and expensive unless thinner plates are utilized by laminating the gussets at chord splices.

Cost effective joints can be designed to fit this criteria by developing the required fill plates before adding the next layer of gusset plate so as to connect the web members. Make the thickness of the web member gusset no thicker than needed for connection. Where the main chord is also spliced, smaller sized splice plates can be added inside chord flanges, web, and on top of main gusset plates. Use slip critical type connections.

The figure indicates typical details as designed by us for a large building roof support system.
***Lloyd W. Abbott, P.E.***
**Consulting Engineer**
**Tulsa, OK**

**What is the origin of the Vierendeel truss?**

Professor Vierendeel's development (a truss without diagonals, which maintains its shape by the rigidity built into its joints) was first used in 1893 for the construction of a church steeple in Flanders Belgium. Then, for the International Exposition of Brussels in 1897, Vierendeel designed a riveted steel bridge 103 feet long.

After the overcoming of initial opposition by many engineers to the concept, well over 100 Vierendeel truss railroad and highway bridges were built in Belgium, the Belgian Congo and elsewhere. In recent years, it seems to be used more in buildings than in bridges.

It is true that Vierendeel truss design by hand can be tedious. However, a method developed by Grinter and Tsao, presented in the October 1953 Proceedings of the American Society of Civil Engineers, simplified the procedure greatly in those days before computer solutions were commonly available. The system consisted of an adaption of the Hardy Cross method of moment distribution by successive approximations, with the usual Hardy Cross stiffness factors being modified by simple multipliers. This method was useful to me some years ago, when I had to produce a design for the lower floor portion of several stories of a section of building spanning a city street, in which architectural requirements for windows prevented the use of diagonal web members. The solution was story-high Vierendeel trusses, made up of heavy 14 in. steel sections with welded joints.
***Herman Soifer, P.E.***
**Shah Associates**
**Bellmore, NY**

**The use of channel sections or other lightweight narrow flange sections as girts supporting non-bearing exterior wall assemblies against wind load is common practice. How is lateral instability of the unsupported compression flange accounted for when the wall is subject to outward pressure due to suction at the leeward face of the building? These outward forces are equal to or greater than the inward forces.**

I have found guidance in Galambos (*Guide to Stability Design Criteria for Metal Structures*, 4th Ed., 1988, Wiley & Sons, New York, pp. 172ff). In particular there is an expression for determining the critical moment of a symmetrical wide-flange beam with the tension flange provided with an infinitely stiff, continuous, lateral (not torsional) restraint. Most girts and metal studs are not symmetric wide flanges, but other work suggests that the equations for wide flanges are only about 5% non conservative for hot rolled channels. In many cases the critical moment is much greater than the yield moment, so the discussion becomes academic.

A lower bound for any section as proposed by Winter is also discussed. It essentially treats the entire compression area as a partially restrained column. The "truth" no doubt lies somewhere in between the two approaches. However, the methods converge fairly closely for very slender girts, and may prove useful. I have found that the majority of channel girts attached fairly frequently to metal siding have very high critical moments (even without considering the rotational restraint of sag rods), and thus are governed by yield considerations.

I am told that additional guidance may be found in Yu (Cold-Formed Steel Design, 1985, Wiley Interscience, New York), but I am unfamiliar with the work and have not used it.
***Peter S. Higgins, S.E.***
**Peter S. Higgins & Associates**
**Glendale, CA**

## New Questions

Listed below are 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 Co nstruction, One East Wacker Dr., Suite 3100, Chic ago, 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.

When, if ever, is it acceptable to consider an inflection point to be a bottom flange brace point in the design of a continuous beam? If an inflection point cannot be considered a brace point, then what values of $L_b$ and $C_b$ should be used?

Is it acceptable to use $K = 1$ for the design of moment resisting columns in an unbraced frame if a second order analysis is performed?
***Andrew D. Betaque***
**Cromwell Architects/Engineers**
**Little Rock, AR**

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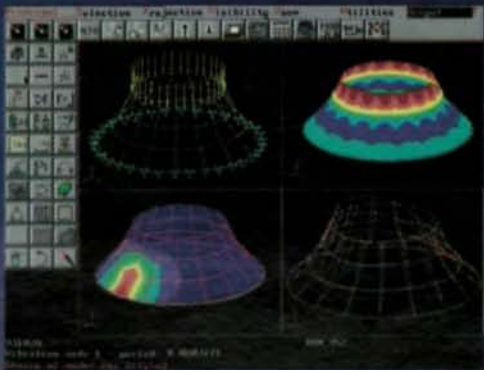

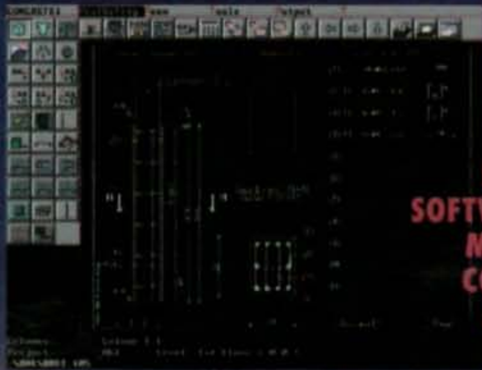

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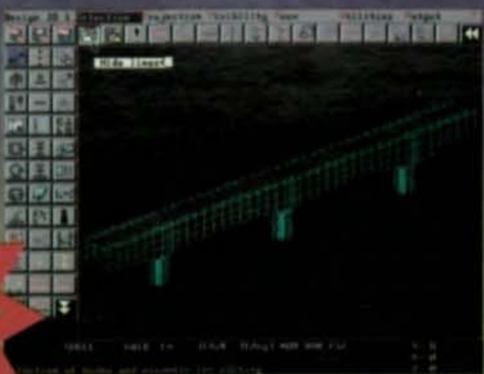

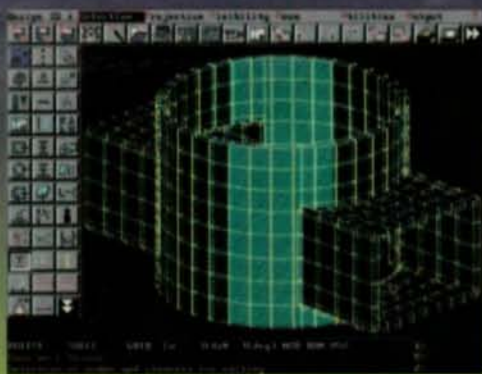

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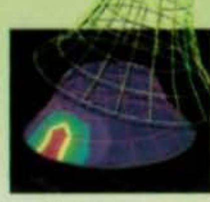

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*This bi-monthly column deals with legal matters of interest to designers, fabricators and contractors. We solicit your comments, concerns, suggestions and questions, both as to individual issues and subjects that you would like to see treated in this column. Some of the issues that we plan on covering in the future include: contract provisions; OSHA standards; employment law; alternative dispute resolution; and dealing with the EPA. Comments should be sent to: Modern Steel Construction, One East Wacker Dr., Suite 3100, Chicago, IL 60601-2001.*

# UNDERSTANDING THE BATTLE OF COMPETING CONTRACT FORMS

ABOUT ONCE A WEEK, OUR OFFICE RECEIVES A CALL from a different subcontractor with an all too common tale of woe and trouble.

It seems that this subcontractor had prepared a bid based on project drawings, specifications and special conditions prepared by the project design professional. The subcontractor had bid on one or two technical sections of the project and submitted its proposal either on its standard company bid form (if it is bidding a private job) or on the bid form required by the contract documents (which typically happens on public projects).

A short time later, the good news arrives, in one way or another, that the subcontractor is the successful low bidder and that a formal subcontract will follow.

In the interim, due to the tight job schedule, the subcontractor is either given a formal notice to proceed or is otherwise ordered to begin the shop drawing process and such other preparatory work as is necessary to keep the job on track. The subcontractor, of course, proceeds on good faith.

And that's when the problems arise.

In due course, the subcontractor receives the general contractor's standard subcontract form and it's a disaster—totally one-sided and loaded with clauses that the subcontractor knows from experience will not be acceptable and/or which contradict provisions in the bidding documents or the subcontractor's proposal.

At this point, the subcontract form becomes a ping pong ball bouncing back and forth between the general contractor and the subcontractor. At some point during this ping-pong game it becomes time to start ordering material and reserving shop time or otherwise mobilizing forces, equipment and material at the job site.

The subcontractor is beginning to feel the heat from at least three directions:

• First, there is the ever-present time pressure caused by being one of the early work activities on the project's critical path.

• Second, there's pressure from the general contractor to sign the unacceptable subcontract or (choose one): (a) be shopped, (b) be terminated, (c) not be paid, or (d) all of the above.

• Third, there is internal pressure from the subcontractor's organization not to sign an unacceptable contract and not to proceed until an acceptable subcontract is in place.

What are the subcontractor's legal rights at this point in time?

Surprisingly, most subcontractors finding themselves in this dilemma are actually in a fairly good legal position.

***Under the foregoing scenario, regardless of what the general contractor may say or think, the subcontractor may well have a binding written contract in place.***

If the proper legal prerequisites have been met, the terms of that contract would be defined by:

(a) the documents upon which the bid was based;

(b) the subcontractor's written bid proposal, including any qualifications or exclusions made in that proposal; and

(c) writings from the contractor accepting the proposal and notifying

*David B. Ratterman, Esq., is Secretary and General Counsel for AISC. His firm, Goldberg & Simpson, P.S.C., in Louisville, KY, concentrates in the area of construction law.*

the subcontractor to proceed with work.

***If, in fact, the subcontractor does proceed with the work upon the general contractor's acceptance of the proposal and notice to proceed, then most courts that have considered the question have held that there is a formal contract in place that cannot be "shopped" and given to another subcontractor by the general without paying termination damages to the original subcontractor.***

I would venture that seven out of 10 contractors do not understand this principle.

***Because of this principle, however, once a subcontractor has been given notice to proceed and has actually started work on the project, it does not have to agree to unacceptable terms proposed by a general contractor (provided those terms were not included in the document upon which the subcontractor based its bid).***

Likewise, a second-tier subcontractor does not have to agree to accept any subcontract terms if those terms were not included in the second-tier subcontractor's bid package and if the second-tier subcontractor has been given a notice to proceed and allowed to actually start work on the project.

General contractors who understand the foregoing principles will normally not issue a notice to proceed or allow a subcontractor to actually start work on a project until a formal subcontract has been executed. Prior to that stage in the proceedings on most projects (other than some public work) it is perfectly acceptable for general contractors to "shop" subcontracts and ultimately to give the work to a competitor even after a sub has been notified that it is the low bidder and that it is the general contractor's "intention" to award the subcontract work to the subcontractor.

***The key to all of this is the notice to proceed and actually proceeding with the contract work.***

**AIA's STANDARD SUBCONTRACTOR FORM IS AS FAIR TO GENERAL CONTRACTORS AND SUBCONTRACTORS ALIKE AS ANY SUBCONTRACT FORM IN USE IN THE U.S. TODAY**

We often advise subcontractors who are caught in this dilemma of arguing unfavorable contract provisions with a sophisticated general contractor to suggest that the standard American Institute of Architects subcontract form (A401, 1987 Edition) be utilized for the subcontract work.

This document is about as fair to general contractors and subcontractors alike as any subcontract form being utilized in the United States today. For this reason, the AISC board of Directors endorsed this subcontract form several years ago and continues to do so today.

***However, subcontractors are cautioned to be certain that they understand all of the provisions of the contract before it is utilized with second-tier subcontractors, as it could give second-tier subcontractors rights beyond those rights which the subcontractor has been afforded in its agreement with the general contractor.***

Another key to all of this, assuming the subcontractor has gotten beyond the formal notice to proceed and is actually working on a project is the provisions that the subcontractor included in its proposal to the general contractor and the general contractor's written acceptance of that proposal. The contents of those documents are crucial and are open to much tactical, and practical discussion.

Regional fabricator workshops are tentatively being scheduled for this fall that will delve into the content and tactics of written proposals. And that, of course, will also be covered in future columns.

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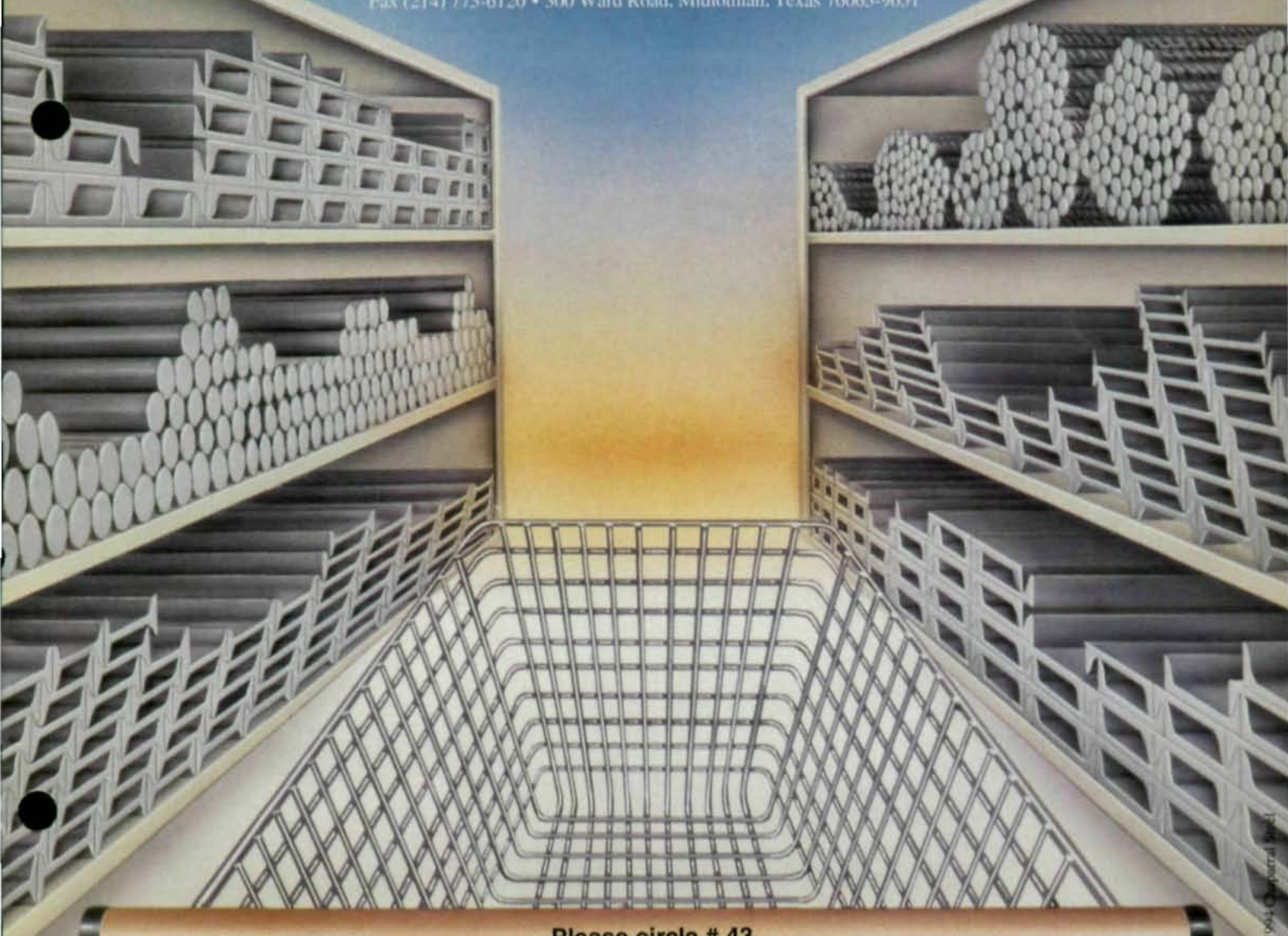

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# CALLS & LETTERS TO AISC

PATRICK M. NEWMAN'S DAY ALWAYS BEGINS with a cup of coffee at 8:30. Then, coffee in hand, AISC's director of technical information services begins working on one of his many assignments—perhaps *Engineering Journal*, maybe some work on an AISC Design Guide. By 8:35 he's usually received his first phone call. It might be an engineer with a question about the LRFD Specification, or a fabricator asking about connection design.

"For example, I recently received a question about tightening bolts," said Newman, a professional engineer who has worked at AISC for the past nine years. "I referred the caller to the Research Council of Structural Connection's Bolt Spec which has a section on installation requirements. Most of the questions we receive can be answered as simply as pointing out Specification references, though some require substantially more detail."

One of his chief responsibilities at AISC—in fact, one of the main duties of the entire seven-man technology and research staff—is handling technical inquiries, not just from AISC-members but from any fabricator, engineer or other design professional. While AISC has been responding to these type of inquiries since 1921, it only recently issued a formal policy on how questions will be handled.

In a nutshell, the policy states that questions received over the phone will be answered verbally; if someone wants a written response, then the question must be posed in writing. While not formally addressed, faxes are fine.

Though AISC does not comment on specific designs, staff engineers will answer questions about the AISC ASD and LRFD Specifications for Structural Steel Buildings and the AISC Code of Standard Practice. In addition, for other technical questions they will cite specific sections of AISC specifications and codes and other standards such as ASTM, the commentaries included in AISC documents, articles in Engineering Journal and other technical publications, and textbooks. Requests on information on connection design are answered with references to Volume II of the Manuals of Steel Construction or to CONXPRT software.

### Disputes

ONE AREA WHERE AISC STAFF ENGINEERS WILL NOT provide an verbal response is when a matter is in dispute. In that case, inquiries must be put in writing. Where appropriate, AISC staff will forward the question to either the Specification Committee or legal counsel.

"AISC has many references available to help answer a wide range of questions," Newman said. "The technology and research staff is here to help engineers and fabricators design in steel and we're always available to provide answers whenever possible or forward them to a source that can provide an answer."

AISC staff logs each inquiry and, when appropriate, publishes an anonymous synopsis of a question along with a response (typically in *MSC* or *Engineering Journal*). Occasionally, these questions also find their way into the Steel Interchange section of this magazine.

If you have a technical question, call AISC at 312/670-2400 (fax: 312/670-5403) or write to: AISC—Research & Technology, One East Wacker Dr., Suite 3100, Chicago, IL 60601-2001.

# QUICK STEEL SURVEY

DESPITE THE ISSUANCE OF THE SECOND EDITION of the *LRFD Manual of Steel Construction*, there are still some skeptics in the engineering community who wonder whether LRFD is truly the steel design standard of the future.

Part of the problem seems to be that no one really knows how many practicing structural engineers are actually designing buildings with LRFD. Estimates range anywhere from less than 10% to as many as 40%. About the only statement that can be made with any certainty is that AISC has sold more than 60,000 copies of the *LRFD Manual of Steel Construction*.

This month's *MSC* Steel Survey will attempt to get a better handle on LRFD usage in the field. Please circle the correct response on the postage-paid reader service card between pages 42 & 43.

| | |
|---|---|
| Only use **ASD** | circle **11** |
| Only use **ASD** but plan on using **LRFD** in the near future | circle **12** |
| Only use **LRFD** | circle **13** |
| Use both **ASD & LRFD** | circle **14** |

# Northridge Update

THE NUMBER OF STEEL BUILDINGS STRUCTURALLY DAMAGED BY THE NORTHRIDGE EARTHQUAKE is now estimated at more than 100. However, there have been no collapses and most of the buildings remain functional. Nevertheless, there is widespread concern, particularly in California and other high seismicity regions, about the fracture problems experienced with welded special moment frame connections.

Short-term, research is currently underway at the University of Texas-Austin. The unique feature of this research is the use of larger main member sections that are more representative of current design/construction practice. Welding electrodes and procedures, as well as various details, are being closely reassessed. Slow cycle cantilever beam and column assembly experiments will evaluate several variables:

1. Grade (strength & toughness) and size (diameter) of weld electrode.
2. Sensitivity to welding workmanship and technique.
3. Continuity plates in column.
4. Vertical "rib" (gusset) plates reinforcing the beam flange connection.
5. Geometry and weld details of vertical and horizontal flange plates.

The objective of this initial project is to quickly identify and substantiate an improved connection design that can be used for repairs and new construction of special moment frames. A balanced group of experts is serving as an Advisory Committee to review and guide the research.

A separate short study at the University of California is focusing on the inherent reserve strength of structurally damaged steel moment frames. A damage questionnaire drafted by AISC is being used by the Los Angeles jurisdictions to document the nature and extent of the problems, type and year of construction, etc., during their inspection reviews.

**NEXT MONTH: Plans For Medium & Long-Term Studies**

Stanley D. Lindsey stays at the forefront of his profession by seeking out and utilizing innovative design methods

# EMBRACING CHANGE

**By Elizabeth Eilendar**

WHEN STANLEY D. LINDSEY STARTED SCHOOL at Vanderbilt University, he had dreams of one day becoming a successful chemist. But after gagging at the smell of hydrogen sulfite fumes, accidentally burning his fingers, and breaking a glass test tube—all on the first day of class—he concluded he was not "attuned to chemistry" and that same day switched his major to civil engineering.

It was definitely a good decision. Lindsey, now 55 and head of Stanley D. Lindsey and Associates, Ltd., is well lauded by his peers as a creative and innovative designer and has earned a reputation as a spokesperson for advances in the engineering field. His firm has for years been at the forefront of the design industry. Lindsey was an early and strong supporter of LRFD, has applied seismic design concepts that originated on the west coast to structures in the midwest and southeast, and has played a significant role in writing building codes and specifications that have stressed the use of advanced technology.

### A Shoe Box Of Ideas

WHEN ASKED TO NAME WHO HAD THE BIGGEST IMPACT on his professional and creative development, Lindsey fondly recalls his days with his mentor and early employer Ted Allen, who always used to say: "Show me a man who never made a mistake and I'll show you a man who hasn't worked to his capacity."

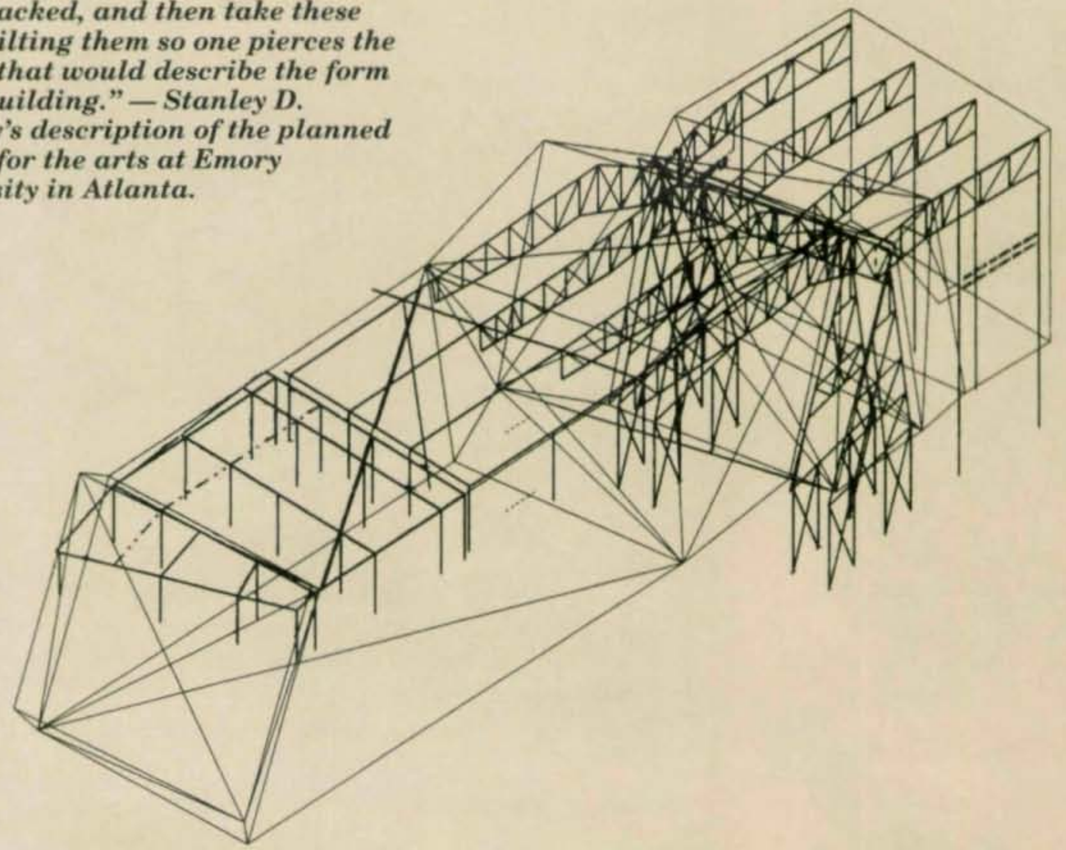
Lindsey's 27-year-old firm employs 57 people in its two offices in Atlanta and Nashville. The company focuses its business on mid-rise and low-rise construction—predominantly hospitals, hotels and educational facilities—though he's not adverse to designing taller buildings, such as the 42-story Stouffer Convention Hotel in Nashville, one of the tallest structures to utilize a staggered truss system. Lindsey attributes his concentration on these market segments to client loyalty, though it also undoubtedly reflects market acumen.

One of his most recent projects is the very unusual Center for the Arts at Emory University in Atlanta, which he designed with Peter Eisenmann, president of Eisenmann Architects in New York. Since hardly any of the walls are straight, Eisenmann describes the building as "a box that seems to undulate and move." As can be expected, translating that architectural vision into a structural design was not a simple task.

"If you took a series of shoe boxes and stacked them and turned each box in a different direction, leaving them stacked, and then take these boxes, tilting them so one pierces the other—that would describe the form of the building," explained Lindsey. "The miracle of this building is that we can figure out how it goes together."

Added Thomas A. Hagood, Jr., P.E., vice president and director of Lindsey's Atlanta office: "The piercing of the various boxes causes multiple planes with a lot of folds, breaks and angles. This system was established by the architect to be geometrically stable so that each coordinate in the complex structure could be calculated. With this information, a three-dimensional model of the structure was built in the com-

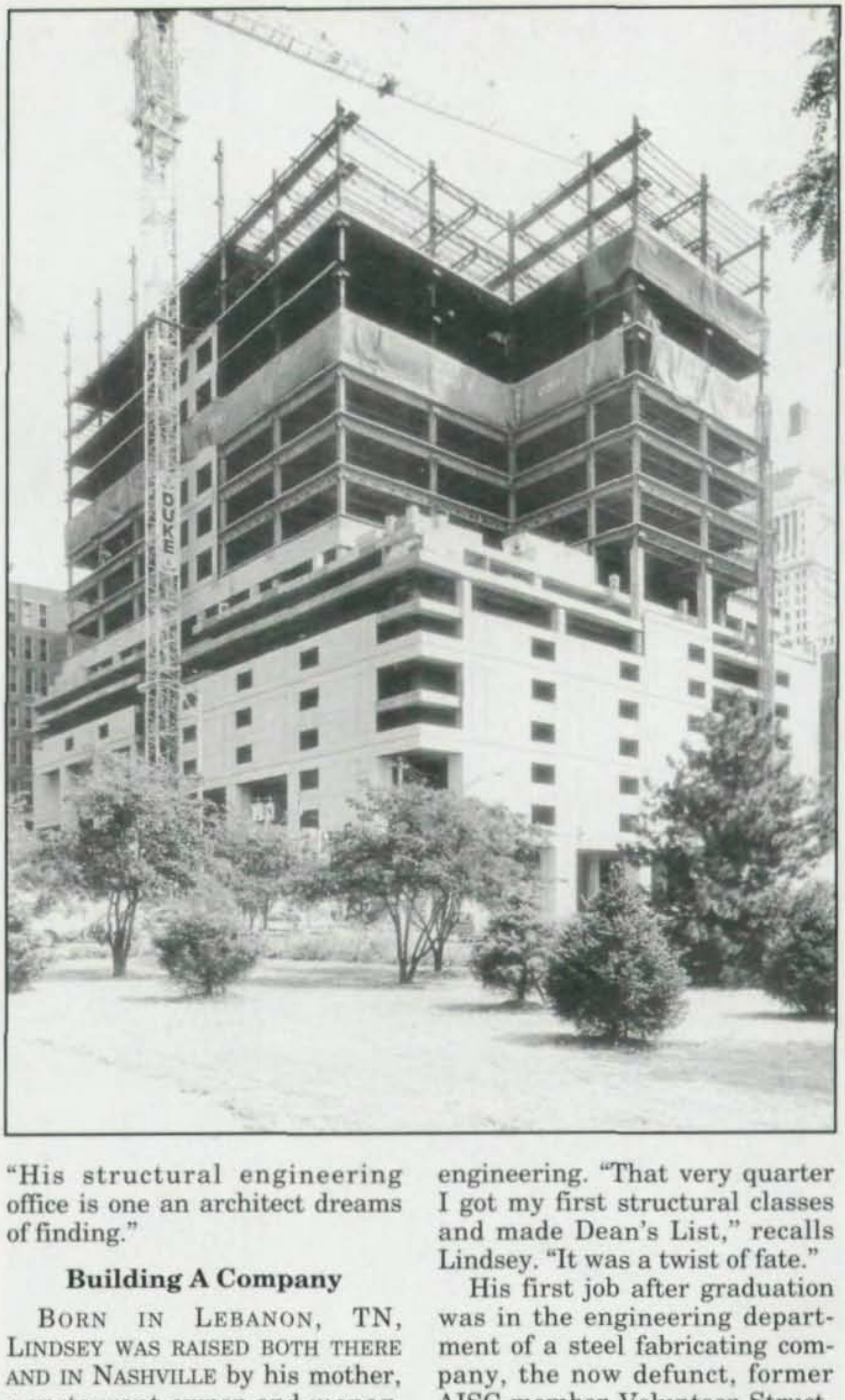
*"If you took a series of shoe boxes and stacked them and turned each box in a different direction, leaving them stacked, and then take these boxes, tilting them so one pierces the other—that would describe the form of the building." — Stanley D. Lindsey's description of the planned Center for the arts at Emory University in Atlanta.*



puter and analyzed. Without the computer and sophisticated analysis and design software, this project would not have been feasible.

The company uses a number of commercially available programs including COMBAT, ADAPT and RAMSTEEL, said Kurt Swensson, P.E., Ph.D., a project manager at Stanley D. Lindsey & Associates. In addition, the company has developed an in-house program that integrates sophisticated three-dimensional analysis with the design of steel, reinforced and prestressed concrete, which was used for the unusual design of the Center for the Arts.

"I never found anyone else as receptive to challenges, willing to try new things and willing to find solutions," said Eisenmann.



"His structural engineering office is one an architect dreams of finding."

### Building A Company

BORN IN LEBANON, TN, LINDSEY WAS RAISED BOTH THERE AND IN NASHVILLE by his mother, a restaurant owner and manager. A lack of funds during his sophomore year at Vanderbilt caused him to drop out. He took a drafting job with the Tennessee Highway Department, and when he had enough savings, enrolled at the University of Tennessee.

Unfortunately, his grades were abysmal. Just when he was close to being kicked out of school, he discovered structural engineering. "That very quarter I got my first structural classes and made Dean's List," recalls Lindsey. "It was a twist of fate."

His first job after graduation was in the engineering department of a steel fabricating company, the now defunct, former AISC-member Volunteer Structures, Inc. Within six months, all of the engineers in the department had resigned to open new firms—all except Lindsey. "The president of the company liked me and became a father image to me," he reminisced. The company president, Ted Allen, paid for Lindsey's graduate studies and Lindsey remained the company's chief engineer until 1967, when he left to open his own firm.

*The 736,000-sq.-ft., 26-story 312 Elm Street Building in Cincinnati features a combination of eccentrically braced, concentrically braced and rigid moment resisting steel frames. The framing system was selected both to minimize costs—the innovative framing concept cut 4% from the project budget and five weeks from the project schedule—and maximize flexibility.*

"I just felt like I could do it and was too dumb to know the pitfalls," he commented. "Ted gave me the opportunity to produce and the inspiration to try to succeed."

### Flexibility and Creativity

PART OF LINDSEY'S SKILL IS HIS ABILITY TO APPLY A CONCEPT in a way that isn't obvious, though his reasoning may be quite straightforward, explained Joseph Yura, a professor of civil engineering at the University of Texas and a long-time friend. One time, Yura recalls, he showed Lindsey a research drawing of how to connect steel beams to concrete columns. By rotating the diagram 90 degrees, Lindsey immediately saw an opportunity to make an economical fixed connection for a steel building on a concrete foundation.

That talent for innovation served Lindsey well on the expansion of Nashville's Opryland Hotel last year. The planned addition called for a 172-ft.-long skylight supported on a very light-weight structural steel frame. The architect, Earl Swensson of Earl Swensson Associates in Nashville, explained that he wanted a romantic look that was light and airy—and a low cost.

"Stan could accept all these limitations," said Swensson. "Many engineers set a very rigid grid. Stan can sit with you in the initial stage and blend his structural knowledge so that you create something with the architect. That's rare. If the architect's program changes, he can adjust to that."

Lindsey's firm designed a virtually invisible bracing system utilizing very light rods interspersed throughout the structure. "They were very small and integrated with other components of the roof," Lindsey explained. To cut costs, he incorporated a modified version of post-tensioning of steel by using a truss in combination with cables, which allowed very long—and very light—spans.

Another area where Lindsey has had an opportunity for innovation is in seismic design. Lindsey is a licensed engineer in California and has written and lectured extensively on the seismic design of steel buildings. And he has brought the use of eccentrically braced frames—a common design concept on the west coast—to the midwest and southeast, according to Kurt Swensson.

In a pioneering approach to resisting wind loads, Lindsey incorporated eccentrically braced framing in the 26-story 312 Elm Street Building in Cincinnati in Cincinnati (see August 1992 MSC). The eccentric bracing was

*The Opryland Hotel in Nashville features a giant, plant-filled atrium.*

used in conjunction with composite trusses to span from the core of the building to the exterior of the building. While composite trusses are used in Canada, they are only infrequently used in the U.S. even though they are very efficient, according to Lindsey.

### Supporting Change

IN ADDITION TO HIS DESIGN WORK, Lindsey spends much time and effort working with code and specification bodies, and he currently is chairman of AISC's Task Committee on Loads, Analysis and Systems where he routinely champions Load and Resistant Factor Design.

When LRFD was being developed in the late '70s, Lindsey says he knew nothing about it. But when AISC asked him to be a member of the committee drafting the Specification, he agreed and tried to educate himself about LRFD. "The more I read, the more convinced I was that this was the only true way to design steel structures because it predicts the behavior of the elements so well," he said.

Using LRFD can have cost saving benefits as well. And, some innovative techniques lend themselves much more readily to LRFD than to ASD, he explained. For example, partially restrained connections can't be used with ASD because there's no technique for doing it right. With ASD, Lindsey explained, there's no real way to accurately take advantage the inherent stiffness of the frames.

"There are people who say this [ASD] has served them well for a number of years and don't see any reason to change," said Lindsey. "I became LRFD's strongest supporter to the point of being obnoxious."

He began using the Specification as soon as it was published in 1986, starting with the General Accident Insurance building in Nashville—one of the first buildings in the country to be designed using LRFD. "The industry is moving to accept LRFD at a pace that could be faster and I think AISC can greatly help that pace of acceptance by saying that 'by 19-something there will be no more ASD Specification.'"

### *Getting Involved*

LOOKING FORWARD, LINDSEY BELIEVES there will be an increased reliance on advanced analytical technology that combines analysis and design into one computer program. Anticipating these trends, his company has produced its own in-house software to integrate design and drafting, and this program was used on such projects as the Center for the Arts. The company also uses a number of commercially available programs. "It's a way of harnessing the power of the computer for use in a structural engineering office," said Kurt Swensson.

All of the engineers at Lindsey's company have computer expertise, a qualification he believes is indispensable in helping to raise industry standards. From an engineer's standpoint, computer knowledge adds confidence, said Yura. "The more confidence you have in your calculations, the less you rely on your sense of the unknown. As a result, you can be more innovative and not rely so much on past experience."

Lindsey said he believes a good engineer has an innate instinct for structures. "Those who have that ability should help the profession by working on codes, papers and helping to educate young engineers." In addition to his work for AISC, he's a member of the Building Seismic Safety Council and the AISI Seismic Advisory Committee. He also teaches

*The 143-bed Jackson Regional Hospital in Jackson, TN, was the first hospital in the area designed to resist seismic activity. In addition, the structure was designed to accommodate a future vertical expansion.*

short courses at the Georgia Institute of Technology and often presents papers at national conferences.

"If you're going to be an engineer, you have to understand the codes and the best way to do it is to write them yourself. You know when the provisions are good or not, and what will appear five years from now," he stated.

Right now Lindsey is still thinking how to stay ahead of the game. "The market is very competitive and today people want you lean and mean. If you're too flashy and ostentatious, it set the wrong example. People want things done for the right dollar." he said.

"You have to be thinking about what you are going to do five years from now. That technology clock just keeps on ticking and if you don't ride the hands, you will be left behind."

*Elizabeth Eilender is a freelance writer formerly based in Evanston, IL.*

# SOMETIMES A CON
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It's not every day that bridge building techniques are used to expand a convention center. Yet, when the growth of Bartle Hall Convention Center in Kansas City was hemmed in on three sides by buildings and on the fourth by Interstate-670, there was but one way to go: over the highway.

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*90' Vulcraft steel joists.*

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*Bartle Hall Convention Center, Kansas C*

# VENTION CENTER
# CONVENTIONAL.

# A New Paradigm For Structural Engineers

By Kurt Swensson, Ph.D., P.E.

It's time for engineers to recognize LRFD's unique benefits for composite construction, partially restrained connections, eccentrically braced frames, seismic design, renovation projects and international competitiveness

On October 6, 1986, one month after the release of the Load and Resistance Factor Design Specification, I began my professional career in structural engineering with Stanley D. Lindsey and Associates Ltd. (SDLAL). I am happy to say that since that beginning, my career has fared better then LRFD. But the resistance to the LRFD specification, which is evident in the design profession, is troubling.

One of my first assignments with SDLAL was the design of the General Accident Insurance Office (GAI) in Nashville. Dr. Lindsey wanted to try a new structural system using partially restrained connections, combined with a design method using second order frame analysis as allowed by the LRFD Specification. The two-story structure was designed almost completely by hand. Computer programs were used to provide the second order analysis, but all the floor and framing members were sized using hand calculations. This investment of time has returned great dividends.

1. The GAI project, as well as our use of LRFD, has provided SDLAL with a great deal of marketing and public relations material.

2. The Owner and Architect were very pleased with the resulting structural savings and selected SDLAL for other projects.

3. The use of LRFD provided me with a great training experience, and SDLAL with a better engineer.

The GAI project was my first experience with LRFD; some say it was the first project designed and constructed using the LRFD specification. The experience showed me the power and rationality of the LRFD design procedure, and I have utilized it successfully for the design of several projects over the past eight years. As a practicing engineer, I have experienced and understand the frustrations in implementation of a new design procedure. However, it is difficult to understand the reluctance of the United States design professional to accept a design procedure for steel which has been:

- used for concrete design for more than 30 years,
- used for steel design in Canada for 17 years,
- accepted by the majority of other developed countries of the world.

Why has SDLAL accepted LRFD as a design procedure for steel? Survival!

SDLAL obtains and keeps clients by providing efficient, economical structural solutions to clients' design problems. In recent days, clients have presented more difficult design problems — additions, renovations, thin floor systems, complicated geometries, complicated loadings, and tight schedules. The market has demanded more economical structures to make a project viable. In many cases the standard structural steel systems available under ASD have not provided the most efficient, economical solution. New structural systems and analyses are required to provide structural steel systems which will compete

in the present market. SDLAL utilizes LRFD because it provides for new structural steel solutions to our clients' structural engineering problems. D.E. Allen of the National Research Council in Ottawa, Canada stated at the 1990 ASCE International Structures Conference that the USD design method, upon which LRFD is based, "allows a wider scope of creative solutions for making our structures safe and useful." SDLAL fully agrees.

### Back to the Future

THE PROCESS BY WHICH PROCEDURES OF SCIENTIFIC THOUGHT OR ANALYSES evolve and change is discussed in *Discovering the Future — The Business of Paradigms* written in the mid-1980's by Joel A. Barker. This process appears to be similar across lines of discipline and over generations. Based on Barker's premise, a look at the acceptance and implementation of the Ultimate Strength Design (USD) method by the American Concrete Institute in the 1950s and 1960s may prove educational. An article by renowned engineer George Winter in the December 1982 *Concrete International Magazine* entitled "Development of a National Building Code for Reinforced Concrete" describes this shift to USD in ACI. Briefly, the USD method was first introduced into the ACI specification in 1956 when the USD method was allowed but no actual provisions were given. In 1963, both USD and Allowable Stress Design (ASD) methods were presented on an equal basis. In 1971, the USD was fully developed and the ASD was specified as an alternative with only one page of text providing general design provisions. Today the ASD method is included as an appendix in the specification.

Review of the article revealed four topics which are relevant in today's discussion of the LRFD specification:

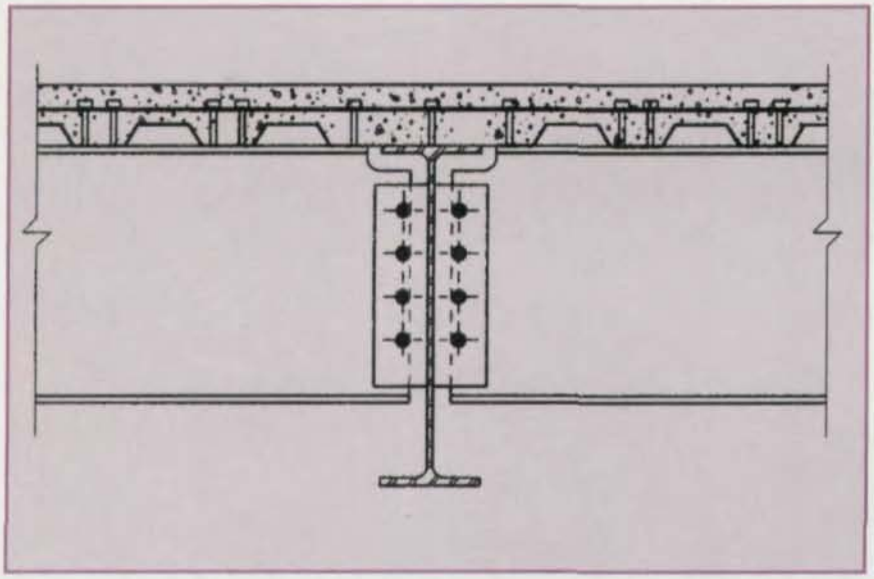
**1. Inadequacy of ASD** — In 1956, the specification recognized that near failure structural materials do not behave elastically and that a reasonable calculation of strength must account for that inelasticity. Dr. Winter continues that "...allowable stresses at design loads are merely a crutch. What designers and owners want to know is the actual strength and safety of these structures."

*The General Accident Insurance (Nashville Branch Office) building was designed using partially restrained connections and LRFD. As a result, considerable savings were obtained—an analysis showed that steel framing costs were reduced by 10%.*

**2. Explicit Discussion of Structural Safety** — When discussing the engineering community's acceptance of discrete safety provisions, Dr. Winter observed that:

> "Engineers were not accustomed, and some still are not accustomed, to thinking explicitly of structural safety. Some authority prescribed allowable stresses to them and as long as these were observed, the designer had no reason to think in terms of structural safety margins."

This statement was made more than 10 years ago and still rings true today. In 1963, load and



*There are a myriad of new structural systems, including the composite design pictured at left, that fit better with LRFD assumptions than with ASD assumptions.*

resistance factors were based on engineering judgement, whatever statistical evidence was available and were checked against the well established ASD design solutions. This is the same process used to develop the LRFD provisions, except the developers of LRFD had more statistical information.

**3. Economy** — Initially, design professionals looked to LRFD to produce significant reduction in the cost of structural steel structures through a reduction in weight. While it is true that savings in weight are available, often they are reduced by serviceability concerns and at best are not as large as originally hoped. It has been said that the cost savings are not worth the extra time required for design. A similar situation occurred with the introduction of USD in concrete in 1963. "The frequently greater economy of USD, particularly for higher strength concretes and steels which just then came into wider use, and for certain load combinations, became only slowly apparent." The opportunities for greater economy of LRFD are just on the horizon. Higher strength steels, composite systems, composite connections, PR connections, and advanced analyses will allow engineers to account for the true capacity of the steel frame and minimize structural costs.

**4.Resistance by Design Professionals** — It seems the USD version of the ACI specification shared the same experience as the LRFD specification. Acceptance of USD by the design profession was very slow.

Some of the barriers to acceptance are the same as today:

- Replacement of design tables, charts, reference material, and now computer design software;
- Concern over explicit treatment of safety;
- Concern over time needed for training.

It is interesting to note that in 1963 no mention was made of the expense of retraining, which has been an argument against the LRFD. My experience was that the great bulk of the LRFD specification was straightforward, and that a little research could explain the more obtuse provisions. Today many engineers coming out of school have already been trained in the use of LRFD.

When discussing a "grandfather" clause in the 1971 ACI specification which allowed continued use of the ASD provision, Winter was particularly pointed.

> "What this does is to permit designers or design offices too lazy to change to continue in the old routine. It is quite amazing and somewhat discouraging to note how many of them did. Only the greater economy of USD in specific, but frequent situations...gradually changed design habits."

It appears that history is repeating itself. Designers will change to the LRFD specification when it is shown to provide greater economy. The greater economy will come through the specific and frequent application of new structural steel solutions made available to designers by the LRFD provisions.

### Safety vs. Reliability

THE DISCUSSIONS SURROUNDING THE DEVELOPMENT AND USE OF THE LRFD SPECIFICATION utilize several terms which need a clear definition:

- **Limit State** — The commentary to the LRFD Specification defines a limit state as a "condition which represents the limit of structural usefulness." A limit state for a structure could relate to many different behaviors but generally they can be related to serviceability or strength.
- **Reliability** — Webster's Seventh Collegiate Dictionary defines this term as the "quality or state of being reliable." The Dictionary goes on to say that the adjective reliable is applied to a "person or thing that can be

counted upon to do what is expected."

• **Reliability Index** — This term is described in Section A5.3 of the Commentary on the AISC LRFD Specification. Basically, the reliability index is the number of standard deviations from the point of violation of a limit state to the mean of the curve representing the probable behavior of the structure.

• **Safety** — Webster's Seventh Collegiate Dictionary defines this term as the "condition of being safe from undergoing or causing hurt, injury or loss." The Dictionary goes on to define the adjective safe as "secure from threat of danger." To the owner and the public, the safety of the structure is defined as its resistance to collapse or the limit state associated with strength.

• **Factor of Safety** — This term is not defined in the AISC ASD provisions; however, it is commonly recognized as a measure of the difference between the anticipated result and the result which would be unwanted.

Neither the ASD nor the LRFD specifications address the serviceability limit states through guidelines or empirical rules. So the discussion of limit states is necessarily restricted to strength limit states. Thus, based on the concerns of the public, the strength limit state which should be most important in the specification is the ultimate capacity of the structure.

LRFD provides information which allows the engineer to determine both the resistance of the structure to a specified loading effect, and the probability that a specified load effect will exceed that resistance, i.e., the specified limit state will be violated. The specified limit state in LRFD is the ultimate strength of the structure. The factor of safety of the structure is represented directly by the reliability index which is a measure of the difference between the anticipated result, the mean value of the structural behavior, and the unwanted result —structural collapse.

The ASD method provides the engineer information to determine the stresses which will be imposed on a structure and limitations for those stresses. The specified limit state in ASD elastic design is the onset of yield in the structure. The factor of safety against exceeding the ultimate strength of the structure is based on a relationship between the yield stress and the allowable stress. The relationship between the ultimate capacity of the structure and the yield stress is not known, but has been set based on experience and has proven to be acceptable over time.

As a structural engineer, the question to be asked is, "What is it I really want the specification to do for me? Do I want a specification that allows me to tell the owner, contractor, and public with some reliability the actual capacity of the structure, and its ability to resist certain load effects, or one that allows me to design a "safe" structure based on past experience, but limits me to determining the onset of yielding in the structure, with no idea of the true capacity of the structure?"

Personally, the writer opts for the former.

### Paradigms

IN THE BOOK MENTIONED EARLIER, *DISCOVERING THE FUTURE — THE BUSINESS OF PARADIGMS*, Joel Barker discusses the theory of paradigms at length. In short, a paradigm is a method or process of doing something. A shift in the paradigm is a change in the method or process used to solve the same problems. For example, designing steel using an Allowable Stress Design method is a paradigm, while making the change to a Strength Design method is a paradigm shift. Typically, a paradigm is not very efficient initially because it must be learned and its use must be streamlined. As its use spreads and becomes familiar, the paradigm solves a great deal of problems efficiently. Then, as competition grows and more difficult problems arise, the original paradigm is not as effective because some of the original assumptions are too limiting, or new equipment has made the paradigm obsolete. This represents the point at which a paradigm shift must be made.

Barker states that the best time to shift paradigms is when its use is just beginning to spread. For a business to survive, it must anticipate the shift in paradigms and take advantage of them to gain an edge on the competition.

One property of a paradigm shift is the resistance to the shift. Practitioners who are invested in the present paradigm, as we all are with ASD, will continue with the present procedure even after its benefits diminish. As long as they can still solve problems, they will consider themselves successful and the cost of change too high. Many will continue in the old way until there is no other choice — when ASD is discontinued and eliminated from the code provisions. These are the ones who will miss the benefits in generation of new business through marketing of a better technology.

It should be pointed out that discussion concerning the specification, or criticism of certain provisions in the specification is healthy and leads to refinement. This is a further property of a paradigm as it comes into wider application and is important in the paradigm's development. Constructive criticism can help refine and improve a paradigm, while unfounded attacks can destroy a beneficial paradigm. Criticism, however, of a certain provision or suggestions for improvement which are frequently published is different from a rejection of the LRFD as a design method. Design professionals who keep current with engineering publications should read all of the information concerning the new LRFD provisions with a critical eye, and test the arguments against what is in the provisions before dismissing the whole specification because of a particular article or conversation.

### It's Time For A Change

WHEN COMPARED TO THE CONCRETE INDUSTRY AND THE DESIGN PROFESSION in other developed countries which are in the expansion phase of the USD paradigm, it appears that the structural steel design profession in the United States of America is moving into the final phase of the ASD paradigm. Some evidence of this is:

***1. The myriad of new systems for structural steel construction which do not fit into the ASD assumptions, such as:***

- Composite systems including columns, joists, trusses, shearwalls, and frames which have been developed and utilized for some time. Larry Giffis won the 1994 T.R Higgins award for his work with these systems.
- Partially restrained connections, including composite connections in frames typical of the work done by Roberto Leon (the 1993 T.R. Higgins Award recipient), and composite connections to provide continuity in beam framing similar to the concepts proposed by Neil Wexler and others proposed by Sam Easterling at the 1994 AISC National Steel Construction Conference in Pittsburgh.
- Composite parking garage systems using steel beams and precast decking presented at the 1993 AISC National Steel Construction Conference.
- Eccentrically braced frames which were developed by Dr. Egor Popov, are used extensively in seismic areas, and were applied in the east for wind resistance by Stan Lindsey.
- The new ATLSS (Advanced Technology for Large Structural Systems) connections which are being developed at Lehigh and were presented at the 1993 AISC

National Steel Construction Conference. This totally new technology may prove to save significant structural erection time and, thus, construction dollars.

***2.Canadians and Europeans as well as others have used USD for some time.***

The Canadian Institute of Steel Construction has been using a USD specification for structural steel design of buildings since the 1970s. Review of this specification shows that the load and resistance factors are similar to those used in the U.S. LRFD. Whether we like it or not, the U.S. structural engineering community will soon be competing in an international marketplace, and ASD will not provide a competitive edge against engineers who have been using USD for years.

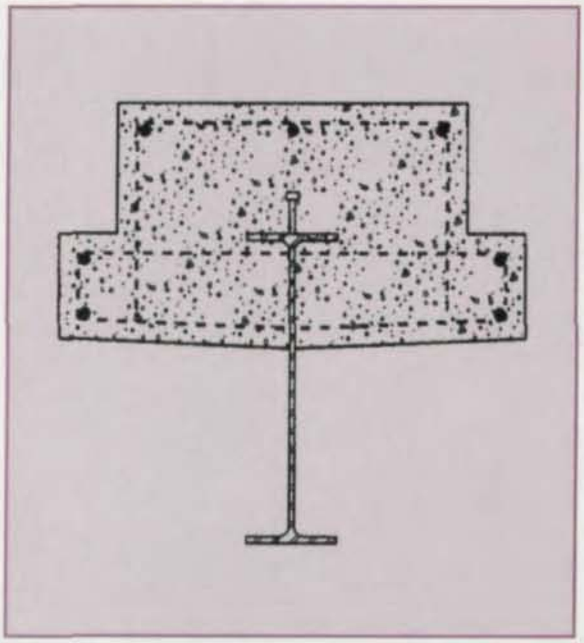
***3.Seismic provisions in the new codes provide loadings in the form of ultimate loads.***

The 1994 edition of the *Standard Building Code*, as well as other model codes, have adopted the provisions of the National Earthquake Hazard Reduction Program which specify seismic forces as ultimate, not service loads. Extra design steps are required to scale back the loads for using ASD procedures. Looking into the future, we could see the same procedure occur with wind and snow loads. These ultimate loadings are not compatible with ASD.

***4. New analysis procedures for frames are available which make the ASD method obsolete.***

As technological advances permit more heavily loaded columns because of high strength materials and more sophisticated analysis, the need for an accounting of secondary moment magnification and leaning column effects has become apparent even in ASD provisions as stated in section B4 of the ninth edition. New procedures have been and continue to be developed for analysis and design of frames in one step with no check

*As new steel systems are developed, most of them are designed to take advantage of the LRFD Specification. Shown at right is a detail for a composite parking garage system, which was presented at the 1993 National Steel Construction Conference.*



for stresses or K-factors. The computation capacity of the computers of today and the future allows for full 3-D analysis, including dynamic effects and secondary moment magnification. These powerful analyses allow for direct design of members without moment magnifiers and reduce design time.

***5. The increasing magnitude of renovation and addition related construction.***

With the building boom apparently behind us in the United States, it is apparent that a large percentage of the design market is already and will continue to be in the renovation and structural addition area. As witnessed by several engineers in published articles, application of LRFD in renovation work leads to greater structural economies. Because replacement or strengthening costs are so high, the ability to take advantage of the entire strength of an existing structure may make an otherwise unfeasible project viable. Further, engineers working in the area of assessing structural capacity, especially for existing buildings to be upgraded to meet higher seismic requirements, are considering utilizing the strength factors as a way to account for the age or condition of an existing structure.

***6. Several groups are developing unified specification that address all structural materials with one set of load factors.***

A unified specification in the United States would be the one change that would make engineering design a more reasonable and profitable profession. A USD version of masonry design is now available and a USD version of timber design is in development. Without an acceptance of LRFD, a unified specification will never happen.

The evidence is hard to refute; LRFD will be the only structural steel specification in the foreseeable future. The time for a wide acceptance of the LRFD specification by the design profession is now. For the only viable reason - survival of your business. As with any paradigm shift, the benefits of the change may not be clear, and it seems that the old ASD is working just fine, but this is the time to begin the change. Once your firm begins to use the LRFD specification, market the fact that your firm is on the cutting edge of technology and can provide the client the best structural solution to his problems. This will attract clients and that is the advantage to the paradigm shift.

### Just Do It

LRFD AS A DESIGN CONCEPT HAS BEEN AVAILABLE to the engineering profession since 1978. It was placed in a specification format eight years later in 1986 and was revised in 1993. The USD method and the use of probabilities in structural design has been an accepted practice for more than 30 years. The LRFD specification has been developed by researchers, educators, fabricators, and design practitioners through consensus over the past 15 years. LRFD is a proven and safe design procedure.

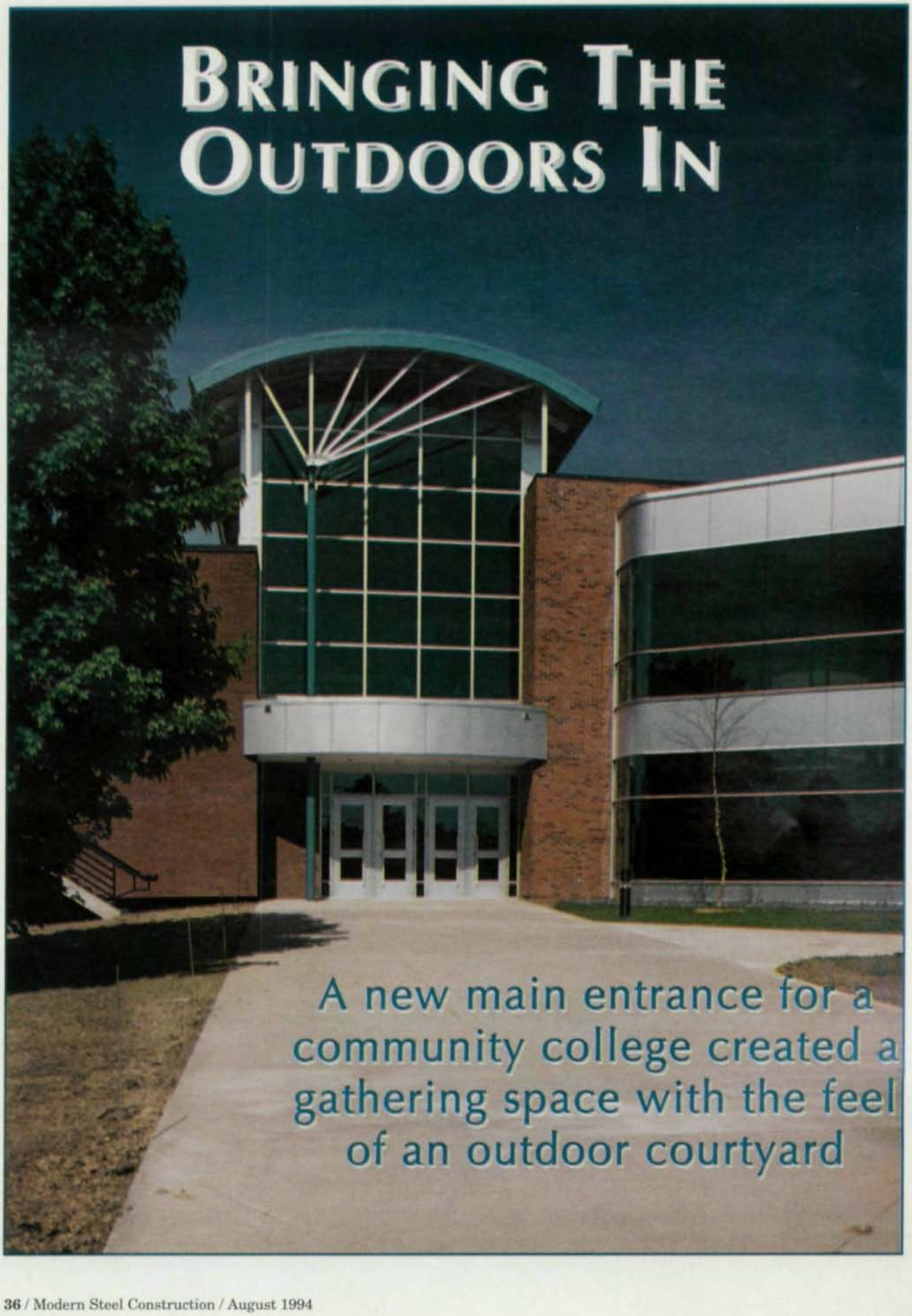
As professionals, it is our obligation to stay abreast of the latest technologies and provide the best product for our client. Further, as you use the LRFD Specification, your comments and input are needed to make this a more workable and effective document. One letter to the editor recently complained that the LRFD was the result of the "academic elite that monopolize the policy making boards." While this could not be farther from the truth since many board members are practicing engineers and steel fabricators, constructive input from more practicing engineers is needed. Use your experience with LRFD to make the document better.

While large structural construction cost savings may not be apparent now, as with the ACI code 30 years ago, new structural steel systems are ready to be applied using LRFD or are just on the horizon. Clients will be asking you to provide them the savings and architectural flexibility these systems afford. Whatever the cost to learn the LRFD specification, it is better to learn now, and take advantage of the paradigm shift. Use the LRFD Specification to gain a competitive edge.

*Kurt Swensson, Ph.D., P.E., is a project manager with Stanley D. Lindsey and Associates, Ltd.*

# Bringing The Outdoors In

A new main entrance for a community college created a gathering space with the feel of an outdoor courtyard

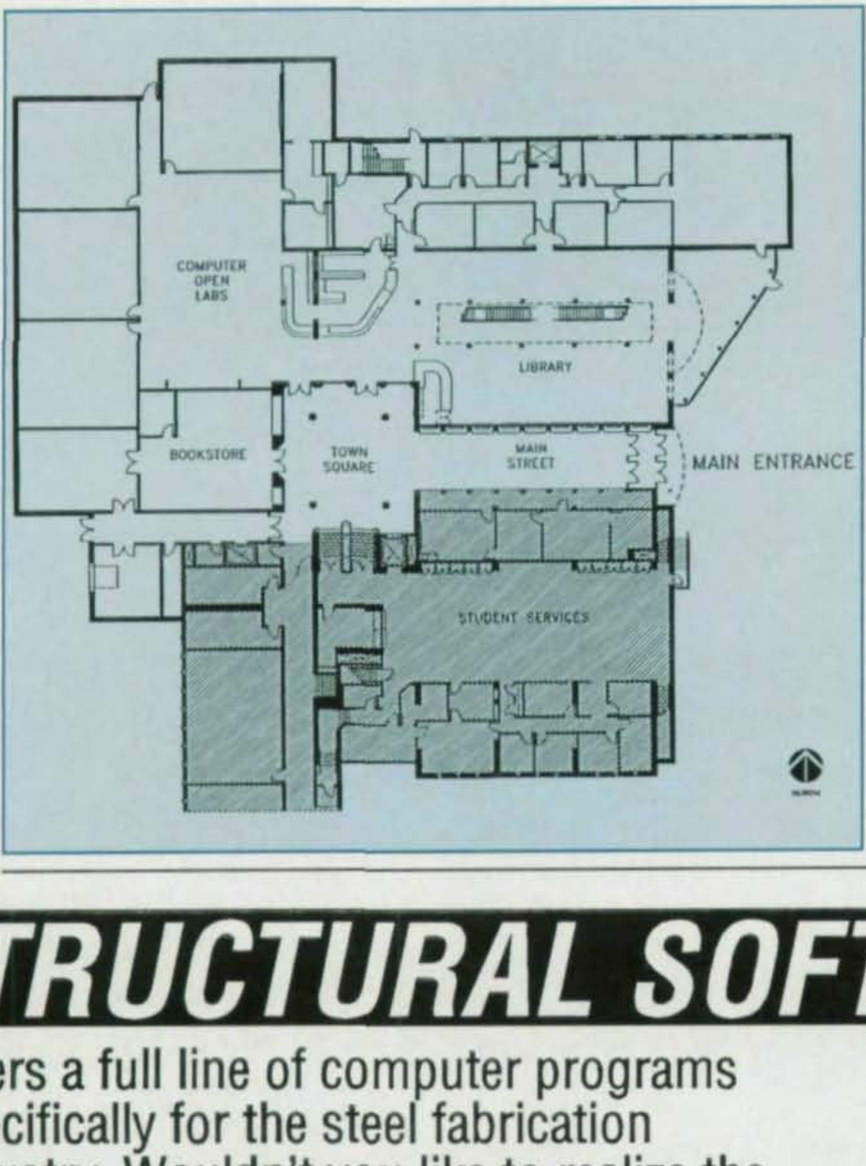


*A series of off-center trusses form a canopy over Austin Community College's Main Street. The trusses are supported on a steel "knuckle" resting on a steel girder spanning over six Lally columns. At the end of the corridor is the larger Town Square.*

As four-year college costs soar, more and more students are turning to community colleges. Adding to the congestion, an increasing number of older students are returning to school. As a result, many of these institutions, including Austin Community College in Austin, MN, are finding themselves squeezed for space.

When Austin decided on their first expansion in 24 years, the administration opted to look at the big picture. Rather than simply adding a new building, the $7.4 million project would include 36,000 sq. ft. of new construction and 133,000 sq. ft. of renovation. The renovation included updating life safety, mechanical and handicap access systems, as well as moving the administrative offices into the old library and moving the nursing classrooms into the old administrative space. The library, along with a bookstore and computer classroom space was accommodated in the new construction. But along with adding space and reconfiguring the campus, the project also involved creating a new identity for the campus.

"We sent a questionnaire to both students and faculty to find out what they thought was needed in the expansion project," explained Gary F. Milne Rojek,




*The shaded area in the diagram at left represents the existing building.*

R.A., project architect/designer for TSP Architects and Engineers in Minneapolis. "Almost every one said there was 'no front door'—that we needed a main entrance that would orient students and faculty to where they were."

The problem was the facility began its life as a secondary school and several buildings had been added in a hodge-podge fashion during the 1960s. Adding to the confusion was the design of the existing buildings—minimalist modern with boxy masonry buildings. Students and even long-term faculty often had to think carefully about where they were on campus and what was the best route to where they were going.

The solution was to create a

new main entrance/atrium corridor between the new library and the old library, which was converted to administration space.

### New Construction

THE NEW LIBRARY IS A TWO-STORY RECTANGULAR BUILDING featuring both concrete block bearing walls and selected areas of exposed steel. For example, a two-story study area features 8-in.-diameter prefabricated Lally columns with continuous 12-in.-deep wide flange beams supporting 8-in. hollow-core precast concrete plank roof deck.

While the rear of the south side of the new building, where the bookstore is located, was built almost against the existing building, the front of the south side of the new library is separated to form an atrium. Then, in the center of the south wall, the new building is further recessed and a square center court is created.

*The photo above, along with the two photos on the following pages show closeups of the connections for the tube trusses that support the steel deck roofing.*

"We get about 20 days of really nice weather here per year," said Milne Rojek. "And indoor spaces of any style or grace are few and far in between. The idea was to create an indoor space that would recall the concept of an outdoor space." Randy L. Moe, AIA, project manager/designer echoed that idea. "We tried to contrast the heavy masonry of the surrounding building with a more ephemeral structure to create an inside/out space. You get the feeling of being outdoors without the problems created by weather."

That desire for a light and airy structure led the designers to structural steel.

However, because the two structures varied in height, a conventional barrel vault truss system was rejected for framing across the new collonade, which the campus named "Main Street." The old building is a single floor with a high roof, roughly one-and-a-half stories in height. The new structure is two floors, but because of the need to accommodate modern mechanical equipment, is much taller than its older neighbor.

The project's designers decided to capitalize on this height differential both to bring natural light into the space and to create a more dramatic space. "The height differential created automatically created an asymmetrical space. We decided it was only natural to use an asymmetrical truss to frame the roof," Milne Rojek explained.

### Structural System

THE VAULTED ROOF IS SUPPORTED ON A TUBE TRUSS THAT CONNECTS to a single row of $8\frac{3}{4}$-in.-diameter Lally columns with continuous W16 x 26 steel beams to support roof trusses. But instead of placing the row of columns in the center of the truss, it is offset next to the lower building and then tied into that building for lateral support. Roof trusses consist of WT 6 x 13 top chord with 3-in. x 3-in. x $\frac{3}{16}$-in. tube steel diagonal members welded to asymmetrical "knuckles" fabricated from $\frac{1}{2}$-in. and $\frac{3}{8}$-in. steel plate. At each end of each truss is a 4-in. x 4-in. x $\frac{1}{4}$-in. tube steel column. Lateral bracing is supplied by $1\frac{1}{2}$-in. x $\frac{1}{4}$-in. steel strap X bracing between trusses on the beam line and $\frac{1}{2}$-in.-diameter rod X bracing at the ends of each truss between the 4-in. x 4-in. steel columns. Each $8\frac{3}{4}$-in.-diameter prefabricated column is braced back to the wall of the existing building with a W6 x 9 steel beam. The roof deck is $1\frac{1}{2}$-in. acoustic metal deck.

Between the roof and the lower building is a row of large

clerestory windows, with smaller windows on the opposite side. The roof overhangs the windows, allowing the low winter sun to provide heat and light, while only allowing ambient light from the high summer sun.

A similar framing system is used for the open square area at the end of the atrium. Called "Town Square," it has an exposed metal roof supported by four 24-in.-diameter concrete columns. Extending radially from the top of each column is a network of 3-in. x 4-in. x $^1/_4$-in. diagonal tube steel "tree branches," which support a 12-in. x 8-in. x $^1/_4$-in. tube steel grid with a $1^1/_2$-in. acoustic metal deck roof.

Because of the nature of the framing, the bulk of the fabrication and erection work was performed in the field. The tube steel grid members were welded together, based on field measurements of the space, on the roof of the adjacent new bookstore. After the grid was assembled, temporary steel columns were set directly adjacent to each of the four permanent columns to support the grid during erection of the diagonal "branches." The grid was then lifted by crane, as a single unit, leveled, and attached to the temporary columns and the four small corner columns. Finally, each of the 48 diagonal "tree branches" were placed, one at a time. The pinned top connection was welded to the grid in the appropriate location and after mitering and cutting the 4-in. x 3-in. tube members to length, they were swung into place and welded to a small vertical fin at the top of the permanent columns.

"The whole essence of the new addition is an investigation of the difference between outside and inside," Milne Rojek said. Spaces were carefully layered to bring light deep into the building. "But the layering goes beyond just lighting," Moe stressed. The corridor is the most public area, and it offers the most natural light. As you go further into the building—away from the corridor—the spaces become more private. In the library, for example, you move from the periodical area, to the book stacks, to study spaces, and finally to private offices.

The materials for the project also were selected to add to the inside/outside nature of the project. "We set up a contrast between the heavy masonry and the light steel," Moe said. "That dichotomy helped to create the feel of inside and outside."

And finally, the public, outdoor nature of the new corridor is enhanced by a series of benches along one wall on both the first and second level.

# FUNCTION COMBINED WITH FORM

The roof shape for a new educational resource center was dictated by both a need to complement neighboring buildings and a requirement for satisfactory acoustics

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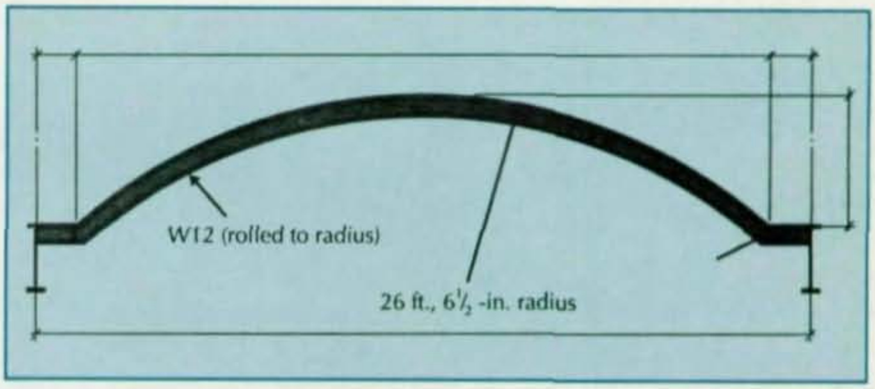
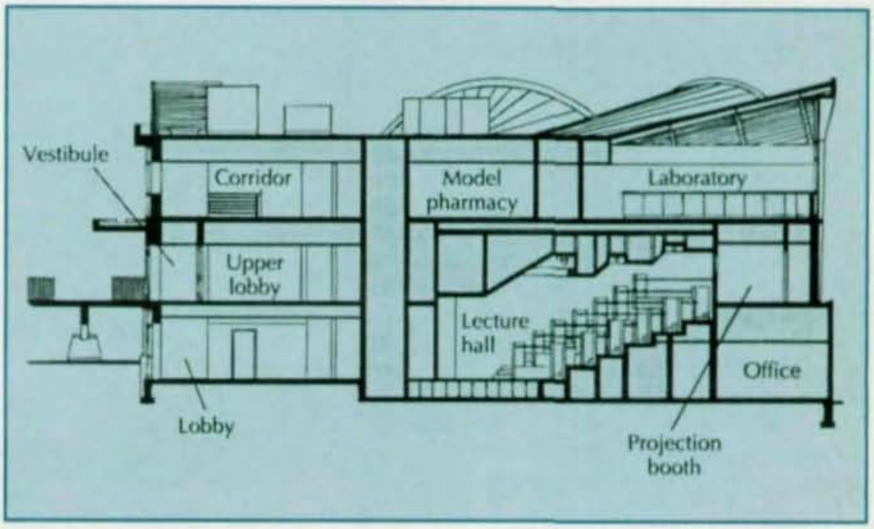
**By Eliot W. Goldstein, AIA, and Michael DeBiasse, AIA**




WHEN THE CHICAGO COLLEGE OF OSTEOPATHIC MEDICINE DECIDED TO EXPAND its Downers Grove, IL, campus to create a new 32,000-sq.-ft. Educational Resource Center for the School of Pharmacy, it faced a major challenge: How to respect the sculptural forms of the existing campus while keeping a lid on construction costs.

The site for the expansion was a gently rolling lawn adjacent to two dramatic cast-in-place concrete shell structures housing a gymnasium and a swimming hall. The sculptural qualities of these existing buildings was most pronounced at their roofs. The domed roof of the gym was supported by four massive abutments, while the roof of the natatorium consisted of a series of parallel barrel vaults. Both buildings were the equivalent of three stories in height, though each contained only two floors. Their facades consisted of battered exposed-aggregate concrete and the ground floor walls featured brick-veneer without windows for the first floor and glazed curtainwall clerestories above.

In response to our client's mandate that the new building respect the architectural precedents immediately surrounding it, we chose to reinterpret the barrel-vaulted forms of the concrete-framed swimming hall.

## Lecture Rooms Dictate Design

THE NEW CONSTRUCTION IS POSITIONED so as to define the south edge on an incomplete "quadrangle" bounded on the west by the two athletic buildings, on the north by the College's administration building/library, and on the east by the student center. Its overall height was set to approximate that of each of its three-story neighbors, and its exterior materials were selected to echo those typical of the entire campus, including the use of large, nonstructural precast arches.

A principal factor in the design was the need to house two separate, pie-shaped, 175-seat lecture rooms, plus 26 faculty offices, two conference rooms and six 800-sq.-ft. research/teaching labs plus several smaller special-purpose labs. While designing rectangular lecture rooms would have been simpler, the faculty preferred pie-shaped rooms for their superior site lines, which was further enhanced through tiered seating in the two-story-high rooms. In addition, the design required that both lecture rooms were immediately accessible from the main lobby. These requirements essentially dictated that the shape of the building be a half circle—two pie wedges with a central corridor in between.

Because the activities planned for the lecture rooms did not require windows, it was determined that the best way to relate the facades of the new buildings to the neighboring structures was to locate the lecture rooms on the first floor. This left the top level for the laboratories and, fortunately, the floor area required for the six labs was nearly identical to that of the two lecture rooms below them. One problem, however, was how to design functional labs in the 30-degree pie-shaped spaces created from dividing a half-circular building design into six equally sized rooms.

Early on, we decided that each lab should be fed from a circumferential corridor, and that it should have a faceted, rather than a curved, exterior wall. Simultaneously, we found that the most efficient way of satisfying the egress requirements applicable to the lecture rooms was to divide each of them into three nearly identical seating area with four radiating aisles. We faceted the back walls of the

lecture rooms in sync with their seating areas, which also was in sync with the laboratories above.

This design also lent itself to the creation of a distinct exterior that complemented the surrounding structures. In the existing buildings, a geometric distinction between the exterior walls of the ground floor and those of the top floor was achieved by battering the former but not the latter. In the new building, a similar effect was achieved by curving the exterior wall of the ground floor, but faceting the exterior wall of the top floor.

### Roof Design

WHILE WE WANTED THE ROOF OF THE NEW BUILDING TO RELATE THE ARCHES of the neighboring swimming hall, the semi-circular plan of the new building did not lend itself to a single barrel vault; instead each lab would have its own barrel vault, with each roof having a 10-degree slope at it extends from the perimeter to the center of the building. We considered a number of ways of framing such a system, including using steel trusses that became proportionately smaller as they approached the center of the curvature or of using arched glue-laminated beams.

However, upon further examination we determined that the shape we were looking for was actually a cylindrical section. While a barrel vault results from slicing a hollow cylinder parallel to its longitudinal axis, what we needed was a slice not quite parallel to the longitudinal axis. The resulting shape would describe an elliptical profile on the cutting plane. Since a cylinder has a constant radius, we would be able to describe this shape fairly easily, and would be able to construct it in just about any material.

Once the shape of the roof form was determined, the decision of what material to use moved beyond pure aesthetics and into a question of function. Since the roof form would be so visually dramatic, it was decided that the structure should be left exposed on the inside. Therefore, it was essential that the finished ceiling be free of acoustic focusing (a common problem with reflective concave surfaces) and be highly sound absorptive. Since concrete and masonry roof decks have problems with both of these requirements, the obvious solution was to use an acoustic steel deck. Deck supplier was AISC-associate member Consolidated Systems, Inc.

The vaults are framed with 12-in. wide flange members rolled to a radius. However, since it was clear that the elliptical edges of each vault's intersection with the roof plane did not coincide with the straight edges of the supporting girders, an intermediate zone needed to be created between the trapezoidal area described by each labs primary framing and the elliptical area described by its secondary vault framing. This actually proved to be beneficial, though, since this zone was utilized for running ductwork, power, sprinkler piping and laboratory services. The minimum depth of each zone, therefore, was set to the accommodate the depth of each laboratory's upper cabinets.

The ribs of the vaults have a constant radius, but varying arc and chord lengths, and the members are tilted to the same degree as the barrel vaults of which they are part. Horizontal stubs at their ends span the gap of varying sizes between the elliptical edge of the vault and the trapezoidal primary framing. Structural engineer on the project was Barry A. Goldberg & Co., Skokie, IL. Design and analysis was performed using Intrasoft's (formerly SAI) Plane

and COMPBM programs.

The vaults are supported on wide flange columns and primarily utilize simple connections, though some Type 2 moment connections were used to resist wind loads. Construction manager on the project was Turner Construction Co.'s Chicago office and fabricator was AISC-member Zalk Josephs Fabricators. Acoustician on the project was Yerges Acoustics, Downers Grove, and site engineer was Bollinger, Lach & Associates, Inc., Oak Brook, IL.

## Easy Orientation

TO DISTINGUISH THE TWO TEACHING LABORATORIES FROM THE FOUR RESEARCH LABS, we decided to give each of the former a linear skylight along the crown of its vault. Shallow steel channels were run longitudinally to support the skylight's edges. To conserve energy, insulated translucent fiberglass panel-type units were chosen. It turned out, by pure coincidence, that the slight tilt of the long axis of the barrel vault was just enough to satisfy the minimum slope requirement of the skylight. Thus, we were able to avoid more elaborate—and expensive—skylight configurations such as vaults or gables.

Whereas the overhangs of the swimming hall's concrete vaults project from their respective facades, we decided to create our overhangs by having the face of each precast arch follow the true curvature of the lower portion of the building's facade, while the curtain wall immediately below followed the straight segments of the faceted laboratory floor plan. Therefore, the overhang is largest where the curtain wall is the tallest—at the mid-span of each arch. The precast arches span about 30 ft. and are tied back to the steel structure not only to carry vertical loads but to prevent overturning from their eccentricity. Their color and texture match the cast-in-place concrete of the swimming hall.

The exposed underside of each vault is painted bright white. Along the curved elliptical fascias are regularly spaced HID up-lighting fixtures that use the acoustic metal deck ceiling as a reflector. Although they produce remarkably uniform illumination of the lab benching, the large windows assure enough natural illumination that the lights are rarely needed during the day.

*Eliot W. Goldstein, AIA, was the partner in charge of design and Michael DeBiasse, AIA, was the project manager for The Goldstein Partnership, an architectural firm located in West Orange, NJ.*

# Bar Codes Track Fabricated Steel

## A new system is being used by a Louisiana fabricator to track steel from fabrication through erection

By C.F. Dahlberg, Jr., and Wallace Sevin, Jr.

WITH THE LATEST BUSINESS RESURGENCE IN NEW ORLEANS, the developer required an outrageously tight fast track schedule for a new manufacturing plant. During one of the many project meetings in the owner's Houston office as construction got underway, he wanted an update of steel shipments to the project's galvanizer. Rather than picking up a phone and calling the fabricator in Baton Rouge, LA, the Manhattan-based general contractor flipped open his laptop computer, dialed up a central database located in Mandeville, LA, and had immediate access to the location of every piece of steel required for the project—whether it was at the fabricator, galvanizer or already on-site.

The central database is part of the SCATS (Standard Commodity Accounting and Tracking System) bar code tracking system with which some fabricators are just beginning to work—though none to the degree mentioned in the above scenario.

About a year ago, AISC-member SS&S Fabricators in Baton Rouge, LA, and St. Mary Galvanizing in Morgan City, LA, began the joint use of SCATS and it has now been used on several large jobs since then. The program was designed by Technical Management Systems, Inc., of Mandeville, LA, a computer programming firm specializing in bar codes, in coordination with SS&S and St. Mary Galvanizing.

Much of the last year was spent debugging the program, but it is now running smoothly. Every piece of steel fabricated by SS&S and shipped to St. Mary Galvanizing is bar coded and those bar codes are used to track the steel during both the fabrication and galvanizing processes. When SS&S also acts as the erector, the bar codes also are used to track the steel throughout the erection process.

### How It Works

SCATS BEGINS WITH THE FABRICATOR COMPLETING DATA FORMS with details about the project team—fabricator, galvanizer or paint contractor, erector, structural engineer, owners representative, etc. This is an important first step because each project member is assigned a password, which is required to access any project information in the central database.

SS&S uses Paradox computer software, a popular off-the-shelf program, to create a data base of all the piece numbers and their descriptions for each fabrication job. At the end of each day, a microcomputer, working with the ASCII file from the Paradox data base, runs the SCATS program and two sets of labels are produced for the pieces to be cut in the fabricating shop the next day. One set of labels goes with the next day's cut list into the shop and, as each piece of steel is cut for the first time and its piece number is written on it with a welding rod, the related bar code label is affixed to the piece. From this point all the way through erection, that bar code will be used to identify that piece of steel.

In addition to the piece number, the label has a human readable translation that shows the names of the fabricator, galvanizer and erector, and a description of the piece, including its weigh, job number, and other information such as the lay down area.

After fabrication, the piece is inspected and the label is scanned by the inspector to indicate acceptance of the work.

When the material is loaded on a truck for dispatch to the coating contractor or for the job site, the material is again scanned. One immediate advantage of the system is that the hand held scanners can accumulate the tonnage loaded on each truck to avoid overweight conditions. Also, a paper report of all the pieces on that truck is generated.

At the end of each day, the scanners are placed in a recharging dock that also serves to upload the information into a local data base. During the night, the local computer automatically dials the central computer in Mandeville and uploads the information to a central database from which anyone with the correct password can obtain status information.

When the truck arrives at the coating contractor or the job site, the pieces are scanned as they are unloaded. When the information is uploaded to the central database, any discrepancies between the shipping and receiving list are automatically noted and an error report is produced.

While at the painting or fireproofing contractor, the material has to be unlabeled for the brief time it is being processed and then relabeled with the duplicate set of labels that were sent along with the fabricator's paperwork. Currently, while the label is readily stripped, the contractor must use a grinder to remove any glue residue. Technical Management Systems is developing a label that doesn't leave a glue residue, and this new label should be available soon.

As the material is loaded for shipment to the job site, they are again scanned, and the scanner prompts the loading crew for pieces that are not yet loaded and provides error messages when needed. That information is then uploaded to the central database, and the erection crew receives shipping information.

The cycle repeats at the construction site, with the erection crew scanning the material as they receive it so any discrepancies can be easily discovered.

### Benefits And Costs

THE PRINCIPAL BENEFIT FROM THE USE OF SCATS has been greatly increased accuracy regarding the status and whereabouts of each piece of steel in a complicated job, which may have thousands of pieces. In addition to smoother shipping schedules, since pieces can be easily located, change orders are more easily accommodated—and without expensive duplications.

The SCATS system currently in use consists of a number of hand-held scanners, the bar code printer, and the SCATS software running on a DOS-based PC equipped with a modem. The total cost for the fabricator was approximately \$10,000, while the coating contractor, who requires fewer scanners, spent about \$3,500, not including the purchase of a computer. In addition, there is a \$1,500 per year maintenance fee and a \$60 per hour connect fee.

In addition to a centralized data base version of SCATS, Technical Management Systems is presently working on a standalone system that would allow a fabricator to use the bar code tracking system without the central database.

Also, in the future, the company intends to interface the SCATS system with an accounting package, which would allow invoicing based on SCATS data, as well as verification of tonnages for percentage completion payments. And, since the data is transmitted by modem, global application will be possible through satellite telecommunications.

*C.F. Dahlberg, Jr., is with St. Mary Galvanizing Co., Inc., in Morgan City, LA, and Wallace Sevin, Jr., is with SS&S Fabricators, Inc., in Baton Rouge, LA.*

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Telephone: 412/331-1776
Fax: 412/331-0383
Information: The new Uni-Bug cutting and welding machine is small enough to carry a cutting torch or welding gun into narrow work areas or around very tight curves without the use of a track. It weighs only 8 lbs. and its new design enables it to run on the workpiece. It runs on material up to $^7/_8$-in. thick and can go from a straight to 6 in. radius inside or out.

**Circle no: 84**

PRODUCT: COATINGS INSPECTION INSTRUMENTS
Company: KTA Services, Inc.
Address: 115 Technology Dr.
Pittsburgh, PA 15275
Phone: 412/788-1300
Fax: 412/788-1306
Information: A new 14-page catalog provides technical information and pricing for equipment, training materials and technical manuals. Equipment includes: worker exposure monitors; air flow monitors; environmental air monitors; confined space monitors; and lead testing and analysis. Also available is the 2nd Edition of the *Industrial Lead Paint Removal Handbook*. The company also offers a series of seminars.

**Circle no.: 85**

PRODUCT: STEEL JOIST SPECIFICATIONS
Company: Steel Joist Institute
Address: 1205 48th Ave. North, Suite A
Myrtle Beach, SC 29577
Phone: 803/449-0487
Information: A 28-minute videotape serves as an introduction to steel joists and as a tool for the proper selection and specifying of steel joist products. The $34.95 tape provides a brief history of steel joists, and describes the four standardized steel joist products and how they are used in buildings.

**Circle no: 54**

PRODUCT: PORTABLE MAGNETIC DRILLS
Company: Hougen Manufacturing
Address: G-5072 Corunna Road, P.O. Box 2005
Flint, MI 48501-2005
Information: Drilling holes in large tubing and pipe is greatly simplified with a new portable magnetic drill adapter. This newly designed adapter converts Hougen's line of Rotabroach Portable Magnetic Drills for safe and efficient use on large steel pipe and tubing so that holes up to $2^1/_{16}$-in.-diameter can be cut safely through round materials of 3-in.-diameter and larger. The adapter kit consists of a platform-type bracket and securing chain. A single adjusting nut draws the chain tight, thus locking the platform firmly into the desired location.

**Circle no: 86**

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