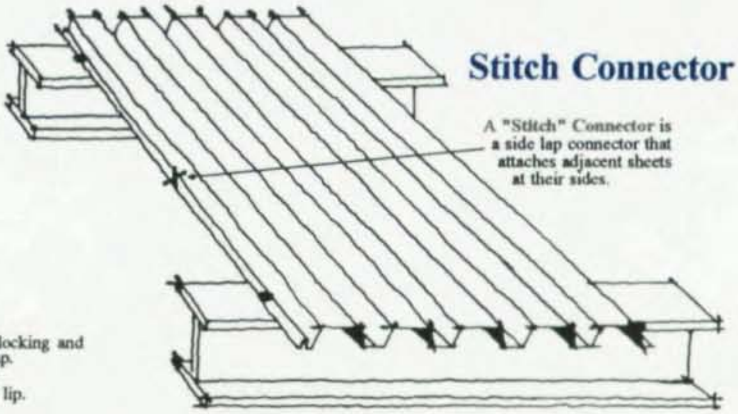
MODERN STEEL CONSTRUCTION

January 1995 $3.00

Renovation

deck connection terms

Stitch Connector

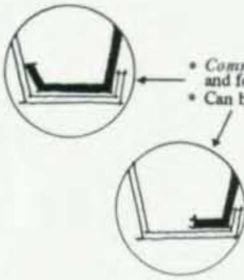


A "Stitch" Connector is a side lap connector that attaches adjacent sheets at their sides.

Side Lap Types

- *Common names include:* interlocking, button punch, and bayonet side lap.
- Can be button punched, welded, or screwed.
- Horizontal return on "female" lip.

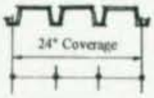
- *Common names include:* interlocking and button punch and bayonet side lap.
- Can only be button punched.
- No horizontal return on "female" lip.



- *Common names include:* overlapping, barge and foot, and nestable.
- Can be welded or screwed.

- Provides adjustment when required.

Typical Frame Fastener Layouts
for roof deck



24/4 pattern

3" N deck

- **Note:** In general the nomenclature is "cover width"/(number of welds).

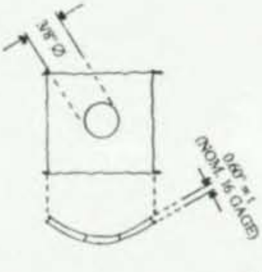
30/6 pattern
30/4 pattern
30/3 pattern

1½" B and F deck

36/9 pattern
36/7 pattern
36/5 pattern
36/4 pattern
36/3 pattern

1½" B and F deck

Welding Washer



- Welding washers are to be used on deck products lighter than 22 gage (0.028"). Do not use welding washers on side laps.

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Gateway Western Railway's bridge at Glasgow, MO. after the flood of July 1993.

NOV. 16TH, 1993

Constr. Mgr.: Design Nine, Inc. St. Louis, MO.
Photography : Dale Graham, Fayette, MO.

60 days after award; thanks to 140 tons of ARBED W44 x 335 Tailor-Made Beams.

JAN. 14TH, 1994

Fabricator : Phoenix Steel, Inc., Eau Claire, WI.
Erector : St. Louis Bridge Co., Arnold, MO.

Consulting Engineers: Modjeski & Masters, New Orleans, LA.
Steel supplier: 140 tons of ARBED W44x16x335 rolled WTM (Tailor-Made) beams in ASTM A572/Gr50, from the TradeARBED stock in Blytheville, AR.

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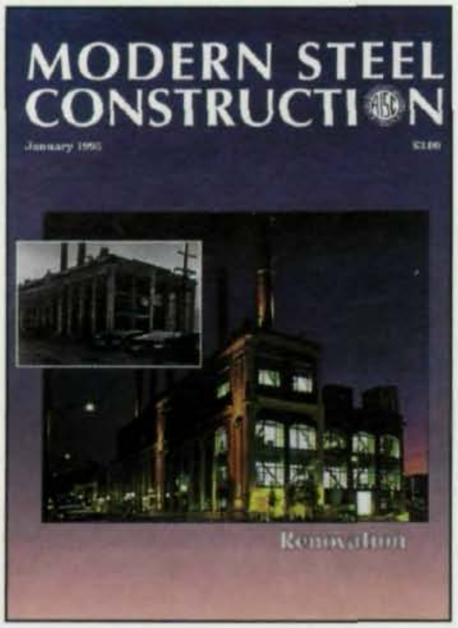
- 390 Brant Street, Suite 300, Burlington, Ontario, Canada L7R 4J4. (905) 634-1400, Fax (905) 634-3536.

Please circle # 35

MODERN STEEL CONSTRUCTION

Volume 35, Number 1 January 1995



Not only did a former steam plant need to be reconfigured to accommodate the needs of a pharmaceutical research company, but it also had to be brought up to current seismic code. The story behind this project begins on page 36.

FEATURES

DEPARTMENTS

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Qualified Optimism

FOR THE PAST FEW YEARS, JANUARY HAS BEEN A PRETTY DEPRESSING TIME OF THE YEAR FOR ME. I guess it's been a combination of post-Christmas blahs, the awful Chicago winters and a depressed construction market. But 1995 is shaping up to be quite different, and not just because I'm looking forward to my upcoming nuptials. In addition to my personal pleasure, this is the first time since the end of the boom years of the late 1980s that I've heard anyone express optimism about the non-residential construction market.

The buzz started, at least for me, a few months ago at a Peddinghaus open house. Big pieces of fabrication equipment (these things cost in the hundreds of thousands of dollars) were selling—well, maybe not like hot cakes, but at a rate no one had seen for at least several years. A couple of large fabricators were in the office not too long afterward, and they actually had some smiles on their faces. And to top it all off, not once, not twice, but three times in the past month I've spoken with engineers about writing articles on interesting projects and have been told that they were too busy with new work to talk about their old stuff.

Okay, I know we're not taking about a return to 1989 levels. But I firmly believe we're over the hump. Not only is the amount of work available increasing, but the number of firms out there competing for it has decreased.

However, the market is still going to remain incredibly competitive and I don't think we're finished with the current industry-wide shakeout. There are still some weak firms that are likely to close their doors in the coming months.

The question, then, is what can firms do to make sure they're on solid footing? Whether you're a fabricator or an engineer, the answer is the same: stay current. For fabricators, this means making sure your plant's equipment and software is state-of-the-art. While it may look like an expensive investment now, it will pay off in the long run. For engineers, it means investing the time to stay current with up-to-date design practice (such as LRFD, eccentrically braced connections, partially restrained composite design, and cutting edge design & analysis software).

It also means investing the time and money in continuing education. AISC offers seminars, breakfast meetings and an annual conference (this May in San Antonio). Likewise, ASCE, local fabrication groups, and local engineering associations offer continuing education opportunities. And lastly, consider subscribing to one or more journals—and reading them. Perhaps the best—and most practical—of the bunch is AISC's quarterly Engineering Journal. Coming up in the first quarter of 1995, for example, are articles on: *Practical Approaches to Mill Building Columns Subjected to Heavy Crane Loads*; *A Practical Approach to the Leaning Column*; and *Geometrical and Mechanical Properties of Large Rolled Steel Angles*. A one-year subscription costs only $18 ($24 outside the U.S.) or $45 for three years. To receive a subscription, send a check to AISC, P.O. Box 806276, Chicago, IL 60680. **SM**

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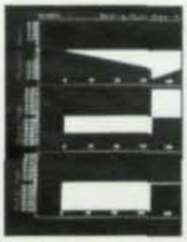

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STEEL INTERCHANGE

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:

In what instances, if any, and under what criteria can the attachment of grating with mechanical fasteners be used to provide lateral bracing to the compression flange of the members supporting the grating in applications such as walkways and catwalks?

Our company manufactures industrial grade fiberglass grating for walkways and catwalks supported by all medias, i.e. steel, aluminum, stainless steel, timber, and fiberglass beams. Weight reduction is very critical for this type of application, and eliminating cross beams is quite common.

Although design criteria for this type of application is limited, two parameters used for design are:

1. The type of mechanical fasteners used - must be capable to resist cross movement and/or twisting of the compression flange. When tightened, the clamping action should produce the proper friction between grating and beam.

2. Use L_c = maximum unbraced length of the compression flange or 2'-0" maximum to determine fastener spacing.

These two general rules seem to satisfy both the fastening requirements for the grating and lateral support for the compression flange.

Richard L. Cole, P.E.
Aligned Fiber Composites
Chatfield, MN

Serviceability is a particular concern for crane systems in industrial buildings but is not clearly covered in the standard code literature. What are deflection limits for crane runway systems?

The references given in a previous Steel Interchange column are mainly concerned with cranes and hoisting equipment. If someone is interested in industry standard references for allowable crane runway deflections, the following are more appropriate:

- Fisher and Buettner, *Industrial Buildings - Roofs to Column Anchorage*, Design Guide 7, AISC, 1993.
- *Guide for the Design and Construction of Mill Buildings*, Technical Report No. 13, Association of Iron and Steel Engineers, Pittsburgh, PA, 1979.
- Merritt, F. S., *Structural Steel Designers Handbook*, McGraw-Hill Book Co., New York, 1972.
- Gaylord, E. H. Jr. and C. N. Gaylord, *Structural Engineering Handbook*, 2nd Edition, McGraw-Hill Book Co., New York, 1972.

Gary J. Davis, P.E.
Phoenix Engineering Services
South Milwaukee, WI

Specifications currently exist which require minimum pretensioning loads for slip critical connections. There is, however, no guidance regarding minimum pre-loading of anchor bolts which occur at column bases. While in most situations this issue is academic since the anchor bolt nut and thread projection are below the plane of the concrete slab on grade and are eventually embedded in concrete at the slab isolation joint, there are instances where the nut and thread projection remain exposed. Is tightening the nut to "snug tight" and tack welding the nut to the bolt thread the only solution in preventing the nut from backing off?

Snug tightening and tack welding the nuts is not the only solution to prevent the nuts from backing off. We have specified A449 high strength anchor bolts (tensile strength = 105 to 120 ksi) instead of the ordinary A36 anchor bolts when the structure is subject to fatigue loading.

We pretension the bolt to develop 70 percent of the specified minimum tensile strength of the bolt. The bolt is greased with bondbreaker all the way to its end to permit stretching of the bolt while tensioning. The tension is developed into the footing by an adequately designed heavy plate at the bottom of the bolt. To further prevent the nut from loosening (which is not likely to occur for a properly pretensioned bolt), a lock nut or Pal nut can be added to secure the nut after pretensioning.

We used the A449 anchor bolts for a 160' tall steel tubular tower that supports a 600 kW wind turbine unit. The tower was designed to meet the UBC and Eurocode 3 Fatigue Provisions. Eurocode 3, Chapter 9, Fatigue, specifies an extremely low stress range for an ordinary anchor bolt without preloading (the lowest stress range category in the Eurocode). The use of high strength anchor bolts with preloading is apparently the common practice in Europe when the fatigue strength is critical in the structural design.

David L. Koo, C.E.
Warren A Minner & Associates
Bakersfield, CA

New Questions

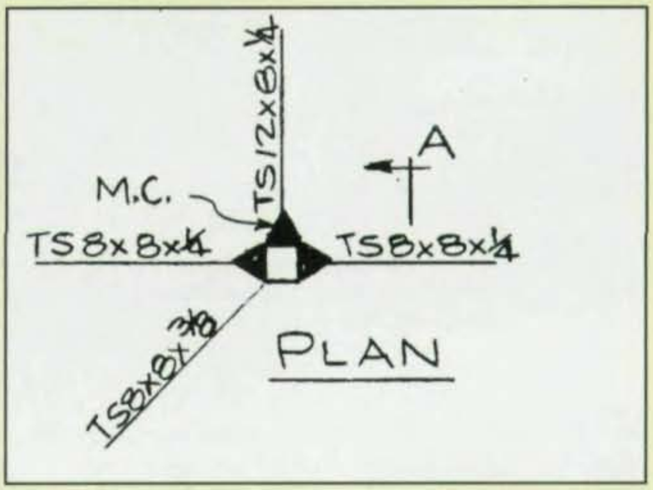
Listed below are questions that we would like the readers to answer or discuss.

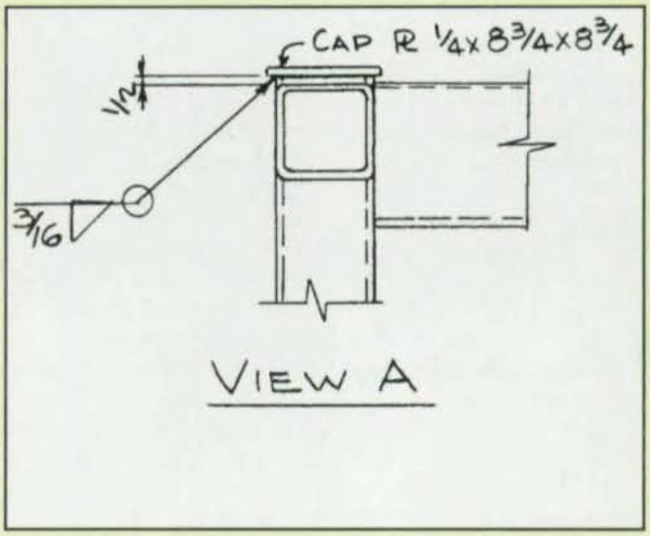
If you have an answer or suggestion please send it to the Steel Interchange Editor, Modern Steel Co nstruction, One East Wacker Dr., Suite 3100, Chic ago, IL 60601-2001.

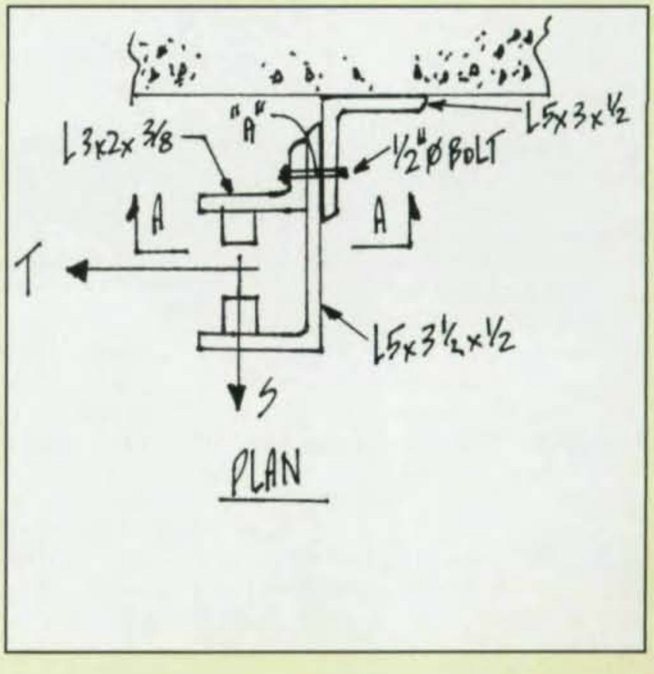
Questions and responses will be printed in future editions of Steel Interchange. Also, if you have a question or problem that readers might help solve, send these to the Steel Interchange Editor.

In the partial plan shown (top & middle), each of the tube beams is to be moment connected to the tube column by welding. All steel is exposed to view of pedestrian traffic, but is protected from the elements. What is an economical procedure for making the joints?
William Dyker
Naperville, IL

How is the L5 x $3^1/_2$ x $^1/_2$ angle shown in the figure (bottom right) designed? The angle is used as a rail guide for a roll-up door and is bolted to other steel members 12" on center.
Glenn Whritenour
Bechtel Savannnah River, Inc.
Augusta, GA







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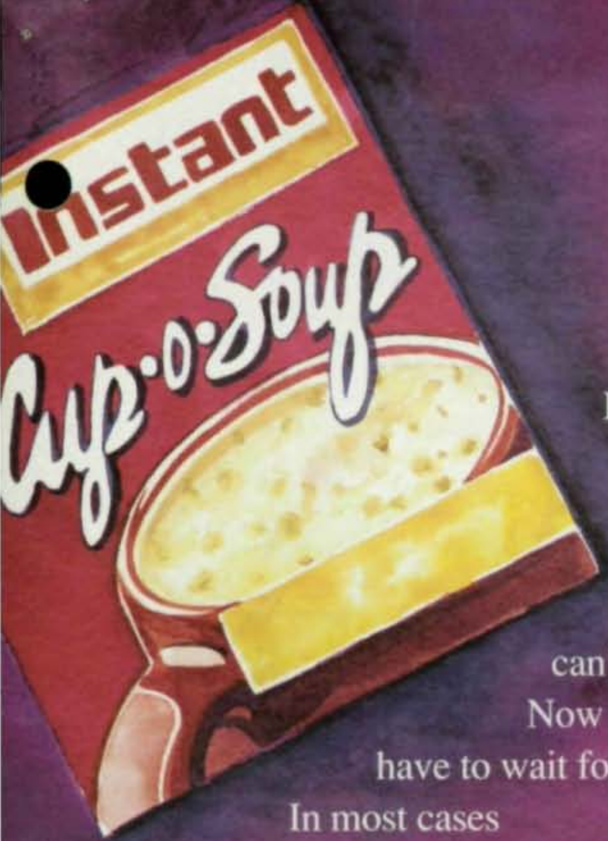

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CHAPARRAL STEEL

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IN MEMORY

By Mark V. Holland, Chief Engineer, Paxton & Vierling Steel Co.

In October, John D. Griffiths, P.E., former AISC regional engineer and most recently a vice president of engineering at AISC-member Paxton & Vierling Steel Co., passed away.

His contribution to the industry cannot be measured in the papers he wrote or the times he spoke. Nor on his recent contributions, such as helping to develop the modern format of the latest AISC Specifications and Manuals. John's greatest contribution was his passion for his life's work during his more than five-decade career.

He came from an age when an engineer would sign in at a hotel and put behind their name "P.E.". It always saddened him to see engineers use disclaimers and approver notes in an attempt to dilute their responsibility. John would always get annoyed by engineers who tried to over-complicate the behavior of steel One of his favorite questions for them was to ask them, through examples, to explain how adding stiffness to a frame could cause it to collapse.

I was one of the lucky young engineers who was able to work under John's tutelage. I remember once computing the shear center of an odd shape. After several hours and many pages of triple integrals, I proudly showed John my work. With only a few lines of simple calculations, he approximated my answer closer than any shop tolerance would require. What the steel industry will be missing, with the passing of John and of men like him, is this practical, accurate and simple understanding of the behavior of steel.

"INNOVATIVE PRACTICES IN STRUCTURAL STEEL" VIDEO NOW AVAILABLE

Though issued too late for Christmas, structural engineers, fabricators and others involved with the design, fabrication or construction of steel-framed buildings can give themselves a late present by purchasing a video-tape version of AISC's popular "Innovative Practices In Structural Steel."

The four-tape series includes information on the latest advances in structural engineering software; an overview of the changes in the 1993 Load and Resistance Factor Design (LRFD) Specification; NEHRP seismic provisions; semi-rigid composite connections, and a look at recent changes in the steel industry and how they affect designers and contractors.

An overview of future technological developments, such as the automated erection system being developed at ATLSS Laboratories, also is presented.

Filmed during the Chicago seminar last year, featured speakers are: Raymond H.R. Tide, former AISC regional engineers and currently a senior consultant with Wiss Janney Elstner in Northbrook, IL; Steve Schneider, Ph.D., an assistant professor at the University of Illinois; Gus Bergsma with Ram Analysis; Robert Lorenz, AISC director of education and training; and Andy Johnson, vice president of AISC Marketing, Inc.

Cost of the video package is only \$75 plus \$5 for shipping & handling (additional sets of handouts are available for \$15 each). In addition to the four videotapes, the package includes the full set of handouts from the lecture. Included are: a copy of the LRFD Specification; an introductory booklet presenting an overview of the Specification; "Interim Guidelines for Repair of Steel Moment Frames & Design of New Connections in High Seismic Zones"; NEHRP recommended seismic provisions; and a two-booklet set of lecture notes featuring copies of slides presented during the seminar.

To order, send a check to: AISC Marketing, Inc., P.O. Box 806286, Chicago, IL 60680-4124 or fax an order (please include your Visa or Mastercard account number along with an expiration date) to: 312/670-5403.

CORRESPONDENCE

(From time-to-time, AISC receives questions of a non-technical nature. When these questions are of general interest, they are printed in *Modern Steel Construction*.)

Q: ***May an AISC Certified Category II or III plant certify another steel fabricator to be AISC Certified to fabricate structural steel members?***

A: No. If a contract requires AISC certification of a fabrication shop, the subcontractor's shop also must be certified by AISC. This certification can only be issued by AISC after submittal of the proper application material and a satisfactory review.

However, if the contract does not specifically call for AISC certification, then certified fabricators can qualify all of their subcontractors and suppliers, including detailers, steel suppliers and subcontract fabricators. How this qualification is done is up to the fabricator, except that any qualifications required by the contract must be extended to the subcontractor.

—Tom Schlafly,
AISC Director of
Fabricating Operations
& Standards

National Steel Construction Conference Expands Scope

In addition to its traditional audience of structural engineers and fabricators, AISC's National Steel Construction Conference is opening its doors to construction managers in 1995. The conference, scheduled for May 17-19 in San Antonio, TX, will feature four professional tracks: Construction Management; Steel Fabrication; Structural Engineering; and Engineering Management. In addition, the conference will include a product exhibition with nearly 100 booths.

"We wanted to expand the conference to involve more of the construction industry," explained Franklin B. Davis, chairman of the AISC NSCC Committee and president of Precise Fabricating. "It's an exciting change that will put more life and spirit into the program."

While seminars are assigned to a specific track, show organizers stressed that there is no additional charge for crossing from one track to another. Registration for the show costs \$320 (\$270 for AISC members) and includes admission to all seminars and general sessions, as well as the trade show. To receive a registration packet, write AISC, One East Wacker Dr., Suite 3100, Chicago, IL 60601-2001 or call 312/670-2400.

Speakers this year include:

- Duane Miller (Lincoln Electric Co.) on welding inspections;
- Jim Scotti (Brown and Root) and Peter Van Nort (H.B. Zachry) on team building/partnering;
- David Harwell (Central Texas Iron Works) on bar coding;
- J.J. Suarez (Belcan) on quality management;
- Eric S. Kline (KTA-Tator) and David Boyd (The Vulcan Group) on paintings and coatings;
- Ken Lee (Goldberg and Simpson) on recent EPA legislation;
- Buck Rogers (Controlled Automation) on preventative maintenance;
- Jim Blackburn (Vernon Tool Co.) on hollow structural section fabrication;
- Tom Webb (Fibre-Metal Products Co.), Joe Derkitch (National Research) and James Morton on new developments in fabrication equipment and methods.
- R. Richard Avent (Louisiana State University) on flame straightening technology;
- Holley Fisk, Phil Fortune and Tag Wilson on how to protect your firm from lawsuits;
- Donald Buettner (Computerized Structural Design) on steel erection awareness;
- Bob Shaw (Steel Structures Technology Center), A.J. Julicher, and John T. Holcomb (Berlin Steel Co.) on the inspection of welded and bolted joints;
- Jim Notch (Notch & Associates); John Nagel (AFCO) and Jim Neil on reducing structural steel costs;
- Enrique Martinez Romero and Carlos L. Ramos on steel construction in Mexico;
- Jim Rowland (Bethlehem Steel) on industrial buildings;
- Stan Rolfe (University of Kansas), John Bell (Nucor), and Peter Wright (Chaparral Steel Co.) on what structural engineers need to know about fracture mechanics, metallurgy and weldability;
- Michael Engelhardt (University of Texas); Tom Sabol (Englekirk & Sabol); and Jim Malley (Degenkolb Associates) on research applications of from the Northridge Earthquake;
- R.M. Korol (McMaster University) and Donald Sherman (University of Wisconsin) on new developments in using structural tubes.

In addition, sessions will be held on: constructability issues for contractors; new OSHA legislation and its effect on fabricators and erectors; and effective project specifications for fabricators and engineers. And, of course, the 1995 T.R. Higgins lecture will be presented. As was the case in previous years, continuing education credits (CEUs) will be given for the conference.

In addition to the educational value of the seminars, the conference is an ideal place to meet colleagues as well as many world renowned experts on steel design and fabrication.

Engineers, fabricators and contractors also will benefit from the extensive trade show. In the past, exhibitors have included manufacturers of: fabricating equipment; bolts; fasteners; paints and coatings; joists; and computer software for engineers, fabricators and detailers. This year, more than 60 exhibitors are expected.

Conference co-sponsors include: American Galvanizers Association; AISI; ASCE; AWI, AWS, Canadian Institute of Steel Construction; Construction Industry Institute; Council of American Structural Engineers; Edison Welding Institute; Mexican Institute of Steel Construction; NEA; NISD; SDI; SJI; Steel Plate Fabricators Association; Steel Service Center Institute; Steel Structures Painting Council; Steel Tube Institute of North America; Structural Engineers Association of Texas; and Texas Structural Steel Institute.

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Section Weight Per Ft.	Nominal b_f	Producer Code
W44 x 230, 262, 290 335	16	T
W40 x 431	16	T
397*	16	N
372	16	T
362*, 324*	16	N
321	16	T
297	16	N
199, 215, 249, 277	16	N, T
174	16	T
W40 x 278, 331	12	T
211, 235, 264	12	B, I, T
183	12	B, I, N, T
149, 167	12	B, I, N, T
W36 x 439, 527, 650, 798	16.5	T
393	16.5	B, N, T
230, 245, 260, 280, 300, 328,359	16.5	B, I, N, T
W36 x 256	12	B, I, N
232	12	B, I, N
135, 150, 160, 170, 182, 194, 210	12	B, I, N, T
W33 x 387*	15.75	N
318, 354, 201, 221, 241, 263, 291	15.75	B, N, T
W33 x 118, 130, 141, 152, 169	11.5	B, I, N, T
W30 x 357*, 391	15	N
261, 292, 326	15	B, I, N, T
284*	15	I
173, 191, 211, 235	15	B, I, N, T
W30 x 99, 108, 116, 124, 132, 148	10.5	B, I, N, T
W30 x 90	10.5	B, N
W27 x 539	14	I
368	14	I, N
336*	14	N
307	14	I, N, T
281*	14	N
258	14	I, N, T
235	14	I, N
146, 161, 178, 194, 217	14	B, I, N, T

Section Weight Per Ft.	Nominal b_f	Producer Code
W27 x 132*	10	I
84, 94, 102, 114, 129	10	B, I, N, T, W
W24 x 335, 408, 492	12.75	T
306	12.75	N
279	12.75	I, N, T
250	12.75	B, I, N
229	12.75	B, I, N, T, W
207	12.75	B, N, W
104, 117, 131, 146, 162, 176, 192	12.75	B, I, N, T, W
W24 x 100*, 120*, 160*	12	N
W24 x 103	9	B, N, W
84, 94	9	B, I, N, W
68, 76	9	B, C, I, N, W
56*, 61*	9	N
W24 x 55, 62	7	B, C, I, N, W
W21 x 182, 201	12.25	I
101, 111, 122, 132, 147, 166	12.25	B, I, N, W
W21 x 83, 93	8.25	B, I, N, W
62, 68, 73	8.25	B, C, I, N, W
48*, 55*	8.25	N
W21 x 44, 50, 57	6.5	B, C, I, N, W
W18 x 258, 283, 311	11	B
175, 192, 211, 234	11	B
130, 143, 158	11	B, N, W
W18 x 130*	11	N
76, 86, 97, 106, 119	11	B, N, W
W18 x 65, 71	7.5	B, I, N, W
50, 65, 60	7.5	B, C, I, N, W
W18 x 35, 40, 46	6	B, C, I, N, W
W16 x 67, 77, 89, 100	10.25	B, N, W
W16 x 57	7	B, I, N, W
36, 40, 45, 50	7	B, C, I, N, W
W16 x 26, 31	5.5	B, C, I, N, W

Notes: Maximum lengths of shapes obtained vary with producer, but typically range from 60 ft to 75 ft. Lengths up to 100 ft are available for certain shapes. Please consult individual producers for length requirements.

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Principal Producers Of Structural Shapes

B. Bethlehem Struct. Prod.
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F. Florida Steel Corp.
I. British Steel
J. J&L Structural Inc.
M. SMI Steel Inc.
N. Nucor-Yamato Steel
R. Roanoke Steel
S. North Star Steel
T. TradeARBED
U. Nucor Steel
W. Northwestern Steel & Wire
Y. Bayou Steel Corp.

Section Weight Per Ft.	Nominal b_f	Producer Code
W14 x 808	16	B
455, 500, 550, 605, 665, 730	16	B, I, T
370, 390, 426	16	B, I, T
311, 342	16	B, I, N, T, W
145, 154, 176, 193, 211, 233, 257, 283	16	B, I, N, T, W
W14 x 90, 99, 109, 120, 132	14.5	B, I, N, T, W
W14 x 82	10	B, N, W
74	10	B, C, N, W
61, 68	10	B, C, N, W
W14 x 43, 48, 53	8	B, C, N, W
W14 x 38	6.75	B, I, N, W
30, 34	6.75	B, C, I, N, W
W14 x 22, 26	5	B, C, I, N, W
W12 x 252, 279, 305, 336	12	B, I
210, 230	12	B, I
170, 190	12	B, I, T, W
65, 72, 79, 87, 96, 106, 120, 136, 152	12	B, I, N, T, W
W12 x 53, 58	10	B, C, N, I, W
W12 x 50	8	B, C, N, I, W
40, 45	8	B, C, N, W
W12 x 26, 30, 35	6.5	B, C, N, W
W12 x 16, 19, 22	4	B, C, N, W
14	4	B, C, W
W10 x 88, 100, 112	10	B, I, N, W
49, 54, 60, 68, 77	10	B, C, I, N, W
W10 x 33, 39, 45	8	B, C, N, W
W10 x 22, 26, 30	5.75	B, C, I, N, W
W10 x 15, 17, 19	4	B, C, I, U, W
12	4	B, C, U, W
W8 x 31, 35, 40, 48, 58, 67	8	B, C, I, N, W
W8 x 24, 28	6.5	B, C, N, W
W8 x 18, 21	5.25	B, C, N, U, W, Y
W8 x 15	4	B, C, U, W, Y
10, 13	4	B, C, M, U, W, Y
W6 x 15, 20, 25	6	B, C, I, N, U, W
W6 x 12, 16	4	B, C, U, W, Y
9	4	B, C, J, M, U, W, Y
8.5*	4	C, J, M, U, Y
W5 x 16, 19	5	B, U
W4 x 13	4	B, C, M, U, Y

Section Weight Per Ft.	Producer Code
M12 x 10.8, 11.8	C, J
M12 x 10.0*	J
M10 x 8, 9	C, J, U
M10 x 7.5*	J
M8 x 6.2*	J
M8 x 6.5	C, J, U
M6 x 3.7*, 4.4	J
M5 x 18.9	B
M4 x 6*	C, U
S24 x 106, 121	B, W
S24 x 80-100	B, W
S20 x 86, 96	B, W
S20x 66, 75	B, W
S18 x 54.7, 70	B, W
S15 x 42.9, 50	B, W
S12 x 40.8, 50	B, W
S12 x 35	B, W
S12 x 31.8	B, C, W
S10 x 35	B, S
S10 x 25.4	B, C, S
S8 x 18.4, 23	C, S
S6 x 17.25	C, S
S6 x 12.5	C, S, Y
S5 x 10	C, Y
S4 x 9.5	C
S4 x 7.7	C, M,Y
S3 x 7.5	C, J, Y
S3 x 5.7	C, J, M, Y
HP14 x 73, 89, 102, 117	B, I, N, W
HP12 x 53, 63, 74, 84	B, I, N, W

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R. Roanoke Steel
S. North Star Steel
T. TradeARBED
U. Nucor Steel
W. Northwestern Steel & Wire
Y. Bayou Steel Corp.

Section Weight Per Ft.	Producer Code
HP10 x 42, 57	B, C, I, N, W
HP8 x 36	B, C, I, N, W
C15 x 33.9, 40, 50	B, N, W
C12 x 30	B, W
C12 x 20.7, 25	B, C, S, W
C10 x 25, 30	B, S, W
C10 x 15.3, 20	B, C, S, U, W
C9 x 20	B
C9 x 13.4, 15	B, S
C8 x 18.75	S, W, Y
C8 x 11.5, 13.75	C, M, S, U, W, Y
C7 x 12.25	S, U, W
C7 x 9.8	M, S, U, W
C6 x 13	M, S, U, W, Y
C6 x 10.5	C, M, S, U, W, Y
C6 x 8.2	C, F, M, U, W, Y,
C5 x 9	C, M, U, W, Y
C5 x 6.7	C, F, M, U, W, Y
C4 x 5.4, 7.25	C, F, M, U, W, Y
C4 x 4.5*	M
C3 x 6	M, U, W, Y
C3 x 4.1, 5	C, F, M, R, U, W, Y
C3 x 3.5*	M, R, U
MC18 x 42.7, 45.8, 51.9, 58	B, N
MC13 x 31.8, 35, 40, 50	B, N
MC12 x 31, 35, 40, 45, 50	B, N
MC12 x 10.6	J, S
MC10 x 28.5, 33.6, 41.1	B
MC10 x 22, 25	B
MC10 x 8.4	J, S
MC10 x 6.5	J
MC9 x 23.9, 25.4	B
MC8 x 21.4, 22.8	B, S
MC8 x 18.7, 20	B, S
MC8 x 8.5	J, M
MC8 x 6.6*	J
MC7 x 19.1, 22.7	B
MC6 x 18	B
MC6 x 15.1, 16.3	B, S
MC6 x 12	B, S
MC4 x 13.8*	S
MC 3 x 7.1*	S

Section by Leg Lengths & Thickness		Producer Code
L8 x 8 x	$1\frac{1}{8}$	B, T
	1	B, S, T
	$\frac{7}{8}$	B, S, T
	$\frac{3}{4}$	B, S, T
	$\frac{5}{8}$	B, S, T
	$\frac{9}{16}$	S
	$\frac{1}{2}$	B, S
L6 x 6 x	1	B, U, Y
	$\frac{7}{8}$	B, U, Y
	$\frac{3}{4}$	B, M, U, Y
	$\frac{5}{8}$	B, M, U, Y
	$\frac{9}{16}$	M, U, Y
	$\frac{1}{2}$	B, M, S, U, Y
	$\frac{7}{16}$	B, M, U, Y
	$\frac{3}{8}$	B, M, S, U, Y
	$\frac{5}{16}$	M, U, Y
	$\frac{1}{4}$*	U
L5 x 5 x	$\frac{7}{8}$	U, Y
	$\frac{3}{4}$	M, U, Y
	$\frac{5}{8}$	M, U, Y
	$\frac{1}{2}$	M, U, W, Y
	$\frac{7}{16}$	M, U, Y
	$\frac{3}{8}$	M, U, W, Y
	$\frac{5}{16}$	M, U, W, Y
	$\frac{1}{4}$*	U
L4 x 4 x	$\frac{3}{4}$	M, U, Y
	$\frac{5}{8}$	M, U, Y
	$\frac{1}{2}$	F, M, R, U, W, Y
	$\frac{7}{16}$	F, M, U, Y
	$\frac{3}{8}$	F, M, R, U, W, Y
	$\frac{5}{16}$	F, M, R, U, W, Y
	$\frac{1}{4}$	F, M, R, U, W, Y
$L3\frac{1}{2}$ x $3\frac{1}{2}$ x	$\frac{1}{2}$	F, M, U, W, Y
	$\frac{7}{16}$	U, Y
	$\frac{3}{8}$	F, M, R, U, W, Y
	$\frac{5}{16}$	F, M, R, U, W, Y
	$\frac{1}{4}$	F, M, R, U, W, Y
L3 x 3 x	$\frac{1}{2}$	F, M, U, W, Y
	$\frac{7}{16}$	U, Y
	$\frac{3}{8}$	F, M, R, S, U, W, Y
	$\frac{5}{16}$	F, M, R, S, U, W, Y
	$\frac{1}{4}$	F, M, R, S, U, W, Y
	$\frac{3}{16}$	F, M, R, U, W, Y
$L2\frac{1}{2}$ x $2\frac{1}{2}$ x	$\frac{1}{2}$	F, U, Y
	$\frac{3}{8}$	F, R, S, U, Y
	$\frac{5}{16}$	F, R, S, U, Y

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T. TradeARBED
U. Nucor Steel
W. Northwestern Steel & Wire
Y. Bayou Steel Corp.

Section by Leg Lengths & Thickness		Producer Code
	1/4	F, R, S, U, Y
	3/16	F, R, U, Y
L2 x 2 x	3/8	F, R, S, U, Y
	5/16	F, R, S, U, Y
	1/4	F, R, S, U, Y
	3/16	F, R, S, U, Y
	1/8	F, R, S, U, Y
L8 x 6 x	1	B, S
	3/4	B, S
	9/16	S
	1/2	B, S
	7/16	B, S
L8 x 4 x	1	B, S
	7/8	S
	3/4	B, S
	5/8	S
	9/16	S
	1/2	B, S
	7/16	S
L7 x 4 x	3/4	B, Y
	5/8	B, Y
	1/2	B, S, Y
	7/16	Y
	3/8	B, S, Y
L6 x 4 x	7/8	B
	3/4	B, M, S, U, W, Y
	5/8	B, M, S, U, W, Y
	9/16	M, S, U, Y
	1/2	B, M, S, U, W, Y
	7/16	U, Y
	3/8	M, S, U, W, Y
	5/16	M, S, U, W, Y
L6 x 3 1/2 x	1/2	M, U, W, Y
	3/8	M, U, W, Y
	5/16	M, U, W, Y
L5 x 3 1/2 x	3/4	M, U, Y
	5/8	M, U, W, Y
	1/2	M, U, W, Y
	3/8	M, U, W, Y
	5/16	M, U, W, Y
	1/4	M, U, W, Y
L5 x 3 x	1/2	F, M, U, W, Y
	7/16	F, Y

Section by Leg Lengths & Thickness		Producer Code
	3/8	F, M, U, W, Y
	5/16	F, M, U, W, Y
	1/4	F, M, U, W, Y
L4 x 3 1/2 x	1/2	F, M, U, W
	3/8	F, M, R, U, W
	5/16	F, M, R, U, W
	1/4	F, M, R, U, W
L4 x 3 x	5/8	U, Y
	1/2	F, M, U, W, Y
	7/16	U, Y
	3/8	F, M, R, U, W, Y
	5/16	F, M, R, U, W, Y
	1/4	F, M, R, U, W, Y
L3 1/2 x 3 x	1/2	U, W
	3/8	M, U, W
	5/16	M, U, W
	1/4	M, U, W
L3 1/2 x 2 1/2 x	1/2	U
	3/8	U, W
	5/16*	U, W
	1/4	U, W
L3 x 2 1/2 x	1/2	U, W
	3/8	U, W
	5/16	U, W, Y
	1/4	R, U, W
	3/16	U
L3 x 2 x	1/2	F, U
	3/8	F, S, U
	5/16	F, S, U
	1/4	F, R, S, U
	3/16	F, R, U
L2 1/2 x 2 x	3/8	R, S, U
	5/16	S, U
	1/4	R, S, U
	3/16	R, S, U

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Principal Producers Of Structural Tubing (TS)

A. Acme Roll Forming Co.
B. Bull Moose Tube Co.
C. Copperweld Corp.
D. Dallas Tube & Rollform
E. Eugene Welding Co.
H. Hanna Steel Corp.
I. Independence Tube Corp.
J. Vest Inc.
L. Laclede Steel Co.
M. Maruichi American Corp.
N. Hannibal Industries, Inc.
P. IPSCO Inc.
R. Standard Tube Co.
S. Sonco Steel Tube
T. Atlas Tube
U. UNR- Leavitt, Div. of UNR Inc.
V. Valmont Industries
W. Welded Tube Co. of America
X. EXLTUBE
Z. Welded Tube of Canada Ltd.

Nominal Size and Thickness	Producer Code
32x32x5/8, 1/2, 3/8	V*
30x30x5/8, 1/2, 3/8	V*
28x28x5/8, 1/2, 3/8	V*
26x26x5/8, 1/2, 3/8	V*
24x24x5/8, 1/2, 3/8	V*
22x22x5/8, 1/2, 3/8	V*
20x20x5/8, 1/2, 3/8	V*
18x18x5/8, 1/2, 3/8	V*
16x16x5/8, 1/2, 3/8	V*, W
16x16x5/16	W
14x14x5/8	V*,W
14x14x1/2,3/8	V*,W
14x14x5/16	W
12x12x5/8	B,S,W
12x12x1/2,3/8,5/16,1/4	B,S,T,W
10x10x5/8	B,C,S,W
10x10x1/2,3/8,5/16,1/4, 3/16	B,C,P,S,T,U,W
8x8x5/8	B,C,S,W
8x8x1/2,3/8,5/16,1/4, 3/16	B,C,P,S,T,U,W,Z
7x7x5/8	B,C,S
7x7x1/2,3/8,5/16,1/4, 3/16	B,C,P,S,T,U,W,Z
6x6x5/8	B,S
6x6x1/2	B,C,P,S,T,U,W,Z
6x6x3/8, 5/16	B,C,D,P,R,S,H,I,J,T,U,W,Z
6x6x1/4, 3/16	B,C,D,P,R,S,H,I,J,T,U,W,X,Z
6x6x1/8	B,C,D,S,H,I,J,Z
5 1/2x5 1/2x3/8,5/16,1/4,3/16,1/8	B,D,S,H,I,Z
5 1/2x5 1/2x1/8	B,S,I,Z
5x5x1/2	B,C,P,R,S,T,U,W,Z
5x5x3/8, 5/16	B,C,D,H,I,J,P,R,S,T,U,W,Z
5x5x1/4, 3/16	B,C,D,H,I,J,M,P,R,S,T,X,U,W,Z
5x5x1/8	B,C,H,I,J,M,P,S,T,Z
4 1/2x4 1/2x1/2	C
4 1/2x4 1/2x3/8, 5/16	T,H,I,P,W,Z
4 1/2x4 1/2x1/4, 3/16	B,C,D,H,I,P,T,X,W,Z
4 1/2x4 1/2x1/8	B,C,H,I,P,T,X,Z
4x4x1/2	B,C,P,R,S,T,U,W,Z
4x4x3/8, 5/16	B,C,D,H,I,J,R,S,T,D,P,U,W,Z
4x4x1/4, 3/16, 1/8	B,C,D,E,H,I,J,L,M,N,P,R,S,T,
	X,U,W,Z
3 1/2x3 1/2x5/16	I,J,P,S,T,U,W,Z
3 1/2x3 1/2x1/4, 3/16, 1/8	B,C,D,E,H,I,J,L,M,N,P,R,S,T,
	U,W,X, Z
3x3x3/8	C, H
3x3x5/16	C,H,I,J,P,S,T,W,Z

Nominal Size and Thickness	Producer Code
3x3x1/4, 3/16	A,B,C,D,E,H,I,J,M,N,P,R,S,T,U,W,X,Z
3x3x1/8	A,B,C,D,E,H,I,L,M,N,P,R,S,T,
	U,W,X, Z
2 1/2x2 1/2x5/16	I,S,T
2 1/2x2 1/2x1/4, 3/16	A,B,C,D,E,H,I,J,L,M,N,P,R,S,T,
	U,W,X,Z
2 1/2x2 1/2x1/8	A,B,C,D,E,H,I,J,L,M,N,P,R,S,
	T,U,X,W,Z
2x2x5/16	I,S
2x2x1/4	B,C,D,H,I,J,L,M,N,R,S,T,U,W,X,Z
2x2x3/16, 1/8	A,B,C,D,E,H,I,J,L,M,N,P,R,S,
	T,U,W,X,Z
1 3/4x1 3/4x1/4	H
1 3/4x1 3/4x3/16	H,Z
1 1/2x1 1/2x3/16	B,E,H,L,N,P,R,S,U,W,Z
1 1/2x1 1/2x1/4	L
32x24x5/8, 1/2, 3/8	V*
30x24x5/8, 1/2, 3/8	V*
28x24x5/8, 1/2, 3/8	V*
26x24x5/8, 1/2, 3/8	V*
24x22x5/8, 1/2, 3/8	V*
22x20x5/8, 1/2, 3/8	V*
20x18x5/8, 1/2, 3/8	V*
20x12x1/2, 3/8, 5/16	V*,W
20x8x5/8, 1/2, 3/8	V*,W
18x12x1/2, 3/8	V*
18x6x1/2, 3/8, 5/16	B,W
18x6x1/4	B
16x12x1/2, 3/8, 5/16	V*,W
16x8x1/2, 3/8, 5/16	B,W
16x4x1/2, 3/8, 5/16	B,W
14x12x1/2, 3/8	V*
14x10x1/2, 3/8	B,S,W
14x10x 5/16	W
14x6x5/8	B
14x6x1/2, 3/8, 5/16, 1/4	B,W
14x4x5/8	B,S
14x4x1/2, 3/8, 5/16, 1/4	B,S,W
14x4x3/16	B,S
12x10x1/2, 3/8, 1/4	B, S, U
12x8x5/8	B, C, S,W
12x8x1/2, 3/8, 5/16, 1/4	B, C, S, T, W
12x8x3/16	B, C, S, U
12x6x5/8	B, S
12x6x1/2, 3/8, 5/16, 1/4	B, C, S,U,W
12x6x3/16	B, C, S, U

Notes: *Size is manufactured by Submerged Arc Welding (SAW) process and are not stocked by steel service centers (contact producer for specific requirements). All other sizes are manufactured by Electric Resistance Welding and most are available from steel service centers.

Some manufactures produce a .120 size instead of a 1/8; please check with individual manufacturers

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I. Independence Tube Corp.
J. Vest Inc.
L. Laclede Steel Co.
M. Maruichi American Corp.
N. Hannibal Industries, Inc.
P. IPSCO Inc.
R. Standard Tube Co.
S. Sonco Steel Tube
T. Atlas Tube
U. UNR- Leavitt, Div. of UNR Inc.
V. Valmont Industries
W. Welded Tube Co. of America
X. EXLTUBE
Z. Welded Tube of Canada Ltd.

Nominal Size and Thickness	Producer Code
12x4x5/8	C, S
12x4x1/2, 3/8, 5/16, 1/4, 3/16	B, C, S, U, W, Z
12x3 1/2 x3/8, 5/16	Z
12x3x5/16, 1/4, 3/16	C, B, Z
12x2x1/4, 3/16	B, S, U, Z
10x8x1/2, 3/8, 5/16, 1/4, 3/16	B, C, S, U, W
10x6x1/2	B, C, S, T, U, W, Z
10x6x3/8, 5/16, 1/4, 3/16	B, C, D, P, S, T, U, W, Z
10x5x3/8, 5/16, 1/4, 3/16	B, C, D, S
10x4x1/2	B, C, P, S, T, U, W, Z
10x4x3/8, 5/16, 1/4, 3/16	B, C, D, P, S, T, U, W, Z
10x3 1/2 x3/16	Z
10x3x3/8, 5/16, 1/4	B, D
10x3x3/16	B, D, Z
10x2x3/8	Z
10x2x5/16	D, P, S, T, U, W, Z
10x2x1/4, 3/16	B, D, P, S, T, U, W, Z
9x7x1/2, 3/8, 5/16, 1/4, 3/16	B, C, W, Z
9x5x1/2, 3/8, 5/16, 1/4, 3/16	B, C, W, Z
9x3x1/2	C
9x3x1/2, 3/8, 5/16	C, Z
9x3x1/4, 3/16	B, C, Z
8x6x1/2	B, C, P, S, T, U, W, Z
8x6x3/8, 5/16, 1/4, 3/16	B, C, D, P, S, T, U, W, Z
8x4x5/8	B, S
8x4x1/2	B, C, P, S, T, U, W, Z
8x4x3/8, 5/16	B, C, D, H, I, J, P, R, S, T, U, W, Z
8x4x1/4, 3/16	B, C, D, H, I, P, S, W, X
8x4x1/8	B, C, D, I, J, P, S, Z
8x3x1/2	C, P, T, U
8x3x3/8, 5/16	C, D, H, I, P, U, W, Z
8x3x1/4, 3/16	B, C, D, H, I, P, S, U, W, Z
8x3x1/8	B, C, D, I, P, S, Z
8x2x3/8	H, J, S, T, U, Z
8x2x5/16	H, I, J, P, S, T, U, W, Z
8x2x1/4, 3/16	B, D, H, I, J, P, S, T, U, W, Z
8x2x1/8	B, D, I, J, P, S, T, Z
7x5x1/2	B, C, P, S, T, U, W, Z
7x5x3/8, 5/16, 1/4, 3/16	B, C, D, H, I, P, R, S, T, U, W, Z
7x5x1/8	B, C, I, P, S, T, X, Z
7x4x3/8, 5/16, 1/4, 3/16	B, C, D, H, I, P, S, U, W, Z
7x4x1/8	C, I, P, S, Z
7x3x3/8, 5/16	B, C, D, H, I, P, S, W, Z
7x3x1/4, 3/16	B, C, D, H, I, P, S, W, X, Z
7x3x1/8	C, D, H, I, P, S, Z
6x4x1/2	B, C, P, S, T, U, W, Z
6x4x3/8, 5/16	B, C, D, H, I, J, P, R, S, T, U, W, Z
6x4x1/4, 3/16	B,C,D,H,I,J,M,P,R,S,T,U,W,X,Z
6x4x1/8	B, C, D, I, J, P, S, T, V, X, Z
6x3x1/2	C, P, S, T, U, Z
6x3x3/8, 5/16	B, C, D, H, I, P, S, U, W, Z
6x3x1/4, 3/16	B, C, D, H, I, P, R, S, U, W, X, Z
6x3x1/8	B, C, D, H, I, P, R, S, U, X, Z
6x2x3/8	H, S, U, W, Z
6x2x5/16	B, H, I, J, P, S, T, U, W, Z
6x2x1/4, 3/16	B, C, D, E, H, I, J, M, N, P, R, S, T, U,W, X, Z
6x2x1/8	B,C,D,E,H,I,J,M,N,P,R,S,T,U,W,X,Z
5x4x3/8, 5/16	B, C, I, P, T, W, Z
5x4x1/4, 3/16	B, C, D, I, P, T, W, Z
5x3x1/2	C, P, S, T, U
5x3x3/8, 5/16	C, D, H, I, J, P, R, S, T, U, W, Z
5x3x1/4, 3/16	B,C,D, E,H,I,J,M,N,P,R, S,T,U,W,X,Z
5x3x1/8	B, C, D, E, H, I, J, M, N, P, R, S, T, U, W, X, Z
5x2x1/4, 3/16	Z
5x2x5/16	I, J, P, R, S, T, W
5x2x1/4, 3/16, 1/8	B,C,D,E,H,I,J,M,N,P,R,S,T,U,W,X,Z
4x3x3/8	B, S, T
4x3x5/16	I, P, S, W
4x3x1/4, 3/16	B, C, D, H, I, J, E, L, M, N, P, R, S, T, U, W, X, Z
4x3x1/8	B, C, D, E, H, I, J, L, M, N, P, R, S, T, U, W, X, Z
4x2 1/2 x1/4	Z
4x2x3/8	H, S, T
4x2x5/16	H, I, J, P, S, T, W, Z
4x2x1/4	B, C, D, E, H, I, J, L, M, N, P, R, S, T, U, W, X, Z
4x2x3/16	A, B, C, D, E, I, J, L, M, P, R, S, T, U, W, X, Z
4x2x1/8	A,B,C,E,H,I,L,M,N,P,R,S,T,U,W,X,Z
3 1/2 x2 1/2 x1/4	Z
3x2 1/2 x1/4	Z
3x2x5/16	I, S, T
3x2x1/4	B, C, D, E, H, I, J, L, M, N, P, R, S, T, U, W, X, Z
3x2x3/16	A, C, D, E, I, J, L, M, P, R, S, T, U, W, X
3x2x1/8	A, B, C, D, E, H, I, J, L, M, N, P, R, S, T, U, W, X, Z
3x1 1/2 x3/16, 1/8	C, E, I, U, W
3x1 1/2 x1/4	I, Z
2 1/2 x1 1/2 x1/4	A, B, C, E, I, S, U, X
2 1/2 x1 1/2 x3/16	B, C, E, H, I, R, S, U, X, Z
2x1 1/2 x3/16	Z
2x1x3/16	Z
1 1/2 x1 1/2 x1/4	H, L

Notes: *Size is manufactured by Submerged Arc Welding (SAW) process and are not stocked by steel service centers (contact producer for specific requirements). All other sizes are manufactured by Electric Resistance Welding and most are available from steel service centers.

Some manufactures produce a .120 size instead of a 1/8; please check with individual manufacturers

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D. Dallas Tube & Rollform
E. Eugene Welding Co.
H. Hanna Steel Corp.
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J. Vest Inc.
L. Laclede Steel Co.
M. Maruichi American Corp.
N. Hannibal Industries, Inc.
P. IPSCO Inc.
R. Standard Tube Co.
S. Sonco Steel Tube
T. Atlas Tube
U. UNR- Leavitt, Div. of UNR Inc.
V. Valmont Industries
W. Welded Tube Co. of America
X. EXLTUBE
Z. Welded Tube of Canada Ltd.

Nominal Size and Thickness	Producer Code
20x.500, .375	P*, W
20x.250	P*
18x.500, .375	P*, W
18x.250	P*
16x.500	P*, W
16x.375	P*, W
16x.250	P
16x.188	P
14x.500	P, W
14x.438	P
14x.375	P, W
14x.250, .188	P
12.75x.500	P, W
12.75x.406	P
12.75x.375	P, W
12.75x.188, .125	P
12.5x .625, .500, .375, .312, .250, .188	C
11.25x.625, .500, .375, .312, .250, .188	C
10.75x.500, .365, .250	P, W, Z
10x.625	C
10x.500, .375, .312	C, Z
10x.250, .188	C, Z
10x.125	V
9.625x.500	C, U, Z
9.625x.375, .312, .250, .188	C, P, U, Z
8.75x.500, .375, .312, .250, .188	C
8.625x.500	P, S, U, Z
8.625x.375	P, S, U, Z
8.625x.322	P, S, U, W, Z
8.625x.250, .188	P, S, U, Z
8.625x.125	P, S
7.625x.125	Z
7.5x.500, .375, .312, .250, .188	C, R
7x.500	C, P, U, Z
7x.375, .312, .250	C, H, P, R, S, U, Z
7x.188	C, H, P, R, S, U, Z
7x.125	C, P, Z
6.875x.500, .375, .312, .250, .188	C
6.625x.500, .432	P, U, Z
6.625..375, .312	H, P, R, U, Z
6.625x.280	H, P, R, U, W, X, Z
6.625x.250, .188	H, P, R, U, W, X, Z
6.625x.125	P, Z

Nominal Size and Thickness	Producer Code
6.125x.500, .375, .312, .250, .188	C
6x.500	S, Z
6x.375, .312	H, R, S, Z
6x.280	H, R, S, X, Z
6x.250, .188	H, R, S, Z
6x .125	H, Z
5.563x.500	Z
5.563x.375	P
5.563x.258	P, R, W, X, Z
5.563x.188	
5.563x.134	P, R, Z
5.5x.375, .258	U, Z
5x.500, .375, .312	C, P, T, Z
5x.258	C, P, R, T, U, X, Z
5x.250, .188	C, H, L, P, R, S, T, U, Z
5x.125	C, H, L*, P, R, S, T, U, Z
4.5x.337	Z
4.5x.237, .188	C, H, L*, P, R, S, U, W, X, Z
4.5x.125	C, H, L*, P, R, S, U, Z
4x.337	H, R, S, U
4x.250, .188	C, H, R, S, U, Z
4x.237	C, H, R, S, U, Z
4x.125	C, H, R, S, U, Z
3.5x.313	Z
3.5x.300	H, P, S, X, Z
3.5x.250, .203, .188, .125	H, P, S, U, Z
3.5x.216	H, P, R, S, U, X, Z
3x.250, .203, .188, .152	H, L, R, S, U, Z
3x.300	S, X, Z
3x.216	R, S, U, X, Z
3x.120, .134	Z
2.875x.250	L*, P, U, Z
2.875x.203	L*, P, U, W, Z
2.875x.188, .125	L*, P, U, Z
2.375x.250, .218, .188	H, L, P, S, Z
2.375x.154	H, L, P, S, U, W, X, Z
2.375x.125	H, P, R, S, U, Z

Notes: *Size is manufactured by Submerged Arc Welding (SAW) process and are not stocked by steel service centers (contact producer for specific requirements). All other sizes are manufactured by Electric Resistance Welding and most are available from steel service centers.

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Chaparral Steel Co.
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(800) 529-7979

Florida Steel Corp.
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J&L Structural Inc.
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& Wire Co.
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North Star Steel Co.
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Eagan, MN 55121-0620

Nucor Steel
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Nucor-Yamato Steel
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(800) 289-6977

Roanoke Electric Steel Corp.
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CANADA
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Bull Moose Tube Company*
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Copperweld Corporation*
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Dallas, TX 75354-0873
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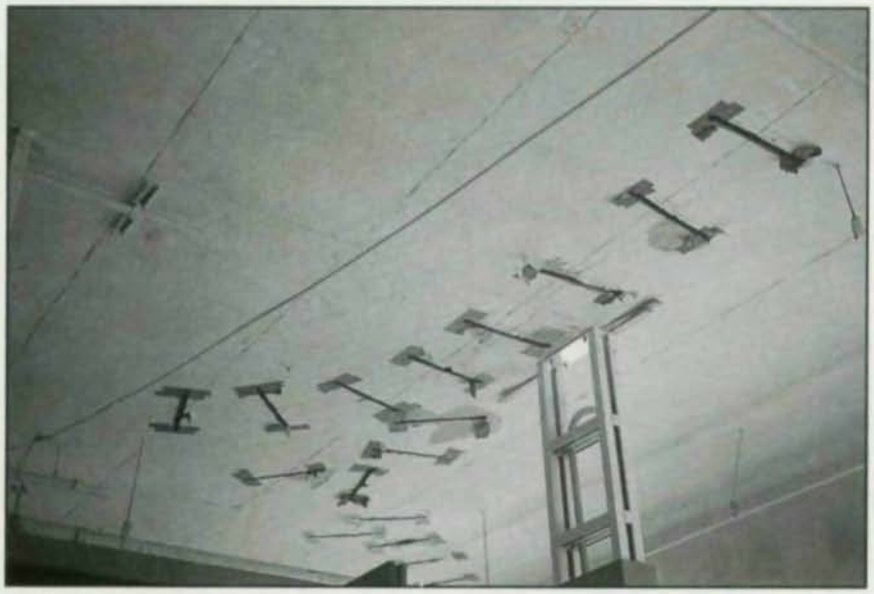
Renovation Remedies Structural Headaches

Renovating a vintage 1917 concrete building with planar steel frames allowed Boston University to modernize a laboratory while adding additional space



Several techniques were used to repair and strengthen the existing concrete frame. Shown above are chemically anchored dog stitches. Shown at top is a newly mounted steel beam.

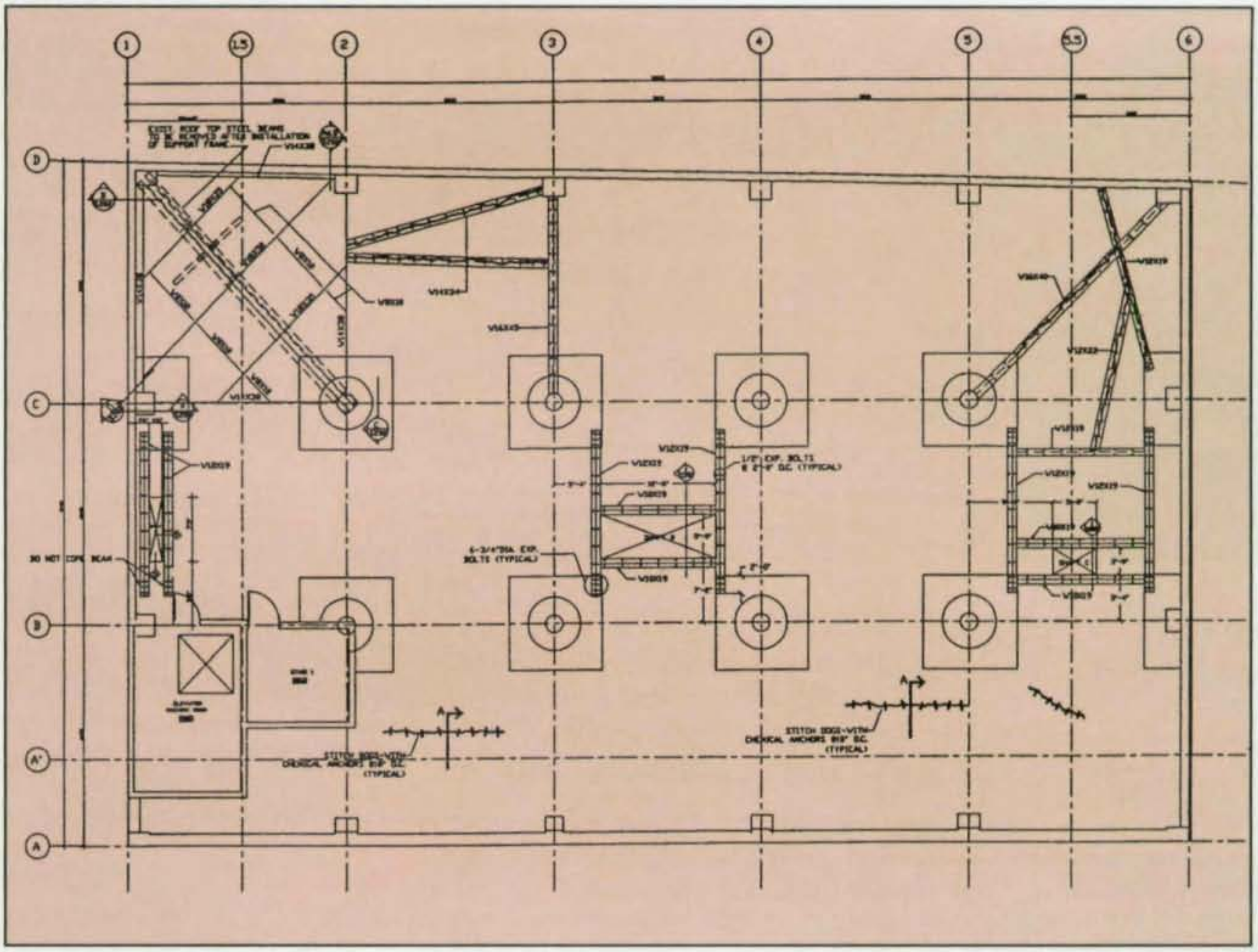
By Zareh B. Gregorian, P.E., and Garen B. Gregorian

RATHER THAN CONSTRUCTING A NEW FACILITY, BOSTON UNIVERSITY OPTED TO BUILD its Cantor Smith Laboratory by reconfiguring and modernizing an existing three-story concrete building. Built in 1917, the building had previously housed a library on its first and second floors with research space on its upper floor. To increase the work space for the tenants, the university shifted the existing library space on the second floor to the basement and added new mechanical space on the roof to house the equipment displaced from the basement.

Complicating the project, however, was the previously unknown poor structural condition of the existing building and the need to fit construction into an academic schedule requiring all work to be done between the end of the spring session and the start of the fall term.

Existing Conditions

The existing building was an SMI (Smulski) flat slab system with a circular reinforcing pattern, which was a popular design in the northeast at the time the building was originally designed. In this system, each of the five panels (one on each face of the column and one at the center) act as independent elements, with circular reinforcement installed at each panel and with minimal continuity between panels provided by reinforcing bars. Due to the discontinuous pattern



of the reinforcing, poor quality of the concrete, and bad construction, major cracks had developed at the third floor slab. In addition, large deflections—in the order of 7 in.—had occurred, and large cracks had developed in the roof slab.

The design was so poor that sometime in the past a pair of 24-in. steel beams had been placed above the roof to help overcome the sagging of the roof slab. The beams span diagonally between columns and were used to hang the slab by rods.

Adding A New Floor

The new mechanical level was framed in steel to minimize weight requirements and to speed the construction. However, construction of the new mechanical level required the removal of the two existing diagonal beams from the roof and repairing the cracked and sagging slabs. Several options were considered for remedying the problem of the sagging slab, including removing the deteriorated panels. However, that would have required shoring of the structure and the removal and replacement of at least three 26-ft. x 28-ft. bays at various locations—all while the lower floors were in operation.

Since the building is located in a crowded institutional area, heavy cutting equipment, which would generate excessive noise, could not be used.

After reviewing various options with the project team, which included Paul McGowan, senior vice president and design principal with Cannon, Youngjo Sul, senior associate with Cannon, Paul Rinaldi, director of the office of space management at Boston University, and Gus Stathis, director of project management at Boston University, the decision was made to repair damaged portions of the slabs rather than replacing entire bays. Structural engineer on the project was Gregorian Engineers, Belmont, MA.

In addition to the corner slab that was hung from the steel beams, two additional bays were severely cracked and sagging and in need of immediate repair. The solution was to install a grid of steel beams to support the sagging slabs. The grid consists of a W18x50 member spanning diagonally between two columns, with a W18x35 member picking up the additional load of the slab. In addition some W8x10 tie members were utilized. The beams were tied to the column heads by expansion anchors. Special details were developed to provide connections to the drop panels and capitols.

The support frames were designed to support the weight of the slab and the live load.

Shown above is the grid of new steel beams after fire proofing was applied.

Auxiliary members were installed between main frame members under cracks to reduce the acting span of the existing slabs. The design utilized one W18x50 member framing diagonally from column-to-column and two W18x35 members framing into four W14x38 beams connecting four concrete columns at the corner of the structure. Six W8x10 intermediate short span members frame between main steel members for additional support. Shear connector anchor bolts are used to connect new steel girders to concrete columns, capitals and drop panels.

In areas with excessive sagging, structural T sections were cut at the web and welded to the top of the steel members to shape the beam in the form of the deflected slab. Non-shrink grout was packed between the top of the steel beams and the bottom of the slab to provide load transfer from the slab to the steel frame and finally to the concrete columns.

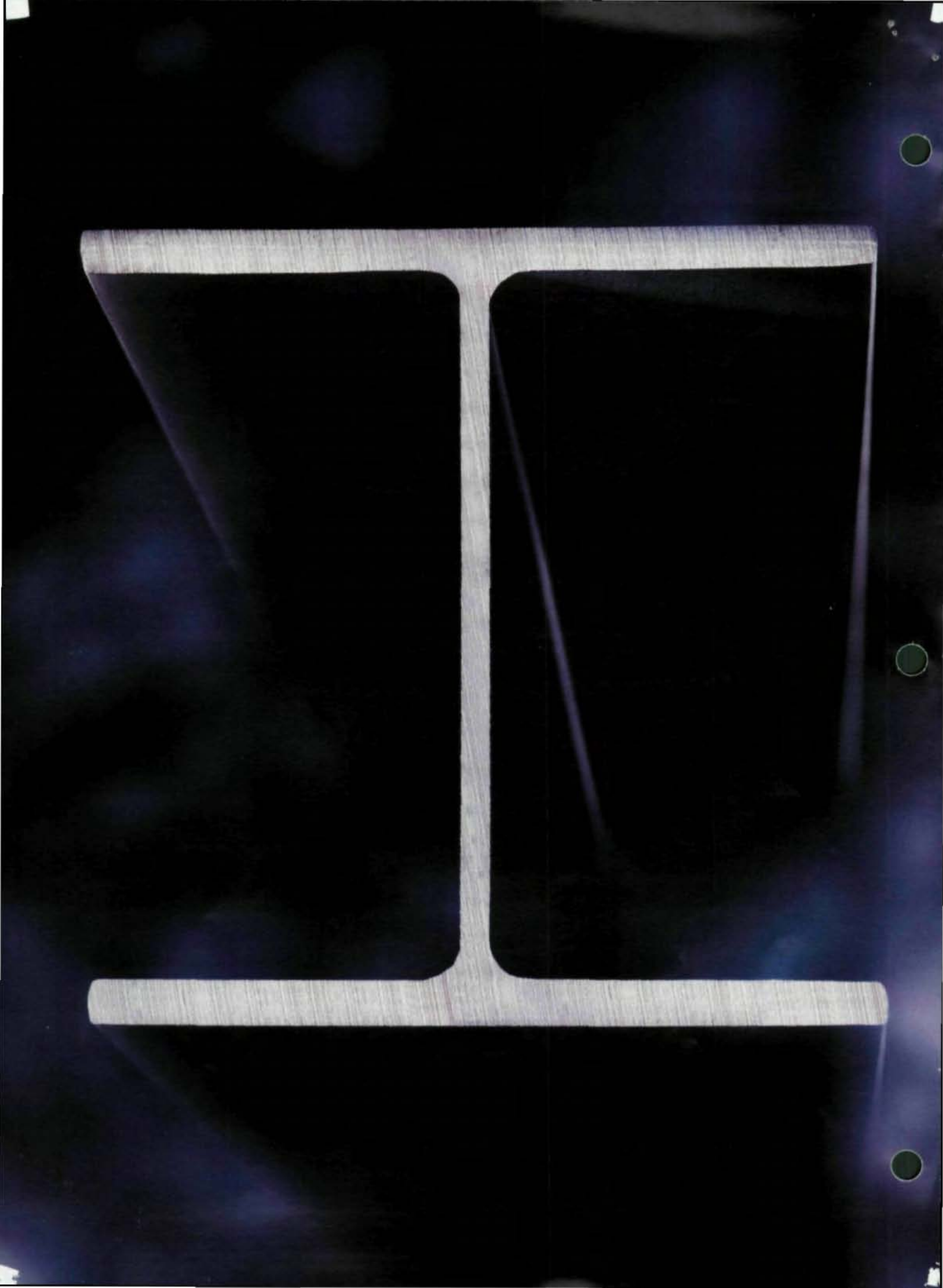
In other roof slab and third floor slab areas with minor cracks, pressure injected epoxy and chemically anchored dog stitches were used to prevent the existing cracks from further propagation. Bent and threaded rods were installed in pre-drilled holes from underneath the slab and anchored to the slab by chemical epoxies. To select the diameter of the dog stitches and the required penetration lengths and spacing, the Smulski system was analyzed to obtain the pattern of bending moments and the resulting tensile forces in various parts of the slabs in crack locations.

RAPID ERECTION

It took two skilled steel erectors only one day to install the frames for each panel. Fabricator and erector on the project was AISC-member American Architectural Iron Co. General contractor was Walsh Brothers of Cambridge, MA. The epoxy injection and grouting took an additional day, which brought total installation time to less than one week. Accordingly, the project was completed in September in accordance with the university's schedule and requirements.

In contrast, the concrete alternative to using steel frames would have resulted in the cutting and removal of huge areas of the existing structure, column reinforcement, and the installation of 11 new concrete boundary beams and new slabs with the requisite welding of new reinforcement bars to the existing slabs. Finally, placing new concrete would have required at least three weeks for the concrete to obtain the required strength. In short, the process would have been expensive, noisy, time consuming, and would have required extensive shoring and disturbance to the on-going operation of the building tenants.

Zareh Gregorian, P.E., is principal and Garen B. Gregorian is project engineer for Zareh B. Gregorian Consulting Structural Engineers in Belmont, MA.



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EXTERNAL BRACING PROVIDES SEISMIC SUPPORT

The retrofit of a 1960s university building was economically accomplished with a system of external steel braces

An external steel frame was used to bring this laboratory building up to current seismic code level.

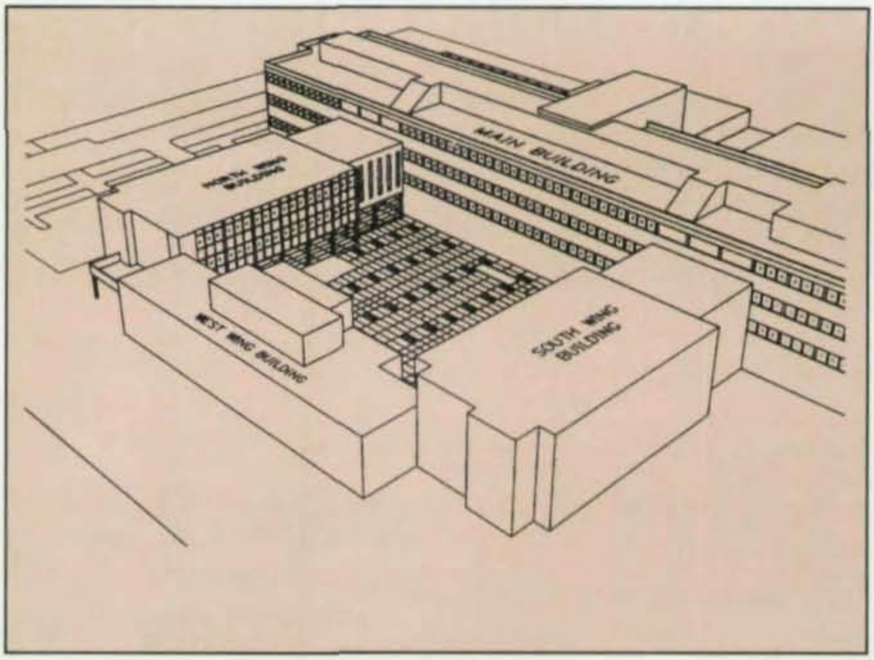
By Peter A. Timler, P.E., and John G. Sherstobitoff

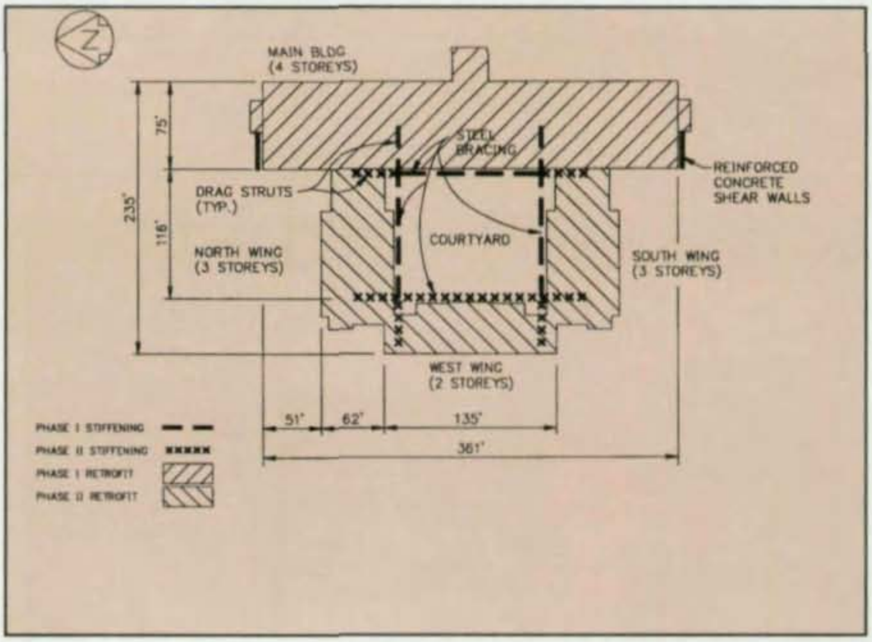
THE INFLUENCE OF CALIFORNIA'S EARTHQUAKES EXTENDS BEYOND THE STATE'S, and indeed the U.S.'s, border. After the Loma Prieta earthquake of 1989, the government of British Columbia—the Canadian province due north of California—began evaluating and upgrading many of its older and more vulnerable structures. Recently, the primary laboratory teaching facility at the British Columbia Institute of Technology (BCIT) was upgraded to bring it to 100% of current code requirements.

Objectives for the renovation of the building, located in the Vancouver suburb of Burnaby, included: minimizing costs; completing the project within a three-month period during the summer of 1993; minimizing disruption to mechanical and electrical systems, since all adjacent buildings shared the system and were to be fully occupied and operational during the construction period; and maximizing the aesthetics of the finished renovation.

The existing building was constructed in 1962. However, because it was constructed under federal jurisdiction, it was exempted from local building codes and it is unknown whether it was designed to meet the existing standards. The main building is a four-story structure consisting of 5-in. or 6-in. lightweight concrete floor slabs supported on steel beams and concrete encased steel columns. The 361-ft. by 75-ft. building is rectangular in plan with an interstory height of 12-ft. 9-in. A light steel-framed penthouse covers approximately 50% of the roof floor plan area. The building was connected with neighboring buildings to form a courtyard. The existing lateral load system consisted of four lightly reinforced concrete stairwells well distributed along the building's length. Evaluation of the structural details of the existing building indicated a structure with very nominal capacity because of the lack of specific detailing for ductile behavior. The elastic capacity of various elements ranged from 20% to 40% relative to current code requirements.

Initially, the renovation called for incorporating 20 new internal reinforced concrete shear walls at a cost of $3.3M CDN, excluding any non-structural seismic restraint or any improvements within the building envelope. However, after careful consideration, the designers—in consultation with the building's users—created a scheme combining external steel bracing with external shear walls. In addition to reducing the cost of the renovation by half, it created a striking visual concept for an "Institute of Technology" that appealed to the client. A final advantage was the some of the elements of this project could be incorporated into a future planned retrofit of the adjacent buildings in the complex.





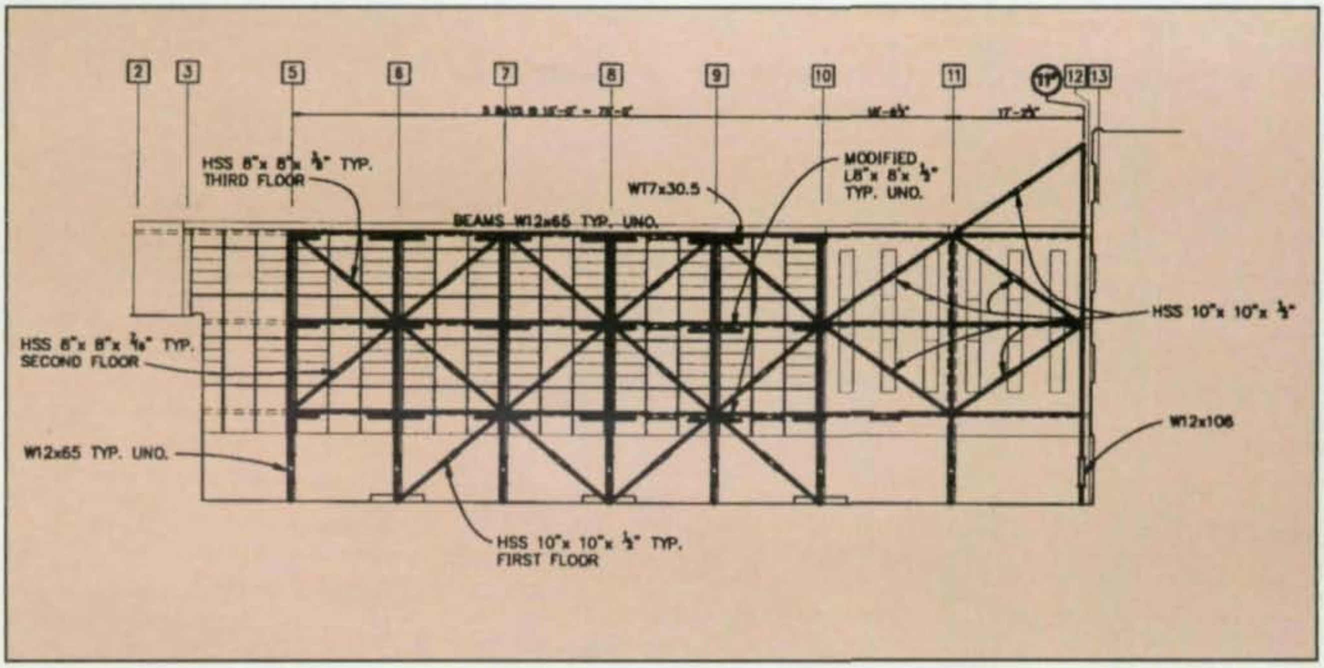
The renovation was accomplished under the CAN/CSA-S16.1-M89 (S16.1) Limit States Design of Steel Structures code, the first Canadian code that specifically addressed the ductility requirements of steel structures in seismic design. Each steel lateral load-resisting system is addressed with compatible design rules commensurate with the force modification factor R. The R value is relative to the system's capacity to absorb energy by undergoing inelastic deformations. The code recognizes overstrength provision (or the capacity design approach), in which brace sizes selected for reasons other than actual strength or stability thereby exhibit resistances greater than those required to carry the seismic loads and therefore impose potentially larger connection design forces because of their increased reserve in strength. For this building, a calculated design base shear equivalent to 31% of the weight of the structure was dictated by the code.

The code also contains ductility requirements for braced frames expected to undergo intense cyclic loading. The code recognizes the need for redundancy in opposing directions per planer frame. Redundancy restricts dramatic changes in overall torsional resistance that would otherwise lead to subsequent catastrophic loss in shear capacity as compression braces buckle. Additionally, controlling local buckling of members is emphasized by the imposition of more severe width-thickness ratios than Class 1 limitations. To maintain reasonable levels of *energy absorption while undergoing* plastic bending during overall buckling conditions, diagonal bracing members also must meet stricter slenderness ratios. As significant reserves in strength, which can easily be drawn upon through capacity response of the frame, are likely to exist in the bracing members themselves, connections are designed for higher load levels, i.e., twice those obtained from elastic analysis. Coupled with the braces overall energy dissipation requirements through out-of-plane buckling, gusset plates must be detailed to avoid brittle failures.

External Bracing

A ductile-bracing frame scheme with an R value of 3.0 was selected for several reasons. The ductility rating of this system would approach equivalence with that of the proposed reinforced concrete end walls, which have an R value of 3.5—an important consideration for retrofit performance. Also, overall member force levels wold be reduced significantly; 33% over nominally ductile and 50% over non-ductile steel-reinforced framing schemes because of increased deformational characteristics. However, greater *demand, required in the design* and detailing of connections, would ensure the necessary ductile behavior. Reducing the force levels was an important consideration because of the long plan dimension in the north-south direction. As a result, an unusually large torsional component had to be added to the east-west oriented code earthquake base shear.

As a result of these considerations, along with architectural and erection considerations, the reinforcement system was designed with wide flange beam and column grillage incorporating hollow structural steel bracing. To reduce the size of the



bracing members, a fully braced system was used on the west face of the main building, with near fully braced systems on the west and east faces of the north and south wing structures, respectively. The near fully braced systems allowed unrestricted student and faculty access to the courtyard.

Aesthetic Concerns

Unlike an internal strengthening system, great care must be taken to visually integrate an external bracing system with the existing structure. Particularly important is to minimize window coverage. In addition to visual concerns, an erection plan was needed that would allow the use of a small mobile crane capable of entering the courtyard through a 9-ft. vertical clearance breezeway.

Selection of a framing connection system was based on the erection sequence of the members and on minimization of field welding for quality control. As a result, end-plate connections on beams with bracing gusset hardware were chosen. The gusset plates, which would receive the slotted HSS braces prepared with angle end clips, would enable quick erection bolting followed by brace-to-gusset field welding. To meet architectural requirements, a series of scalloped gusset plates were developed. The detailed radii of these plates were relative to each braced connection coinciding at the joint and other local joints.

The new external bracing system was connected directly to the floor diaphragms of the existing structure. Connection design force levels of the frames to the building were limited to two times the anticipated earthquake shear equally distributed to each connector location. When this force level presented conditions in which an unreasonable number of anchors were necessary and their clustering interfered with their efficiency, a total floor shear force was calculated on the basis of the buckling capacity of every brace associated with the floor level under consideration. Because of the optimization of the bracing sizes for the frames, this overstrength limitation ranged between 1.3 and 1.7 of the design earthquake shears.

The exterior finish the main building differed from the two wing buildings, but a similar connection, utilizing T-sections or angles, was provided.

The main building was finished with an exposed aggregate

stucco. A full length band of connection zones was sawcut and lightly jack-hammered to expose the formed concrete surface of the upstand beam at the diaphragm level. A $^3/_{16}$-in.-thick industrial grade neoprene strip of durometer hardness 50 was installed behind the flanges to accommodate some of the finish variations from the original forming. A flashing was incorporated to provide waterproofing. Prefabricated T-sections welded between the flanges of the beam facilitated connection via its web to the unit previously secured to the building. Galvanized shims made up erection discrepancies between the connector units secured to the face of the building and the beams of the frames. Adhesive concrete anchors bolted the connector units directly to the building.

Horizontal reactions from the slabs at each floor level and the roof were transferred through drag struts to the walls along the north and south wings of the complex. Openings cut in the main building's walls allowed the fabricated struts, which consisted of inverted T-sections welded to wider top flange plates, to be installed from the courtyard. The top flange of each drag strut was bolted with adhesive anchors to the underside of the slab. Because of the crammed connection, $1^1/_4$-in.-diameter A490 bolts were used.

Peter A. Timler, P.E., is a senior structural engineer, and John G. Sherstobitoff is a project manager with Sandwell Inc. in Vancouver. This article is based on a paper first presented at the 1994 National Steel Construction Conference.

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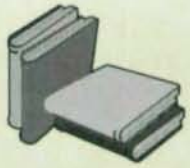

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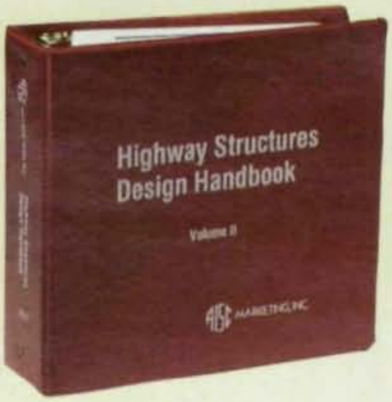

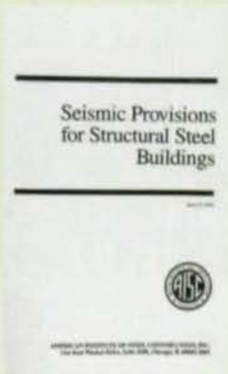

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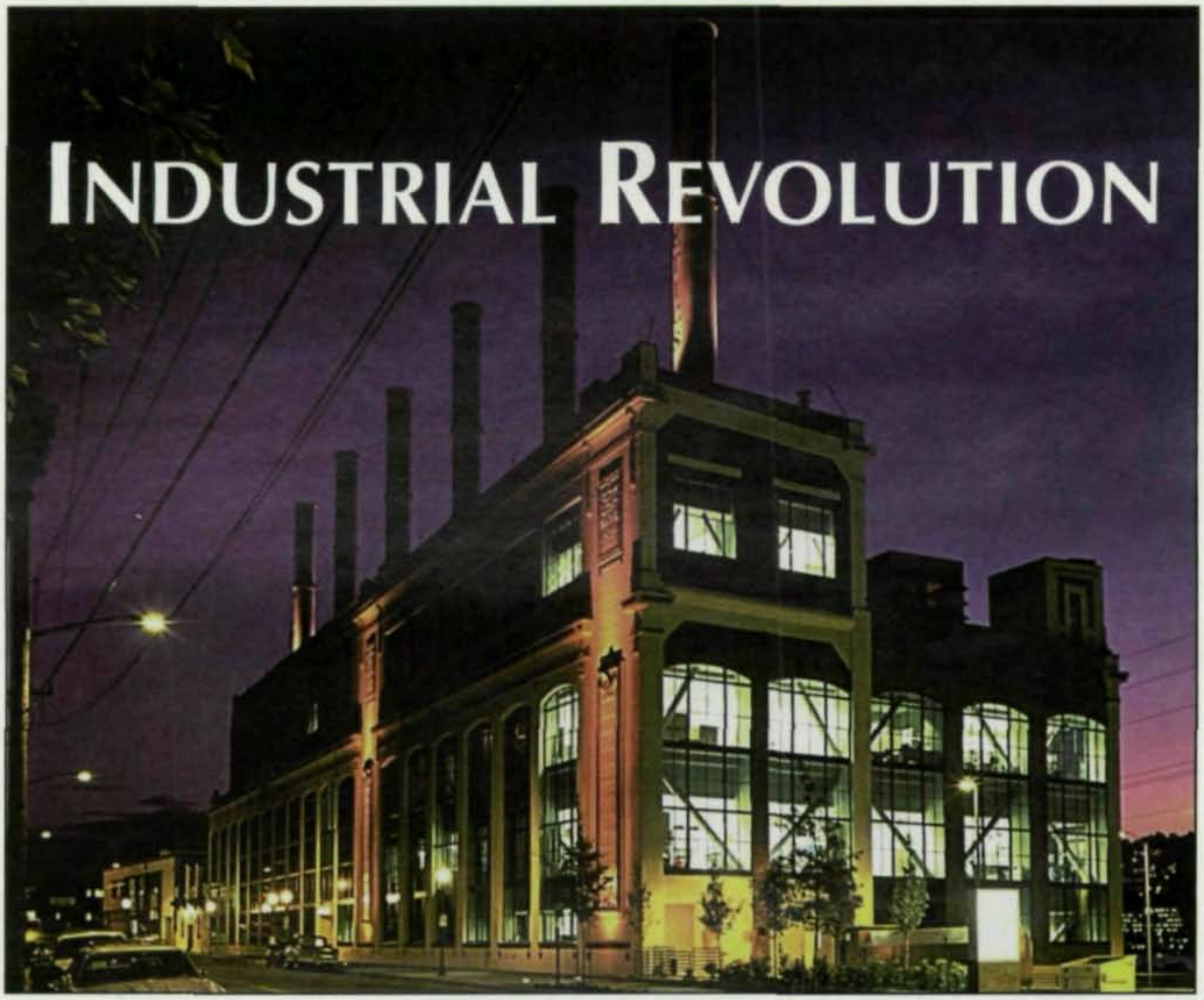


An outdated, yet historic, steam plant proved the perfect new home for a pharmaceutical research company

BY TERRY LUNDEEN, P.E., TODD PERBIX, P.E., AND JOHN SCHWARTZ, R.A.

FOR MORE THAN SEVEN DECADES, THE LAKE UNION STEAM PLANT provided auxiliary power for Seattle. But in 1984, the facility, located on the east shore of Seattle's Lake Union and visible from many vantages throughout the city, was decommissioned.

Sentiment and historic sensibilities demanded that the large concrete building be preserved. The original structure was built in three phases from 1911 to 1922—the end of the era when utilitarian buildings were designed as notable civic works. And the Lake Union Steam Plant was no exception—though essentially a 300-ft. by 90-ft. trapezoid, it featured exquisitely detailed monolithic concrete spandrels.

After the plant was closed, Seattle City Light tried unsuccessfully to find a new use or buyer for the property. Finally, in 1989, the Koll Company approached the City with a proposal to convert the building into a 109-unit condominium. Unfortunately, financing could not be obtained for the project. After other uses were evaluated, a plan was developed to convert the building into a research/office building with ZymoGenetics, the American research arm of a large Danish pharmaceutical company, as tenant.

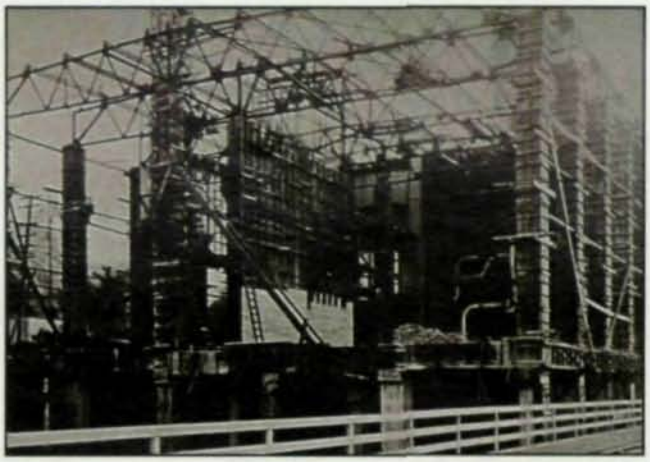
EXISTING STRUCTURE

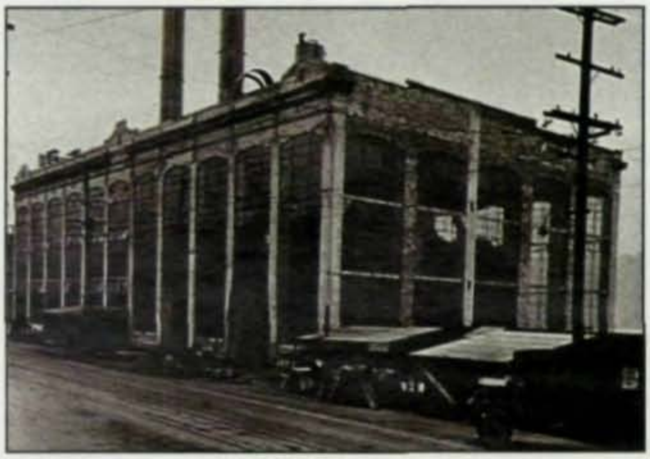
The building was supported on 30-in. to 36-in. square concrete columns. These columns are spaced 16-ft. on center in three longitudinal rows with spacings of 34-ft. and 51-ft. between rows. On the perimeter, the columns were interconnected with deep spandrels, providing lateral stiffness.

There were two primary operating levels in the original building: The basement and the main floor located 20 ft. above the basement. The basement and main floor were cast-in-place concrete beam and slab structures designed for heavy industrial loads up to 600 psf and were supported on the main columns along with a labyrinth of intermediate columns. Isolated from the main structure, the generators were located on the main floor. The main floor and columns below supported the boilers, which were constructed with a steel skeleton and brick shell. The boilers supported the 92-in.-diameter steel smoke stacks, which extended 105-ft. above the roof. In turn, the stacks were laterally supported by guy wires attached to the top of the concrete columns.

The roof was supported on steel trusses, which spanned between the three column rows. The top chords of the trusses were pitched, with the truss depth varying from 5-ft.-9-in. to 7-ft.-9-in., and the bottom chord was located 38 ft. above the main floor. The trusses were constructed of riveted double angles with chord cover plates. Most trusses were unique, due to the phased construction and the varying openings for stacks. The roof itself comprises a cast-in-place concrete slab supported on steel purlins, which framed into the panel points of the truss top chord. At the northwest corner of the building, a penthouse housed transformers and switchgear. The penthouse floors and roof were supported on deep concrete beams that span in the transverse direction.

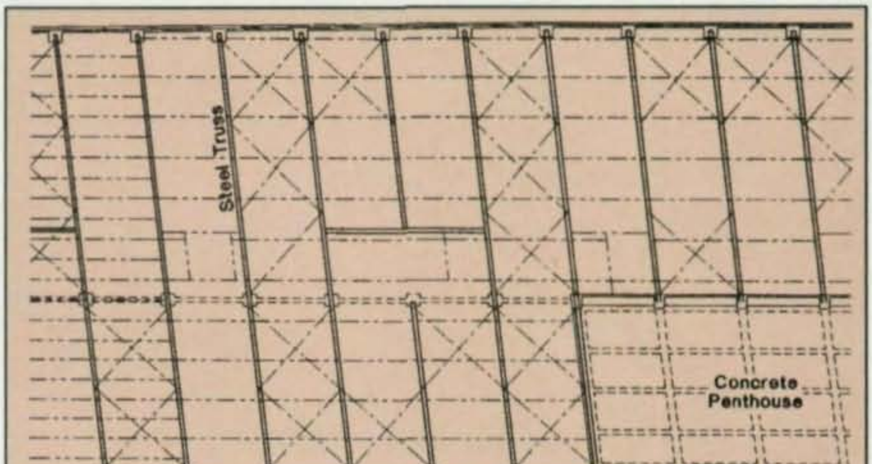
Since the building was located over the edge of Lake Union, it was supported on approximately 2,000 12-in.-diameter piles. Controlled by locks downstream near Puget Sound, the lake is set at two levels each year. The pile caps were set such that the tops of the piles would always be submerged. The mud line varies from 10 ft. below to 2 ft. below the bottom of the pile caps.





Three stages of evolution: the origional steam plant under construction (top left); after completion in the 1920s (middle left); and as it looks today (opposite).

Shown below is the roof framing plan of the current building.



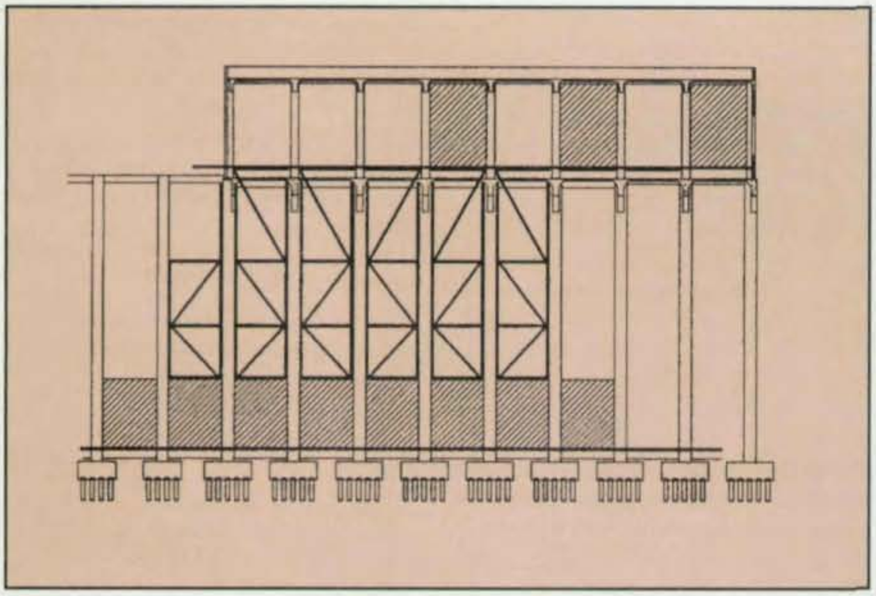
Redevelopment Plan

Initial design studies concluded that a typical lab module, at the east and west sides of the building with a common service core in between, would fit well into the existing shell. This layout, coupled with the sites proximity to the University of Washington and the new campus for the Fred Hutchinson Cancer Research Center and its conve-

nient in-city location, made it ideal for its new tenant.

Since the building is a designated Landmark Structure, the Seattle Landmarks Preservation Board had to approve all changes, modifications or repairs to the structure. In addition, a great deal of input was provided by a Citizens Advisory Committee. Changes to the structure included replacement of the original stacks, replacement of the window system, integration of new floor lines, penthouse expansion to support new stacks, interior layouts, and the configuration and finish of added diagonal bracing.

The programming phase of the project started with detailed discussions with individual senior scientists to outline each labs function, equipment needs, proximity requirements, mechanical and lab gas requirements and other special needs or desires. This process also was conducted for all support and administration departments. The process detailed a need for approximately 95,000 sq. ft. at the time of initial occupancy. ZymoGenetics also desired predominately clearspan lab spaces and a well organized mechanical distribution system that would easily accommodate future modifications or expansion. In addition, the company wanted labs



oriented to the exterior of the building to take advantage of the views and natural light, grouping offices in the center of the building to encourage informal interaction between the various scientists, and providing a design that expressed the dynamic and exciting work in which the company is involved.

By utilizing a negotiated construction contract and design-built subcontractors for the mechanical, electrical and plumbing contracts, these individuals were identified early and were available to assist the design team at the start, where there input could have the greatest benefit.

As the design team developed various options, it became apparent that the vertical floor clearance at the labs would be critical. With the height and bulk variances limiting any potential expansion of the building envelope, the substantial space required for lab mechanical systems, and a stringent client budget limit, a three-floor scheme was identified for the interior of the main Steam Plant building. This scheme also accommodated the clients desire to incorporate a limited interstitial access concept within the ceiling spaces at the second and third floor labs. An original concept to provide steel catwalks in this area was eliminated for cost reasons, but the vertical clearance still allows access for future work on the building systems.

Gravity Framing System

Before attempting to develop structural schemes, it was necessary to evaluate the existing building and understand its limitations.

The main columns were adequate with the exception of an insufficient cover of reinforcement and segregation of aggregate at cold joints. Cores from the boiler support columns indicated that the average compressive strength was 2,500 psi. The steel trusses were in excellent condition and chemical testing confirmed weldability. The major area of concern, then, was the piles. However, a foundation survey by divers confirmed the size and condition of the piles and core samples showed no deterioration of the wood.

Given concerns with known hazardous materials below the basement level, it was clear that foundation work needed to be minimized. Fortunately, the geotechnical engineer on the project discovered a 1915 University of Washington research paper on the construction of the building that provided information on pile lengths and blow counts. Based on this information, and the new

borings, the allowable pile capacities were set at 30 tons and the allowable existing and future loads on pile caps were calculated. The roof structure also was analyzed, as was the main floor structure.

The lab space and parking requirements, along with the foundation considerations, were the driving factors in developing the framing layout. While the total load on the foundation would decrease significantly from the original use, many of the pile caps were located in areas that needed to be column free. An initial attempt to utilize only the three primary existing column lines was unsuccessful because the piles at the central columns would be overloaded. Thus, a fourth column line was established, which resulted in transverse column spacing of 35 ft., 15 ft. and 35 ft. Because of the location of existing pile caps, the longitudinal spacing of the new columns did not align with the 16-ft. skewed module of the existing columns. The framing and architectural floor layouts were adjusted to accommodate this misalignment.

In order to maximize the floor-to-floor space in the labs for mechanical systems, the parking levels were located as low as possible. The existing basement structure was used for the lower parking level and the upper parking level was constructed as a transversely post-tensioned concrete slab with mild reinforced wide shallow longitudinal beams to minimize structure depth.

The three main office and lab floors were framed with composite steel beams. A post-tensioned slab, similar to the parking level, also was considered. However, while somewhat thicker, the steel framing was found to be more cost effective for the higher lab floor loads. Additionally, the owner had concerns that a post-tensioned slab would limit future floor penetrations. Finally, complex connections would have been required to allow the slab to freely shorten and creep without distressing the relatively stiff existing columns. The steel framing also had a scheduling advantage over all cast-in-place options since it allowed top-down construction.

The longer span beams are W18s and the purlins and shorter beams are W12s and W14s. All wide flange material was ASTM A572 Grade 50. The framing was arranged orthogonally wherever possible to minimize skewed connections. Floor edge beams were set back 42 in. from the window line to satisfy historical requirements for the building elevations. The deck edges were then stiffened with 7-in. channels to meet tight deflection tolerances for the custom window frames.

While the owner was concerned with floor vibrations, they felt that most of their sensitive equipment would have to be locally isolated regardless of structure type. Even so, vibration characteristics were somewhat improved compared with typical office construction by using a $4\frac{1}{2}$-in. normal weight topping slab over a 2-in. metal deck. In addition, the extra slab thickness attained a two-hour fire rating without fireproofing the deck.

The expanded penthouse contains several unique framing systems. The floor-to-floor heights established by the existing parapet height made it difficult to obtain functional lab space. In the penthouse addition, four column lines were established that limit span lengths. Three of these lines aligned with either existing or new columns below.

The fourth line is supported on transfer girders at the lower penthouse level. These transfer girders were made of built up W12/WT12 sections placed as close as possible to the existing roof, establishing the new floor level. with the shorter spans above, no transverse framing was necessary and longitudinal runs of mechanical and lab services could be installed directly to the bottom of the floor slab.

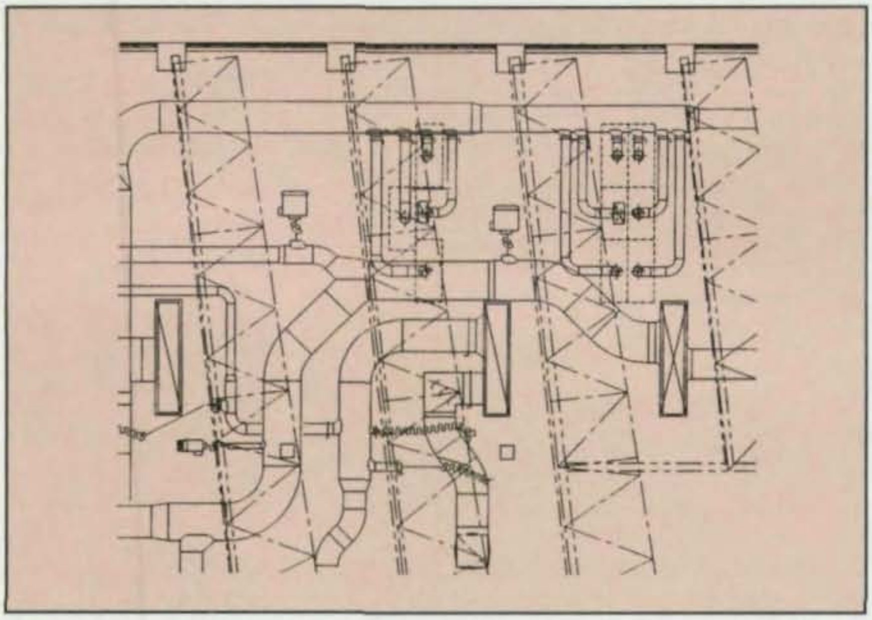
CONNECTIONS

Single shear plates were used for the steel-to-steel connections wherever possible. Due to limited beam depths and high loads, some double angle connections also were specified. All connections were made with horizontal slots, since there is no chance to "plumb" columns in a large renovation project.

The steel-to-concrete connections were perhaps the most critical structural element. Since they had to be fire rated, epoxy anchors were not an option. Thru-bolting the columns also was not feasible because, in addition to the high cost, the bolts would have been visible on the historic exterior building finish. Instead, high capacity expansion anchors, with ICBO certified allowable shear loads exceeding 7,500 lbs., were specified. Typical connections contained eight of these $\frac{5}{8}$-in. bolts spaced at approximately 8-in. on center. Because of the uncertainty of the concrete condition at each anchorage, a load-indicating type option was selected for the bolts.

SEISMIC DESIGN

As with any major renovation in Seattle, developing appropriate seismic criteria is an important project consideration. Due to the change-of-use and extensive demolition in this project, an extensive seismic retrofit was mandated. While the building had withstood two major earthquakes without any sign of damage and the total weight of the building was being reduced with the removal of heavy equipment, the new floors created new load paths in the non-ductile concrete frame. Although the structure had significant strength and stiffness, its ability to withstand a subduction zone type earthquake of long duration was questionable. Therefore, a new seismic system, designed to resist current UBC Zone 3 forces, was designed.



In order for the new lateral system to be effective, it needed to be stiffer than the existing spandrel frames. The choices boiled down to steel concentric braced frames and/or concrete shear walls. As for the gravity framing, foundation considerations were paramount in locating the new lateral systems. Specifically, the overturning forces were limited by the compression pile capacity. Additionally, given the timber pile/concrete pile cap interface, no net tension forces could act on a pile cap. In the longitudinal direction, the obvious location for the primary system was along the existing central column line. Because the lab spaces could not be interrupted in the transverse direction, overturning forces on internal elements with resulting high aspect ratios were excessive. After several options for transverse interior core elements with outriggers to exterior columns were considered, exterior bracing elements were selected.

The main bracing system consists of shear walls in the parking levels below the first floor and steel braced frames above. To preserve the industrial character of the building, all of the 10-in. and 12-in.-diameter pipes are exposed and architecturally featured. The existing columns are part of the longitudinal braced frame. Since concrete columns are not allowed in Zone 3 braced frames in new construction, the columns were evaluated for strength under amplified ($^3/_8 R_w$) earthquake loads. Because three of the 12 existing exterior columns are unreinforced brick infill, the transverse-braced frames were set just inside the building and include new steel columns. In addition to resisting primary frame forces, the columns also were used to strongback the historic brick infill. Torsional forces, resulting from the single offset longitudinal element, are resisted by the exterior transverse elements. Lateral loads in the penthouse are resisted in the transverse direction with steel braced frames and in the longitudinal direction with concrete shear walls.

There are several unique diaphragm elements in the structure. Because it was difficult to transfer tensile drag forces through the existing columns to the longitudinal braced frame, a collector element was developed at the adjacent new column line. The beam sizes along this line were increased for axial forces and the tensile connection forces were resisted with full penetration flange welds. Diaphragm chord forces at the large central slot in the building are resisted by 5-in. structural tubes. Tensile forces in these tubes are developed with pairs of 30-ft.-long, $1^3/_8$-in. high-strength threaded rods, extending through two existing columns. Areas of the existing roof diaphragms that were not sufficient to transfer forces to the exterior frames are supplemented with topping slabs.

The connections between the new and existing elements in the lateral system were quite challenging. Recognizing their importance, the connections were designed for amplified forces according to the current code. Among a host of special conditions, the steel-to-concrete connections in the longitudinal braced frame received the most scrutiny. Steel channels were installed from floor-to-floor to distribute vertical frame forces to epoxy anchors. Each $1^1/_4$-in. anchor has an ultimate shear capacity of 62 kips and in-place load tests were performed beyond this level as part of a contractor substitution submittal. Given the concrete strength, spacing and edge distance requirements, this appears to be the maximum load per unit length that can be obtained with any product on the market. These channels and anchors also are exposed in the finished building.

Using ETABS software, a three-dimensional structural model was developed of the building, containing all new and existing elements that contributed to the lateral stiffness. The structure was analyzed to assure that no existing elements were overloaded. The next step in the analysis was to remove all existing elements and verify the adequacy of the new frames and shear walls. Dynamic analysis was performed since the structure had many of the vertical and plan irregularities listed in the UBC. The foundation was modelled with vertical, lateral, and plan rotational springs to properly evaluate the loads on the piles.

This article was condensed from a paper delivered at the 1994 National Steel Construction Conference. Terry Lundeen was an associate with the Seattle structural engineering firm Ratti Swenson Perbix, Inc. and is currently with Coughlin Porter Lundeen. Todd Perbix is a principal with Ratti Swenson Perbix, Inc. John Schwartz is the managing associate at the Seattle architectural firm Daly & Associates.

STRUCTURAL ENGINEERING SOFTWARE SURVEY

THE PROLIFERATION—AND IMPROVEMENT—OF STRUCTURAL ENGINEERING SOFTWARE makes choosing a package more and more difficult. Fortunately, many vendors are now offering demonstration disks.

Recently, to further help engineers choose a software package, *Modern Steel Construction* surveyed users of 22 software programs. The methodology of the survey involved asking each vendor for the names of 30 active users, with an emphasis on relatively recent purchasers of the program. Each of these users was mailed a survey and asked to return it in a postage paid reply envelope. The return rate averaged around 60%. To further control the survey, we asked how often a respondent uses the program and discarded responses from anyone using the program less than once a month.

The questions reported on the following pages are:

• How easy was it to become familiar with the program's features? (rate the program from 1 to 10 with 10 being easy to learn and 1 being very difficult)

• What was the quality of the provided documentation (rate the documentation from 1 to 10 with 10 being clear and complete and 1 being incomplete and difficult to understand)

• Does the vendor provide adequate customer service (rate customer service from 1 to 10 with 10 being excellent service and 1 being very poor service; if you haven't required customer service, please skip this question)

• How easy is it to use the program? (rate each of the following items from 1 to 10, with 10 being excellent and 1 being poor)

—ease of input
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—output quality

• Does the program perform up to expectations? (rate the program's quality from 1 to 10, with 10 being it fulfills all of the vendors claims and 1 being it does not perform at all)

• Has the program increased your productivity? (rate the program for increased productivity from 1 to 10, with 10 being it has substantially increased your productivity and 1 being it has had no effect on productivity)

• Has the program provided good value for the price paid for it? (rate the program for cost vs. value, with 10 being an extremely cost effective program and 1 being a poor value)

• Would you recommend this program to others? (rate the program from 1 to 10, with 10 being definitely and 1 being no)

The answers to the above questions were computed for both mode (the most frequently occurring response) and mean (the average response).

Generally speaking, there appears to be a slight correlation between length of ownership and perceptions about a program, with the longer the length of ownership, the less positive the perception. One possible explanation for this is that longer users are more likely to be using an older version of the program.

In addition to these questions, we asked about the operating system currently being used and which operating system is preferred. Most users are working on IBM-compatible computers (the only notable exception being users of the Macintosh-based Multiframe program). The vast majority are running DOS-based software, and surprisingly, about half prefer DOS to Windows. One possible explanation for a DOS preference is the existing comfort level that most engineers already have in that system. But just as likely is the realization that DOS-based programs will run quicker than Windows-based programs, especially on older computer systems.

We also asked about how easy it was to integrate the software with other applications. Most of the software packages performed very poorly in this area, though most vendors report that they are working on this area and expect substantially easier integration in the near future. We also asked whether program documentation includes information about program limitations and assumptions. For the most part, according to this survey, vendors are doing a good job of explaining this area.

Some vendors opted not to participate in this survey. Some information on some of these programs is included at the end of the survey results.

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Documentation	8	7.4
Customer Support	10	7.9
Input	7	8.2
Graphics	10	5.5
Connectivity	10	7.7
Output Quality	8	8
Performance	8	7.5
Productivity	9	6.6
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Documentation	7	5.9
Customer Support	7	7.6
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Graphics	9	5.5
Connectivity	10	7.2
Output Quality	10	7.7
Performance	9	7.7
Productivity	8	8.1
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37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84
85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132

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h. Institutional
i. Low-Rise
j. High-Rise

2. Your position
Please circle **ONLY** one
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b. Chief Engineer/ Chief Architect/ Department Head
c. Staff Engineer/ Staff Architect/ Construction Manager
d. Other

3. Type of business
Please circle **ONLY** one
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b. Civil engineer
c. Structural steel fabricator
d. Other fabricator
e. Educator/libary
f. Architect
g. Building owner/developer
h. Steel mill
i. Erector
j. Steel product manufacturer
k. GC/CM
l. Student
m. Other

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b. Immediate or Future Purchase

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Use these cards to request information from manufacturers and other companies mentioned in this issue. Simply circle the numbers referenced in the advertisement or article, fill out the rest of the information requested on the card, and either mail it to: Modern Steel Construction, Creative Data Center, 650 South Clark St., Chicago, IL 60605-9960 or fax it to: **312/922-3165.**

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( ) ( )

business telephone fax number

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49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72
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b. Office Buildings
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b. Civil engineer
c. Structural steel fabricator
d. Other fabricator
e. Educator/libary
f. Architect
g. Building owner/developer
h. Steel mill
i. Erector
j. Steel product manufacturer
k. GC/CM
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Please circle **ONLY** one
a. Information file
b. Immediate or Future Purchase

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650 S CLARK ST
CHICAGO, IL 60605-9960

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MODERN STEEL CONSTRUCTION
Reader Service Card

SES Steel Design Package
Ecom Associates, Inc.
8324 N. Steven Road
Milwaukee, WI 53223
phone: 414/365-2100
414/365-2110
CIRCLE NO: 90

Learning	6	8.2
Documentation	5	6.5
Customer Support	8	8.3
Input	8	7.5
Graphics	6	7
Connectivity	10	8.2
Output Quality	9	7.6
Performance	9	8.7
Productivity	9	8.1
Cost Vs. Value	9	8.1
Advice	10	8.1

Includes both LRFD & ASD. Package offers steel beem, steel column, composite beam and quick steel design.

ETABS
Computer & Structures, Inc.
1995 University Ave.
Berkeley, CA 94704
phone: 510/845-2177
fax: 510/845-4096
CIRCLE NO: 31

Learning	8	8.1
Documentation	8	7.9
Customer Support	10	8.3
Input	10	8.3
Graphics	9	7.3
Connectivity	9	7.3
Output Quality	9	7.6
Performance	9	8.6
Productivity	9	8.1
Cost Vs. Value	9	8.1
Advice	10	8.3

Provides sophisticated 3D analysis of multi-story buildings using either ASD or LRFD. Includes AutoETABS, an analysis & drafting program running inside of AutoCAD.

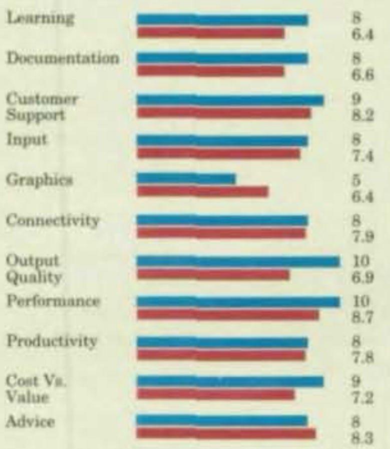
FLOORVIB
Structural Engineers Inc.
537 Wisteria Dr.
Radford, VA 24141
phone: 703/231-6074
fax: 703/639-0713
CIRCLE NO: 78

Learning	8	7.3
Documentation	8	6.5
Customer Support	10	6.5
Input	9	7.9
Graphics	9	6.6
Connectivity	9	6.1
Output Quality	6	7.8
Performance	6	7.4
Productivity	9	5.2
Cost Vs. Value	9	6.9
Advice	9	6.3

Provides vibration tolerance evaluation of steel member-concrete slab floor using a variety of criteria, with a final report generated for each evaluation.

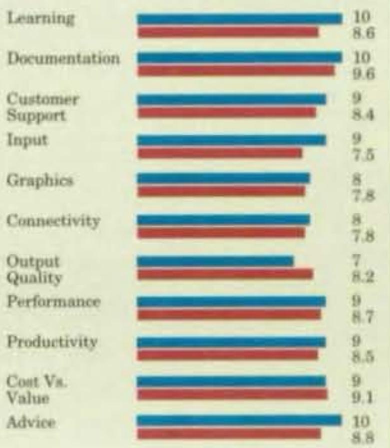
Modal Response
Mean Response

GT Strudl
Georgia Tech Research Corp.
790 Atlantic Dr.
Atlanta, GA 30332-0355
phone: 404/894-2260
fax: 404/894-8014
CIRCLE NO: 71



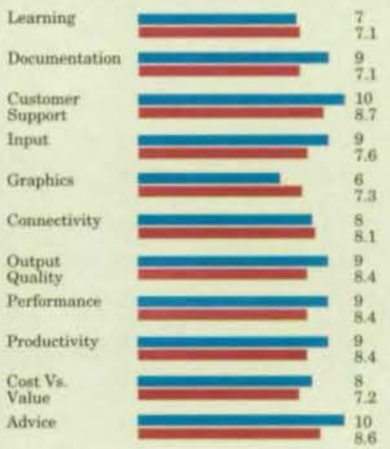
Finite element analysis and structural design CAE system including member design & code checking, nonlinear static & linear dynamic analysis and a graphics modeler.

Images 3D
Celestial Software
2150 Shattuck Ave., Ste. 1200
Berkeley, CA 94704
phone: 510/843-0977
fax: 510/848-9849
CIRCLE NO: 91



2D-3D finite element analysis program offering shear & moment diagrams, P-Delta, static, modal & dynamic analysis, and AISC code check.

MDX
MDX Software
1412 Ridgemont Court
Columbia, MO 65203
phone: 314/446-3221
fax: 314/446-3278
CIRCLE NO: 47



Design and analysis of curved and straight steel bridge girders, compliance with AASHTO specs, I girders, box girders and rolled shapes, ASD or LFD design, and metric units with conversions.

MERLIN-DASH

Opti-Mate, Inc.
P.O. Box 9097, Dept. A
Bethlehem, PA 18018
phone: 610/867-4077
fax: 610/865-1030
CIRCLE NO: 53

Learning	8	7.2
Documentation	8	7.1
Customer Support	9	8.5
Input	9	8.4
Graphics	7	6.7
Connectivity	9	8.2
Output Quality	8	8
Performance	8	8.2
Productivity	10	8.3
Cost Vs. Value	8	7.6
Advice	10	8.5

Bridge design using choice of WSD, LFD or LRFD DL+LL analysis in either English or metric units. Both tapered and parabolic members can be used.

Multiframe 3D

Graphic Magic
180 Seventh Ave., Ste. 201
Santa Cruz, CA 95062
phone: 408/464-1949
fax: 408/464-0731
CIRCLE NO: 92

Learning	10	9.4
Documentation	8	8.4
Customer Support	8	8.2
Input	9	9.1
Graphics	10	9.3
Connectivity	10	9.5
Output Quality	10	8.9
Performance	9	9.1
Productivity	8	8.8
Cost Vs. Value	10	8.9
Advice	10	9.3

Macintosh-based modelling program that includes special elements such as springs, prescribed displacements, member releases and pinned joints. Can use English or metric units.

Multiframe 4D

Graphic Magic
180 Seventh Ave., Ste. 201
Santa Cruz, CA 95062
phone: 408/464-1949
fax: 408/464-0731
CIRCLE NO: 92

Learning	10	8.8
Documentation	9	7.4
Customer Support	10	7.6
Input	10	9
Graphics	10	9.8
Connectivity	10	9.8
Output Quality	10	9
Performance	9	9.2
Productivity	9	9
Cost Vs. Value	10	9.3
Advice	10	9.7

Macintosh-based program provides completely graphical approach to structural modeling, analysis and interpretation of results. Includes database of U.S. and international shapes.

Modal Response
Mean Response

	RAMSBEAM Modal	RAMSBEAM Mean	RAMSTEEL Modal	RAMSTEEL Mean	RISA 2D Modal	RISA 2D Mean
Learning	9	9.3	8	8.4	9	9.1
Documentation	9	8.4	9	8.4	10	8.8
Customer Support	9	9	10	8.8	10	8.6
Input	10	9.2	10	8.8	10	9.7
Graphics	10	8.8	10	8.8	9	8.6
Connectivity	10	9.2	10	8.2	10	8.7
Output Quality	10	8.8	8	8.8	10	9.1
Performance	10	9.7	10	9.3	10	9.7
Productivity	9	8.3	10	8.6	10	9.3
Cost Vs. Value	10	9.1	9	9.2	10	9.8
Advice	10	9.5	10	9.4	10	9.7

RAMSBEAM
Ram Analysis
5315 Avenida Encinas, Ste. 220
Carlsbad, CA 92008
phone: 619/431-3610
fax: 619/431-5214
CIRCLE NO: 81

Single steel/steel composite beam program for ASD or LRFD. Includes almost any loading condition, frame checking, intractive trial designs, partial or full composite, and a library of shapes.

RAMSTEEL
Ram Analysis
5315 Avenida Encinas, Ste. 220
Carlsbad, CA 92008
phone: 619/431-3610
fax: 619/431-5214
CIRCLE NO: 41

Analysis, design & drafting of gravity load resisting members of steel-framed buildings. ASD & LRFD. Includes interface to CONXPRT software for connection design.

RISA 2D
RISA Technologies
26212 Dimension Dr., #200
Lake Forest, CA 92630
phone: 800/332-7472
fax: 714/951-5848
CIRCLE NO: 40

Static analysis & design of frames, trusses, beams, shear walls and retaining walls.

RISA 3D
RISA Technologies
26212 Dimension Dr., #200
Lake Forest, CA 92630
phone: 800/332-7472
fax: 714/951-5848
CIRCLE NO: 40

Learning	10	9.7
Documentation	10	9.1
Customer Support	10	8
Input	10	9.7
Graphics	10	9.7
Connectivity	9	8.2
Output Quality	10	9
Performance	10	9.5
Productivity	10	9.2
Cost Vs. Value	10	9.7
Advice	10	9.8

Includes static and dynamic analysis, P-Delta effects and steel design. Includes shape library. Extensive graphics allow true scale rendering, as well as rotation & zooming.

ROBOT V6
Metrosoft, Inc.
332 Paterson Ave.
East Rutherford, NJ 07073
phone: 201/438-4915
fax: 201/438-7058
CIRCLE NO: 51

Learning	7	6.2
Documentation	6	5
Customer Support	10	7.6
Input	10	6.7
Graphics	8	7.9
Connectivity	10	7.6
Output Quality	9	7.1
Performance	10	7.2
Productivity	7	5.9
Cost Vs. Value	10	7.1
Advice	10	7.1

Fully integrated graphical system for structural analysis & design in LRFD & ASD. Linear & non-linear static and buckling, P-delta and dynamic analysis. Includes interface to CONXPRT.

SAP90
Computer & Structures, Inc.
1995 University Ave.
Berkeley, CA 94704
phone: 510/845-2177
fax: 510/845-4096
CIRCLE NO: 31

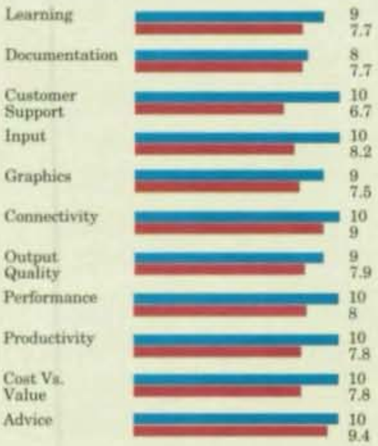
Learning	8	7.5
Documentation	9	7.3
Customer Support	10	8.3
Input	8	7.1
Graphics	9	8
Connectivity	10	9
Output Quality	10	8.4
Performance	9	8.9
Productivity	9	8.9
Cost Vs. Value	9	8.6
Advice	10	9

Large capacity structural analysis program for bridges & buildings. Finite element, static and dynamic analysis using ASD or LRFD. Included are graphical pre- and post-processors.

Modal Response
Mean Response

SDI Floor

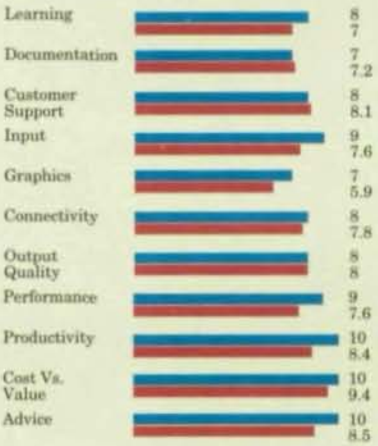
Steel Deck Institute
P.O. Box 9506
Canton, OH 44711
phone: 216/493-7886
fax: 216/493-7886
CIRCLE NO: 77



Set of expert knowledge systems for design of composite and non-composite bays, beams and girders using LRFD. Used to determine most economic design solution.

SIMON Systems

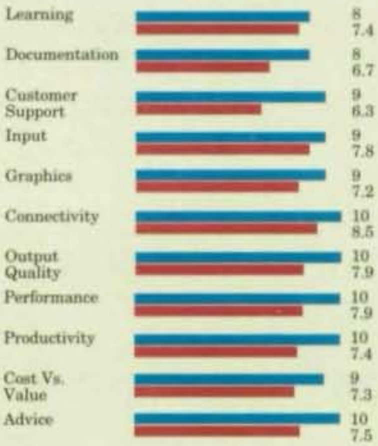
AISC
1 East Wacker Dr., Ste. 3100
Chicago, IL 60601
ph: 312/670-2400
fax: 312/670-5403
CIRCLE NO: 1



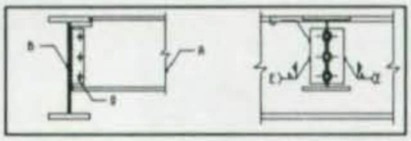
PC software system for the design of straight steel plate girder bridges. Designs I-shaped or mulitple single-cell box-shaped girders with up to 12 continuous spans (and may include hinges).

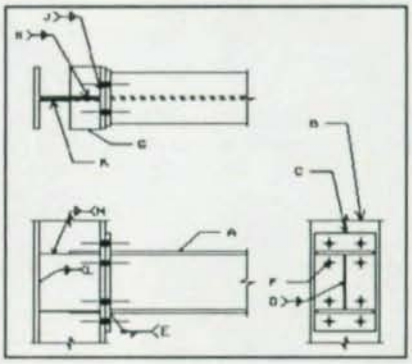
STAAD-III/ISDS

Research Engineers, Inc.
22700 Savi Ranch Parkway
Yorba Linda, CA 92687-4613
phone: 714/974-2500
fax: 714/974-4771
CIRCLE NO: 34

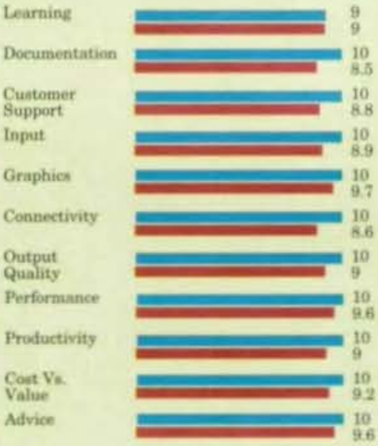


Analysis inlcudes linear and non-linear 2D/3D static/dynamic/seismic/P-Delta, frame/plate/shell elements and all loading & support conditions. Uses both ASD and LRFD.





SteelPlus
Barry Bowen Associates
3394 Coleman Road
Memphis, TN 38128
phone: 901/373-6468
fax: 901/373-6468
CIRCLE NO: 48



Drafting/detailing of structural shapes. Includes all structural shapes(W shapes, channels, angles, tubing, M, S, HP shapes and tees) listed in 9th Edition Manual of Steel Construction.

OTHER STRUCTURAL ENGINEERING SOFTWARE

ANALYSIS*GROUP*

Integrated Engineering Software
8840 Chapman Road
Bozeman, MT 59715
phone: 406/586-8988
fax: 406/586-9151
CIRCLE NO: 87

Suite of six specialized analysis tools for the rapid analysis of rectangular plates, continuous beams, mat footings, beams on elastic foundations, circular tanks, and shear wall rigidity problems.

DAST

Das Consulting, Inc.
865 Turnpike St.
North Andover, MA 01845
phone: 508/794-1487
fax: 508/685-7230
CIRCLE NO: 82

Integrated package offering 2D/3D static inlcuding P-Delta, seismic and dynamic analysis and steel & concrete design per American, Canadian, and other International codes & standards.

OPIMIZER

Engineering Design Automation
1600 Riviera Ave., Ste. 300
Walnut Creek, CA 94596
phone: 510/933-2525
fax: 510/933-1920
CIRCLE NO: 93

Stand-alone program for 3D frame analysis & steel design. Includes: properties & component library; advanced static & dynamic analysis; post processing; code checking; optimal member resizing; and CAD interfaces.

SC-BRIDGE

SC Solutions, Inc.
1451 Grant Road
Mountain View, CA 94040
phone: 415/903-5050
fax: 415/691-9452
CIRCLE NO: 94

Generates both stick and 3D models for dead load, live load and seismic analysis to be used with either GT STRUDL or ADINA. Includes both open steel and concrete box girders.

SABRE

Opti-Mate, Inc.
P.O. Box 9097, Dept. A
Bethlehem, PA 18018
phone: 610/867-4077
fax: 610/865-1030
CIRCLE NO: 53

Reduces time needed to analyze/design highway sign structures and creates more efficient structures. Models and prismatic or tapered steel members for most-used tower and beam configurations.

STRUCAD*3D

Zentech, Inc.
8582 Katy Freeway, #205
Houston, TX 77024
phone: 713/984-9171
fax: 713/984-9175
CIRCLE NO: 95

Graphics-oriented FEM design package including: elastic supports; permanent settlements; torsion design checks; 3- and 4-node plate elements; truss elements; code checks, static, dynamic & seismic analysis; machine vibration analysis; material takeoffs; and section libraries.

SODA—STRENGTHENING OPTIMIZATION DESIGN & ANALYSIS

Acronym Software
22 King St. St., #302
Waterloo, Ontario N2J1N8
Canada
CIRCLE NO: 96

Automatically designs least-weight 2D or 3D steel frame or truss from a libary of commercially available steel sections. Includes: ASD, LRFD and CISC; and P-Delta and first order design & analysis.

TRAP-JR.

Opti-Mate, Inc.
P.O. Box 9097, Dept. A
Bethlehem, PA 18018
phone: 610/867-4077
fax: 610/865-1030
CIRCLE NO: 53

Performs an analysis or group loading of a simple or continuous truss having up to six spans. Output includes verification of truss geometry, a force summary for DL+LL+I, and inventory, operating and posting ratings. New version includes LRFD & LFD.

VISUALANALYSIS

Integrated Engineering Software
8840 Chapman Road
Bozeman, MT 59715
phone: 406/586-8988
fax: 406/586-9151
CIRCLE NO: 87

Windows-based general purpose finite element analysis package. Includes service & factored loads, smart combinations, response spectrums, static and dynamic analysis. Offers graphical results and context sensitive help.

WINSTRUDL

C.A.S.T.
P.O. Box 14676
Freemont, CA 94539-4676
phone: 510/226-8857
fax: 510/226-7328
CIRCLE NO: 97

Windows-based general purpose finite element analysis program including static, P-Delta and dynamic analysis and AISC (ASD & LRFD) code checks.

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