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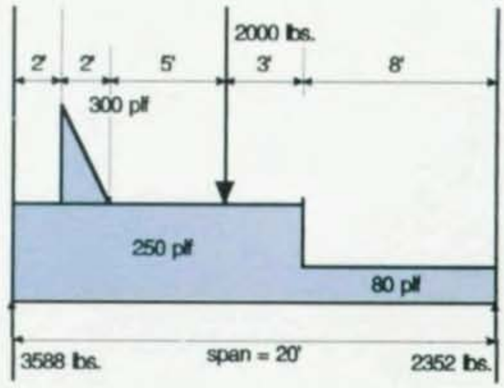
example



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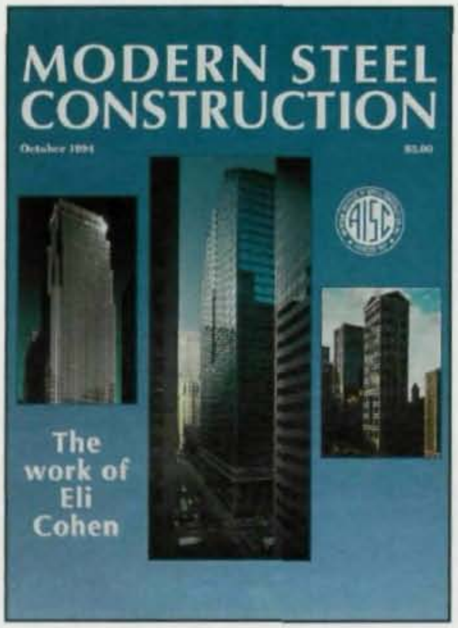
Volume 34, Number 10 October 1994



Eli Cohen is Chicago's foremost practictioner of structural engineering today. It's hard to walk along any downtown street in Chicago without seeing one of his numerous projects.

Modern Steel Construction (Volume 34, Number 10). ISSN 0026-8445. Published monthly by the American Institute of Steel Construction, Inc., (AISC), One East Wacker Dr., Suite 3100, Chicago, IL 60601-2001.

Advertising office: The Ramage Group, O'Hare Lake Office Plaza, 2400 E. Devon Ave., Des Plaines, IL 60618 (708) 699-6049.

Subscription price:
Within the U.S.—single issues $3; 3 years $85.
Outside the U.S.—single issues $5; 1 year $36; 3 years $100.

Postmaster: Please send address changes to Modern Steel Construction, One East Wacker Dr., Suite 3100, Chicago, IL 60601-2001.

Second class postage paid at Chicago, IL and at additional mailing offices.

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GEERHARD HAAIJER

Tragedy recently befell the steel industry—and the entire structural engineering community—with the loss of Geerhard (Jerry) Haaijer. For the past 11 years, Jerry was AISC's Vice President of Technology and Research and a driving force in many of the progressive design changes occurring in the fabricated structural steel industry.

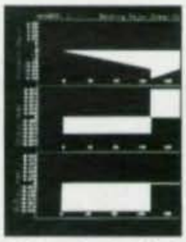
Before that, he spent 27 years with U.S. Steel's Research Laboratory, including 17 as chief of the Design Technology Division. He also served an adjunct professor at Carnegie-Mellon University in Pittsburgh. His many papers included such topics as autostress bridge design, plastic design theory, and hybrid girder design.

While Jerry will be remembered and honored for his many professional accomplishments, he will also be missed for his remarkable personality. Like a favorite uncle, he would illustrate a point with a story. And like a great teacher, he could take even the most complicated subjects and explain them so clearly that even the poorest student understood. Often, when I had problems understanding one topic or another that I was writing about, I found myself in Jerry's office. Sometimes just a few words would suffice. But more often, he'd put pen to paper and draw me a clear and concise answer. In the five-and-a-half years I was privileged to have known and worked with Jerry, I came to respect not only his brilliance, but also his ability to remain unflappable despite the turmoil around him. Even more impressively, he was able to extend that calmness to others. No one was better at diffusing a tense meeting or situation.

He was also remarkable for how much effort he was willing to make to help others no matter how busy he was with his own work. If a few of us were discussing something at lunch, it was not unusual for Jerry to drop by my office a couple of days later with a copy of a paper he had dug out of his huge files that he thought might be helpful. And many in the industry will be forever grateful for his mentoring skills. Jerry's legacy won't just be his own accomplishments, but also the accomplishments of his many students and others to whom he gave a professional boost.

A memorial scholarship fund has been established in Jerry's name at Lehigh University. Contributions can be sent to: The Geerhard Haaijer Memorial Scholarship Fund, Lehigh University, 207 Memorial Dr. West, Bethlehem, PA 18010. **SM**

How to get from here



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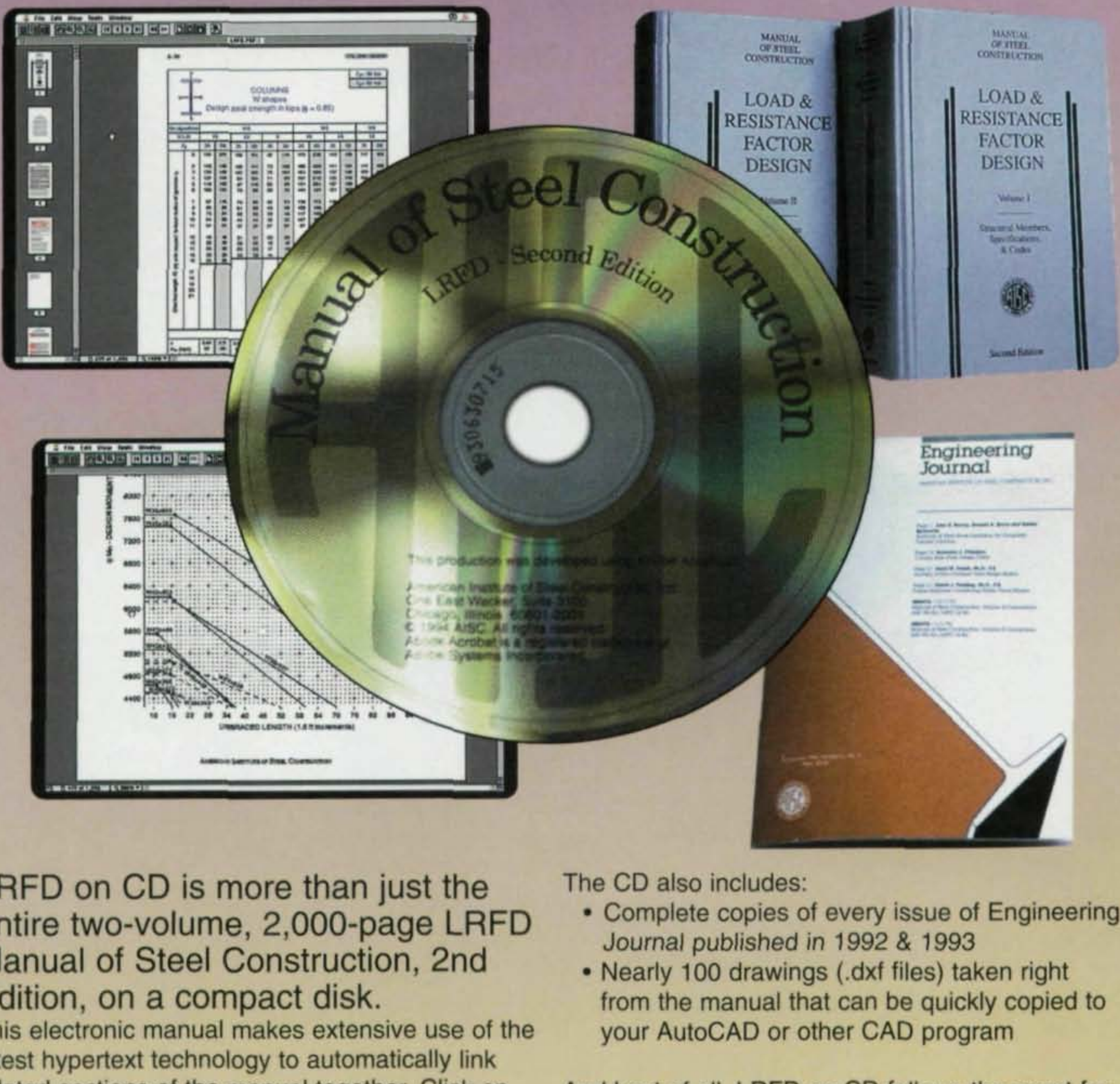

LRFD on CD is more than just the entire two-volume, 2,000-page LRFD Manual of Steel Construction, 2nd Edition, on a compact disk.

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And best of all, LRFD on CD follows the exact format, page-by-page, as the Manual. If you're looking at nominal strength parameters on page 6-115 of the Manual, the identical page is reproduced on the CD.

LRFD on CD is available for $1,000 (or $750 for AISC members).

To order or for more information:
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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

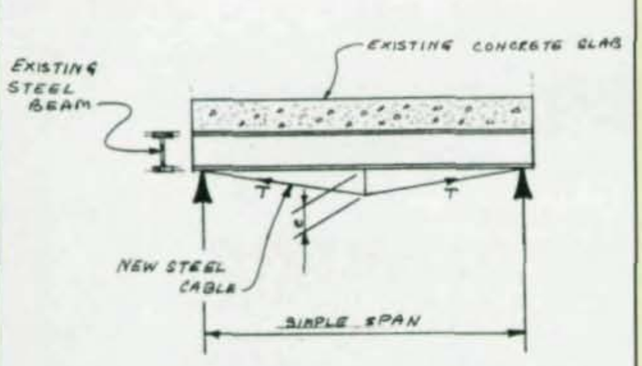
Answers and/or questions should be typewritten and double-spaced. Submittals that have been prepared by word-processing are appreciated on computer diskette (either as a Wordperfect file or in ASCII format).

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:

Can an existing steel beam and concrete slab be made to work together in composite action by adding studs to the steel through cored holes? Are there any special considerations?



M_D = Dead Load Moment
M_L = Live Load Moment
Net Moment = $M_D + D_L - T \times e$
For Crack Control, $M_D \nless T \times e$

It is presumed that the intent here is to enhance the capacity of an existing beam. One option that does not involve composite action is presented in the figure.

A steel cable can be installed to create negative moment in the center of the beam to counteract the positive moment from the gravity loads. The tension in the cable can be developed to counteract the dead load moment. Needless to say, T x e should not exceed MD since that may render the concrete slab susceptible to cracking.
Vijay P. Khasat, P.E.

In a structure that has tubular columns, should weep holes be added at the bottom of the columns in order to drain any water in the column?

Tubular columns which are exposed to the weather, or to temperature change which can *cause interior condensation, should have* weep holes even if the columns are capped. Water can also enter a column through the ends of slots which are not totally covered by washer.

The consequences of water entering a tubular column are that the column may freeze and burst, or may be subject to hidden corrosion.

If, however, a column is protected from the elements and is not subject to drastic changes of temperature, or an overly humid environment, weep holes may not be necessary. Some engineering judgement is required.
David T. Ricker, P.E.
Payson, AZ

When erecting steel beams on a brick wall, could the non-shrink grout be omitted under a proper bearing plate, if the surface of the brick is smooth, clean of any and all debris and leveled?

In practice, we do not believe the omission of grout under a potentially rough bearing surface (or even a smooth surface) is wise since: (a) unanticipated or unaccounted for torsional strain and translation can result if the bearing surface plane is not normal to the loading plane; (b) the bearing surface and bearing plate (or flange) will have zones of excessive stress if the loading not uniform; (c) a failure can result in one or more of the mechanisms involved in the transfer of load from one member to another since the model calcu-

lations might not match the real loading and boundary conditions. These considerations are amplified when the base surface is non-uniform as in the case of masonry construction (brick or c.m.u.). Without the use of a grouted leveling bed, the edge of the base will also be loaded which can result in a premature shear/tension failure at the edge (popping of the corner). As such, we set back the grouted leveling bed and the bearing plate $^1/_2$ inch to minimize this potential failure mode. We specify shrinkage-compensating (the term, "non-shrink grout" is a misnomer) grout in the 5 to 10 ksi ultimate compression strength range as determined by ASTM C1019 depending on the bearing stresses with a minimum thickness of $^1/_2$ inch.
Stephen K. Crockett, P.E.
David M. Berg Associates, Inc.
Needham, MA

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 following national publications deal expressly with the design concerns of all types of hoisting equipment. Serviceability and defection limits are treated in great detail in these documents:

- American National Standards Institute B30.XX series of standards.
- Crane Manufacturers Association of America Specifications 70 and 71.

Joe S. Garcia, P.E.
Santa Fe, NM

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 Construction, One East Wacker Dr., Suite 3100, Chicago, IL 60601-2001.

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

The AISC Manual indicates that design strengths tabulated for clevises and turnbuckles are calculated using ϕ = 0.3 in LRFD (or a factor of safety of 5 in ASD). The Manual indicates that this conservative reduction is used because these devices are most often used for temporary rigging which may be subjected to dynamic and impact loading. When these devices are used in permanent applications and not subject to these considerations, e.g., as part of the permanent bracing system, is it justified to use a of 0.5 in LRFD (or a factor of safety of 3 in ASD)?

What is the most efficient way to enlarge an existing footing, when new loading conditions are applied?
Jake Roth
Roth Metal Works, Inc.
Brooklyn, NY

The bending resistance for square and rectangular sections is doubled when bent about the edge instead of the neutral axis. When is it appropriate to use bending across the edge of the section?
Don A. Finney
Mason & Hanger - Silas Mason Co., Inc.
Amarillo, TX

In addition to the requirement of Section B5, the laterally unsupported length L_b of a box member is based on the ratio M_1 / M_2. What value of M_1 / M_2 should be used in the case of a simply supported beam, where M_1 / M_2 = 0/0, which is mathematically undefined? Note that similar situations occur in the equations for bending coefficients C_b and C_m in the bending and combined axial and bending equations, except that statements are made in the text that cover the case of a simply supported beam.
George R. Lang, Jr., P.E.
Mobil Producing Nigeria, Ultd.
Morgan City, LA

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

Avoiding Professional Liability Traps

WHAT IS THE LIMIT OF PROFESSIONAL LIABILITY for design professionals? Traditionally, the courts have held that professional engineers have a duty to exercise that degree of care normally exercised by design professionals under like or similar circumstances.

Of course, that's a pretty nebulous standard—Who gets to decide what's a "normal" standard of care? Today, though, the issue has been further muddied. Now lawyers are arguing not just ***what*** duty is owed, but also ***to whom*** the duty is owed.

Earlier this century, courts ruled that design professionals did not owe a duty of care to an individual unless the design professional had a direct contractual relationship with that individual.Thus, if the roof of a theater collapsed, the design engineer was not liable to those patrons injured or their heirs because there was no legal contractual relationship between the patrons and the design professionals. However, today the law is different. A designer is responsible to a third party if the designer's negligence caused either injury or property damage to that person—regardless of whether there is any contractual relationship between the designer and the third party.

But what about where an individual doesn't suffer injury or property loss due to negligence by a design professional, but instead suffers an economic loss either through a delay or the need for extra work? Or, just as commonly, one design professional suffers economic loss due to the negligence of another design professional working on the same project? In neither case is there normally a contractual relationship between the two parties.

Third party suits over economic loss are attractive because each group has a contractual relationship with the project's developer, but neither wants to sue the developer and risk souring a future relationship. These suits also are attractive when one group is contractually limited. Under these circumstances, can a potential plaintiff essentially disregard the written contract and sue a party with whom it has no contract?

Unfortunately, this question is still being hotly debated. During the past decade, the highest courts in about two dozen states have considered the question, and the answers differ from state to state. ***About half have adopted the so-called "economic loss" rule,*** which finds its origin in the law of products liability. Under the economic loss rule, a design professional is not responsible for purely economic loss caused to a third party by his or her negligence if there is no contract between the third party and the design professional and there has been no personal injury or property damage.

The remaining states, however, have rendered an opposite opinion, holding that licensed professionals are responsible for all damage, economic or otherwise, arising from their negligence.

Further complicating the issue, not all states have considered the issue, and even in those that have, the law is not necessarily clear. For example, Ohio recently has apparently reversed itself, initially adopting the economic loss rule, then later issuing a contrary decision rescinding the economic loss rule. South Carolina, on the other hand, has issued a series of decisions which say that a first-time homeowner has a right to sue a designer hired by the home's developer for purely economic loss caused by design defects. However, there is some question as to whether that rule also applies to a battle-hardened subcontractor on an industrial project—an issue our office is currently appealing to that

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

state's supreme court.

To add even more fuel to the fire, Maine recently issued a thought-provoking (to say the least) expansion of the law in this area when it held that a design professional who attended a preliminary meeting between an owner and a financial institution at which a construction loan was being negotiated was liable to the financial institution for not advising it that the owner's budget was insufficient to build the project. Which raises an interesting follow-up question: Under that same standard, would a design professional owe the same duty to construction contractors who don't receive final payment from an insolvent owner?

EVENTUALLY, DESIGN PROFESSIONALS WILL BE RESPONSIBLE FOR ALL LOSSES, ECONOMIC AND OTHERWISE, RESULTING FROM BREACH OF THE PROFESSIONAL LEVEL OF CARE

Fortunately, it is unlikely that many states will adopt a standard requiring design professionals to be the watchdog of an owner's financial solvency. ***However, I do believe that, ultimately, most jurisdictions will reject the economic loss rule and eventually design professionals will be responsible for all losses, economic and otherwise, resulting from breach of the professional level of care.*** The law does not move rapidly, though, and such a nationwide evolution may take a generation or longer.

In the meantime, what can designers and contractors do to protect themselves?

• **First**, design professionals should be certain that their contracts clearly define the scope of their work on each particular job and that project documents clearly establish that no contractual relationship (or third party beneficiary relationship) is being established, or should be implied, between the design professional and anyone other than the party directly engaging the design professional. Any contract language that would limit the measure of damages recoverable by a contractor should apply to both the design professional and the owner.

• **Second** (and this is easier said than done), design professionals should not accept jobs where the project owner is not providing sufficient time or remuneration to properly discharge his or her professional responsibilities.

Contractors should not accept contracts or submit competitive bids on projects where the design documents are clearly deficient. If, after a project is underway, an owner changes the ground rules under which the design professional is to perform and those changes are detrimental to the project, then the design professional should either resign the commission or be certain that the record is clear as to the owner's action. The design professional should be remunerated for the impact of these changing ground rules and, in extreme cases, should attempt to have the owner agree to hold him or her harmless from any difficulties which may arise.

• **Third**, communication is the best preventive medicine to avoid litigation. In recent years "partnering" (a new term for the old-fashioned idea of teamwork) has gained great favor on construction projects and is ***heralded by many in the insurance industry as being the single most effective way to avoid litigation on today's complex construction projects.***

• **Fourth**, where litigation appears inevitable, engineers and contractors should utilize the contract chain-of-command in attempting to resolve disputes of this nature. You can be almost certain that insurance carriers will raise the economic loss rule in every instance where a third party negligence suit is brought, even in those jurisdictions where the economic loss rule appears to have been abolished. And, of course, when litigation seems inevitable, design professionals should seek the advice of counsel and the consent of insurance carriers before entering into any agreement to settle a dispute on a construction project where issues related to professional liability have been raised.

As the saying goes, an ounce of prevention is worth a pound of cure.

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TWO NEW LRFD TEXTBOOKS

SEGUI LRFD TEXTBOOK OUT IN RECORD TIME

By Robert F. Lorenz, P.E.

MODERN ADVANCES IN PUBLISHING TECHNOLOGY are catching up to the speed of television. The same month that AISC introduced it's new manual on Load and Resistance Factor Design (LRFD), a textbook on the new Specification landed on my desk. That textbook, *LRFD Steel Design*, is authored by William T. Segui, a faculty member in the Civil Engineering Department at Memphis State University and author of Fundamentals of Structural Steel Design, a textbook on Allowable Stress Design methods.

Segui's latest book contains a lucid text and well-explained example problems that should help the understanding of LRFD, which many perceive as a complex subject. The layout is generous and flowing, and is conducive to enlightened reading, even by students.

The heart of the book, though, is the set of problems following each chapter. This text has more than 300 problems for solution; 48 on eccentric connections alone. Answers to more than half these exercises are listed at the end of the book.

After two rather short introductory chapters, the next five chapters cover tension, compression, bending, beam-columns, and simple connections. The author suggests this much for a basic undergraduate course. Advanced topics are found in Chapter 8 (eccentric connections), Chapter 9 (composite construction) and Chapter 10 (plate girders). Plastic design and ASD are subjects of brief and concise appendices.

Each technical chapter has a dozen or so example problems that are truly updated and contain quite detailed explanations. Subtle changes to the Specification, such as the new C_b formula or the upper bound on shape factor are clearly delineated in these examples. If you're a practicing structural engineer who has heard enough LRFD theory and needs a deep resource of worked-out design examples, this book is for you.

For those steel design educators who want to jump start their courses with a text that has already incorporated the new 1993 AISC LRFD Specification and the 1994 LRFD Manual of Steel Construction, this textbook may be just the thing.

More information on LRFD Steel Design can be obtained from PWS Publishing Co., 20 Park Plaza, Boston, MA 02116; fax: 617/338-6134.

Robert F. Lorenz, P.E., is the AISC Director of Education and Training.

GESCHWINDNER AND COMPANY INTRODUCE LRFD TO ASD LOYALISTS

WHILE EXPERIENCED DESIGN PROFESSIONALS HAVE A WIDE VARIETY OF DETAILED TEXTBOOKS from which to choose, many of these are too complex for students and novice engineers. However, a new textbook, *Load and Resistance Factor Design of Steel Structures*, seems to have been written with the student or novice engineer in mind. Consequently, it provides a firm basis for understanding and continued learning in steel design.

The greatest strength of this textbook is that its topics are covered in a manner that is well organized, completely understandable, and straightforward. In all cases, the authors review the underlying theory, provide practical examples, discuss design considerations and offers real-world applications. Furthermore, the book first presents basic principles and simplified cases, and then builds up to more complex discussions. Above all, the text is loaded with references to other sources of supplementary information—an indispensable benefit for those readers interested in more detailed discussions and/or the pioneering source of certain information.

Like most current textbooks, *LRFD of Steel Structures* is based upon the 1986 LRFD Specification and the 1986 LRFD Manual. However, the solutions manual is expected to summarize the effects of the subtle and substantive changes made in the 1993 LRFD Specification and the 1994 LRFD Manual.

The first three chapters of this textbook provide a thorough discussion of the LRFD method, including the underlying philosophy and principles of LRFD, a discussion of load and resistance factors, and loads and load combinations. In addition, the text provides an excellent discussion of the structural reliability benefit LRFD offers and promotes an understanding of how LRFD grew out of ASD.

The fourth chapter covers materials for steel structures: properties and characteristics of steel; steel grades; and bolt, weld

CONTINUED ON PAGE 20

QUICK STEEL SURVEY

DURING THE PAST FEW YEARS, AISC has produced a series of design guides on such subjects as: Industrial Buildings; Load & Resistance Factor Design of W-shapes Encased in Concrete; Low- and Medium-Rise Steel Buildings; Extended End-Plate Moment Connections; Serviceability Design Considerations for Low-Rise Buildings; Design of Steel and Composite Beams with Web Openings; and Column Base Plates. On what other subjects should AISC consider producing design guides or aids (circle the appropriate numbers on the reader response card near the back of this magazine; you may circle as many as you would be interested in):

100. ....Commercial Buildings
101. ....Office Buildings
102. .....Parking Structures
103. ....Residential Buildings
104. ....Medical Facilities
105. ....Economical Building Details
106. ....Economical Bridge Details
107. ....Practical LRFD Primer
108. ....Metrication
109. ....Short-Span Steel Bridges
110. ....Floor Vibration Criteria
111. ....Stub Girders
112. ....Semi-Rigid (PR) Frames
113. ....Seismic Design
114. ....Eccentrically Braced Frames
115. ....Architecturally Exposed Structural Steel
116. ....Connecting Non-Structural Components to Steel Systems
117. ....Connecting Steel and Concrete Systems
118. ....Connections for Steel Pipe and Structural Tubing

GESCHWINDNER, CONT.

electrode and shear stud steels. Chapters 5 through 8 cover tension members, columns, bending members and plate girders. Chapter 9 examines beam-columns and frame behavior including second-order effects, interaction, braced and unbraced frames, fully restrained frames (with leaning columns), partially restrained frames and bracing design. Chapters 10 and 11 cover composite construction and connections.

The authors are eminently qualified. Louis F. Geschwindner, Ph.D., P.E., is a professor of architectural engineering at Pennsylvania State University. Robert O. Disque, P.E., is a consultant with Besier Gibble Norden Consulting Engineers, Inc., and the former Director of Building Design Technology with AISC. Reidar Bjorhovde, Dr.Ing., Ph.D., P.E., is a professor of civil engineering at the University of Pittsburgh.

This textbook provides an excellent resource for students. Additionally, the discussion of the LRFD method and strong coverage of applied LRFD design examples would be of great benefit to the novice engineer or the experienced engineer unfamiliar with LRFD.

Charles J. Carter is Staff Engineer—Structures with AISC and a former student of Louis Geschwindner at Penn State.

Geerhard Haaijer

(1929-1994)

GEERHARD HAAIJER, PROMINENT STRUCTURAL ENGINEER AND VICE-PRESIDENT OF TECHNOLOGY AND RESEARCH AT THE AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC) has passed away at the age of 65. A native of the Netherlands, Dr. Haaijer received his professional degree in civil engineering in 1952 at the Technical University, Delft, the Netherlands, and his doctorate in civil engineering in 1956 from Lehigh University, Bethlehem, PA.

During his 11 years as Vice President of AISC, Dr. Haaijer was actively involved as a leader in the steel industry both nationally and internationally. He published numerous professional papers and served actively in many professional organizations in civil engineering; the American Society of Civil Engineers, the Structural Stability Research Council, the Research Council on Structural Connections, the American Welding Society, the European Convention for Construction Steelwork, the International Association for Bridge and Structural Engineering, and the Royal (Netherlands) Institute of Engineers.

Before joining AISC in 1983, Dr. Haaijer was employed by United States Steel Corporation's Research Laboratory for 27 years, including 17 as chief of the Design Technology Division. During his tenure, he expanded this division from three engineers to an effective research group of 55. Additionally, he served as adjunct professor in the Department of Civil Engineering at Carnegie-Mellon University in Pittsburgh, teaching courses in structural engineering and mathematics.

His background in research includes the areas of plastic design, development of hybrid girders, new fire-protection methods, cold-formed steel framing for residential structures, finite element analysis and autostress design of steel bridges.

The Geerhard Haaijer Memorial Scholarship Fund has been established at Lehigh University. Contributions can be sent to Lehigh University, 207 Memorial Drive West, Bethlehem, PA 18010.

Upcoming Events

AISC Marketing's popular four-part seminar series, "Innovative Practices In Structural Steel," is quickly winding down with only 13 more seminars sceduled. The lecture includes information on the new LRFD Manual of Steel Construction, inlcuding such topics as the stability of unbraced frames, web crippling equations, and slip critical joints at factored loads.

The seminar also includes a session on state-of-the-art design software, the latest NEHRP Seismic Regulations, and a review of semi-rigid composite connections.

The seven-hour seminar costs \$90 (\$75 for AISC members), including dinner and a variety of handouts. The lecture has a CEU value of 0.4. For more information, call 312/670-5400.

Seminar Dates & Locations

Edison, NJ	Oct. 4
Philadelphia	Oct. 6
Detroit	Oct. 11
Indianapolis	Oct. 13
Memphis	Oct. 18
Phoenix	Oct. 20
Cleveland	Oct. 25
Columbus, OH	Oct. 26
Cincinnati	Oct. 27
Miami	Nov. 1
Orlando	Nov. 3
Portland, OR	Nov. 15
Las Vegas	Nov. 17

This year's T.R. Higgins Award lectures on composite design are currently underway. Lawrence G. Griffis, senior vice president of Walter P. Moore and Associates in Houston, is scheduled to give two lectures in November (for a condensed version of his lecture, see pages 36-47 of this issue). He'll be in Austin, TX, on Oct. 14 at the Annual Convention of the Structural Engineers Association of Texas and in Atlanta on Nov. 15.

For information on the Austin lecture, contact AISC Marketing regional engineer Jim Anders at 214/369-0664.

For information on the Atlanta lecture, contact AISC Marketing regional engineer Dave Magee at 404/642-9707.

SSPC's 1994 International Conference and Exhibition on paintings and coatings for structural steel will be held Nov. 11-17 in Atlanta. The technical program includes 12 seminars and17 tutorials. For more information, contact: SSPC, 4516 Henry St., Suite 301, Pittsburgh, PA 15213-3728 or call 412/687-1113.

The Steel Structures Research Council is accepting papers for its "Stability Problems Related to Aging, Damaged & Deteriorated Structures" conference to be held March 28-29 1995 in Kansas City. One-page abstracts on solutions to stability problems in buildings, bridges, offshore structures or lifeline structures should be submitted by Oct. 15 1994 to: SSRC, Fritz Engineering Laboratory, 13 E. Packer Ave., Lehigh University, Bethlehem, PA 18015.

Eli Cohen's design for 10 South LaSalle St. was the first Chicago structure to preserve a significant portion of the facade of the building it replaced. The first four stories of the new 37-story office tower feature the granite and terra cotta facade of a 16-story office building designed by Holabird and Roche in 1911. The preservation involed keeping the first bay of the old steel-framed structure intact, a solution that helped win Cohen the 1987 Most Innovative Structure Award from SEAOI.

DESIGNING BUILDINGS THAT WORK

Developers and architects appreciate Eli Cohen's ability to design economical—and functional—buildings

By Cindi Crane

CHICAGO'S LEADING STRUCTURAL ENGINEER DOESN'T WORK FOR ITS BIGGEST FIRM or its most publicized. In his approach to structural engineering, he prefers simpler solutions to cutting edge design, diplomacy to obstinacy, and reliability above all else. His structural solutions are "not too exotic," as several of his colleagues put it. But Eli Cohen wouldn't have it any other way.

With almost 40 years of structural engineering experience, the 67-year-old principal of Thornton-Tomasetti/Cohen-Barreto-Marchertas structural engineers (TT/CBM) is as much a fixture in Chicago as the many celebrated buildings he has designed. Cohen is admired and appreciated by developers, architects and contractors for his deftness as a team player, and for consistently offering functional, economical structural solutions. His clients read like a player roster for a building Dream Team—clients such as the American Medical Association, Leo Burnett advertising agency, Miglin-Beitler, and John Buck. Cohen loves his work, and his affections accent the Chicago skyline with impressive edifices that, like him, were built to last.

"He's a fabulous engineer," says Charles Thornton, P.E., of Thornton-Tomasetti structural engineers in New York, which merged with CBM last year.

"Anybody that could be responsible for the number of major projects in Chicago that a relatively small firm has accomplished is unbelievable. When you walk around town with him, he says, 'I did that one, I did that one, I did this one, I did that one.' I mean, there isn't much he hasn't touched in Chicago."

Although CBM's work spans from cooling towers to high rises, it is most noted as a pioneer in the use of composite construction in Chicago. CBM has engineered a number of these type of systems for such renowned architects as Helmut Jahn, Harry Weese, Dirk Lohan, Philip Johnson & John Burgee, Kenzo Tange, Patrick Shaw, Cesar Pelli, Ricardo Bofill and Kevin Roche. "It's challenging working with their ideas," Cohen says. "They're very creative people."

However, Cohen has a well deserved reputation of pleasing both architects and developers. Paul Beitler of Miglin-Beitler, one of Chicago's largest developers, practically sings Cohen's praises. "It's easy to take something complicated and keep it complicated. It's an art to take something complicated and make it simple. Eli has done that," he says. Cohen keeps the leasing objective paramount and is a master at satisfying developers' immediate as well as long-term needs. "Eli works very hard to think about the future," Beitler says. "He allows maximum flexibility in terms of floor loading and the way in which the beams are designed so we can have multiple floor penetrations, and it gives people the maximum flexibility for laying out their space in the building."

Bill Moody, a principal with Chicago-based developer John Buck, agrees: "Eli's buildings are economical enough that they can lease because they can be financially competitive." In fact, the majority of Cohen's buildings in Chicago are currently more than 80% leased—despite Chicago's continuing abundance of office space.

While the exterior of 190 South LaSalle St. gets most of the attention, the interior, with its clean rectangular shape and excellent window placement, is a key leasing point. Every floor features 9-ft. ceilings and can be easily divided into 10-, 15- and 20-ft.-wide offices.

Managing the balancing act between architecture and engineering is perhaps Cohen's greatest skill. "He walks the tightrope" of satisfying all of the involved parties, according to long-time friend and admirer Bill Liddy, a regional engineer with AISC Marketing, Inc. In uniting the two disciplines, Cohen recognizes that the most important component of any structure is the human element. "Anybody can design a column and a beam, but it's a team that puts it together and works together," Cohen says. "You have to put all the brains together to come up with the best solution."

Many times, Cohen's best solution is a composite structure, which involves numerous erection and trade coordination headaches. The principals at CBM "are masters at composite buildings," says Robert P. DeScenza, P.E., Thornton-Tomasetti's transplant from New York who will eventually take over the TT/CBM Chicago office. "[Cohen] knows the whole process, and he stays involved from start to end," he notes. Developers and architects alike credit Cohen's deep involvement in projects—from his practical designs to his timely solutions—with the success of his many structures. "Eli is wonderful at being available and being responsive to recognizing that time is money, particularly in the field," Moody says. "He was always able to come up with a solution, an answer, input on constructibility issues—whatever was required—very, very quickly."

Always An Engineer

RAISED IN ISRAEL, COHEN ALWAYS KNEW what he wanted to be when he grew up. "Somehow I always liked putting things together," he reflects. "I knew I wanted to be in the field of architectural engineering." One of Cohen's greatest inspirations was Thomas Edison ("he was a very creative person who had a vision, practical concepts of how to solve problems and come up with new ideas"). Later, Cohen would be encouraged by the innovations of his good friend Fazlur Khan.

After coming to the U.S. to earn his civil engineering degree from the University of Illinois, Cohen began his career in 1955 with the Illinois Division of Highways. "I liked it, but I preferred buildings," he says tactfully. Within a year, he joined Paul Rogers and Associates in Chicago as chief engineer. In 1965, the firm became an associated partnership as Rogers-Cohen-Barreto-Marchertas, Inc. When Rogers stepped down in 1969, his name was dropped from the letterhead and Cohen became president and principal of CBM, Inc.

Since 1969, the firm, now numbering 16 employees, had undergone little change in personnel—until last September. The small, respected Chicago partnership merged with the much larger Thornton-Tomasetti Engineers of New York.

There were a number of reasons for the merger, which was widely hailed by many in the industry. Almost 20 years of collaboration between the two firms had resulted in a great familiarity between the principals. But more importantly, CBM got out from under 40 years of liability, while Thornton-Tomasetti secured a better hold in the midwest. "All the partners at CBM are about the same age—we're just about to retire," explained Tony Marchertas, who is one year the junior of his longtime friend and partner, Cohen. "We felt it was a good opportunity for the people who are going to stay on to have good continuity.

Thornton says Lev Zetlin, the founding father of what is now Thornton-Tomasetti, once explained to him the gravity of liability. "'It's very, very hard to start a successful engineering company, but it's even harder to stop one,' Zetlin said." The deal between Thornton-Tomasetti and CBM didn't involve a lot of money, Thornton says. CBM's payoff is in the form of freedom from future liability concerns.

For both companies, there is a comfort level in knowing that they each conduct their business with the same philosophy. Unlike some structural engineering firms, neither CBM or Thornton-Tomasetti hire and fire staff as projects commence and finish. "We've tried to maintain the staff through good times and bad," Marchertas says. "We used to, for example, turn jobs down if we saw that we couldn't handle them with our people, because we would hate to hire people and then lay them off. But we found that Thornton-Tomasetti's philosophy was very similar to ours" on that front. Adds Thornton: "We as people and we as two companies were completely compatible."

Over the last four decades, CBM has completed a diverse array of structures—including office towers, hotels, hospitals, retirement housing, schools, manufacturing plants, warehouses, and specialty structures. However, it is the high-rise office towers that garner the most attention. CBM can claim credit for such prestigious addresses in as 35 and 77 W. Wacker Dr., 181 Madison St., 10 and 190 S. LaSalle St., all in Chicago, and 801 Grand Ave. in Des Moines. Most rise more than 40 stories, and several utilize composite design. The edifices have been acclaimed for their functionalism and have been rewarded with

Continued on page 28

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high occupancy rates. The designs are not provocative; they simply work.

Composite Design

COMPOSITE DESIGNS COMBINE THE ADVANTAGES of steel and concrete. "You get the best of both worlds," notes Beitler. However, while composite construction can be quite efficient, it also can be very complicated, since the concrete core is going up at the same time as the steel superstructure. Cohen's ability to coordinate the steel and concrete contractors has proven a benefit on many projects.

The structure at 181 W. Madison St. in Chicago, which won the 1991 Best Structure Award from the Structural Engineers Association of Illinois (SEAOI), is an exemplary example of a composite design. Developed by Miglin-Beitler, designed by Cesar Pelli in his Chicago debut in collaboration with the local firm Pat Shaw & Associates, and engineered by Cohen, this 50-story, 1.1 million-sq.-ft. structure was completed four months early and came in 5% under budget at $225 million, according to Beitler. And even more impressively, it was 40% leased upon completion and more than 97% leased today—despite Chicago's sluggish market.

A pointed tower with multiple setbacks and a distinctive crown, Beitler gives Cohen much of the credit for the building's success. "Eli's very efficient design enabled us to build 181 W. Madison in record time. Eli, being a pragmatist, being a very savvy team player, being flexible, was able to put that together."

The building utilized some of the foundation of a previous structure. Approximately 25% of the caissons were pre-existing and transfer grade beams between the new and existing caissons were used to take the towers wind and gravity loads. The foundation wall on the east side of the building required

To help the developer's leasing efforts, the 50-story 181 W. Madison St. building was built in near-record time. The composite building won the 1991 Best Structure Award from SEAOI.

underpinning, since it shares a common wall with its neighbor, 10 S. LaSalle St., another CBM project.

The column-free interior space provided 43-ft. spans for maximum user flexibility. The many setbacks at the top of the building required all the perimeter columns to be transferred several times. In addition, the columns on either side of the loading dock at ground level also were transferred to increase clearance for trucks. Even with these complications, total steel weight was less than 12 lbs. per sq. ft.

At the base of the building on the north side is a four-story loggia that leads to the five-story lobby with a vaulted, coffered ceiling. A bridge extends across the alley to the south to connect 181 West Madison to the Northern Trust Building.

"Eli was very helpful in the process of checking the shop drawings," says Shaw. "He always put in all his effort, and he took the time to do it right."

Another award-winning CBM composite structure is 77 W. Wacker Dr. in Chicago, which was completed in June 1992. There, the local geological deposits made the project especially challenging. Cohen drove a concrete shaft through a thick layer of relatively soft clay and delivered the building loads to hardpan about 70 ft. below the ground surface. As a result, even though the 50-story (665-ft.), 1.04 million-sq.-ft. building has a light steel frame, it is able to sustain lateral wind forces of as much as 2,000 kips.

The building features 45-ft. column-free spans and a facade free of cross beams. The foundation utilizes composite floor decking throughout. The building also features a magnificent five-story entrance lobby, offering a completely unobstructed 45-ft.-high space.

Architect Ricardo Bofill, working for DeStefano & Partners, teamed with Cohen on the project. Major tenants include R.R. Donnelley & Sons and the building's developer, The Prime Group. The SEAOI also took notice; it awarded the building its 1992 Best Structure Award.

The structure was 92% leased upon completion. "Eli is a big part of why the building was so attractive to tenants," says Jim Runnion of The Prime Group. "The floors were very efficient for them to use."

At another Chicago site, 190 S. LaSalle St., Cohen designed an efficient composite structure for renowned architects Philip

Johnson and John Burgee that saved developer John Buck about $1 million in time and construction costs.

The 900,000-sq.-ft., 40-story (575-ft.-high) pink granite tower features a 55-ft.-high lobby with a gold leaf barrel-vaulted ceiling and mosaic marble floor. This emphasis on ornamental features put additional budget pressures on the structural design. Cohen's steel and concrete solution retained the existing basement of the previous building, eliminating the need for sheet piling and bracing at the busy, congested site. "Eli strove to make the detailing [in the designs] simple so that it could be executed correctly and quickly in the field," says Bill Moody of the John Buck Company, which was able to put the $1 million in structural savings into architectural features.

Concrete pouring commenced in June 1985 and was completed in March 1986. The steel erection started in August 1985 and was topped out in just eight months—a then record for a building of that size. Featuring 41-ft. clear spans, 190 S. LaSalle was only 27% preleased (including tenant Mayer Brown & Platt, the largest law firm in Chicago), but occupancy reached 88% by the end of 1988, despite difficult market conditions.

At 10 S. LaSalle St. in Chicago, Toronto architect Moriyama & Teshima (in a joint venture with Chicago-based Holabird & Root) wanted to preserve and incorporate the former Otis Building's 55-ft. elaborately sculptured terra cotta cladding. However, the facade could not be economically saved if the structure was taken down or the cladding moved and rebuilt. Cohen came up with a solution that earned the SEAOI 1987 Most Innovative Design Award.

After tests confirmed the integrity of the original rock caissons, they were utilized to support transfer girders for the new exterior steel columns, located two ft. inside the tower.

77 W. Wacker won an SEAOI award in 1992,

The existing exterior steel frame, one bay deep, was left in place for the first five floors to support the original wall and cladding—which also saved considerable time and money in building foundations and subgrade construction. Starting with the fifth floor, the new tower provides 40 ft. of unobstructed office space around the central concrete core.

FUTURE PLANS

ELI COHEN'S REPUTATION IS AS SOLIDLY GROUNDED IN HIS RELIABILITY and practicality as his buildings are in the hard rock of Chicago. Asked what lessons he's learned over the years, he answers: "You have to spend more time in the conceptual design because with the first 10% of your time, you can save 25% of the cost of the building."

Aside from engineering highly successful buildings, Cohen is actively involved in his professional community. "He's a very congenial, very gregarious person," says John Zils, a leading structural engineer at Skidmore, Owings & Merrill. "And he's willing to share his knowledge with other professionals." Several years ago, Cohen served as president of SEAOI and is currently on its board of directors. He also is an active member of several prominent committees and professional associations, including the Chicago Committee on High-Rise Buildings, the (Chicago) Mayor's Advisory Commission on Building Code Amendments, ASCE and AISC. This has been a good year for honors for Cohen. Earlier this year he won the Parmer Award from SEAOI, which is awarded to an individual whose career has been acknowledged by his peers an example of excellence in the field of structural engineering. And in October, he received an AISC Special Citation, which recognizes individuals who have made a lasting contribution to the structural steel industry.

Cohen also enjoys teaching. For six years he taught the structural portion of the refresher course for the architectural registration exam. He also has appeared numerous times as a guest lecturer on college campuses, including at Northwestern University, the University of Illinois at Chicago and Iowa State University in Ames. These contributions were recognized by the University of Illinois at Champaign-Urbana when it extended to him its 1990 Distinguished Alumni Award in Civil Engineering and invited him to join the Board of Directors of the Alumni Assoc.

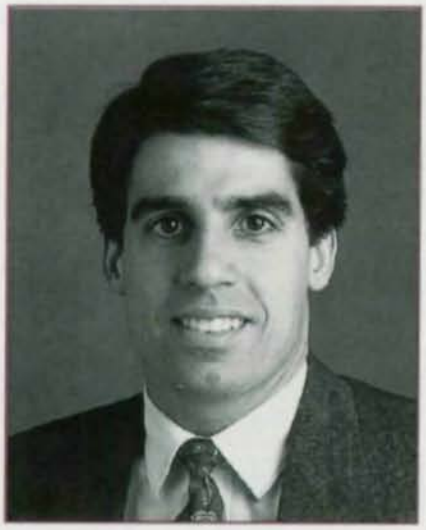
What's next for Eli Cohen? He says he's not ready to retire. "I've cut my hours back from 60 to 40 per week, that's all," Cohen muses. "One of these days I'll write a book. We work for so many different architects all over the country, all over the world. I'll write a book: 'My Experience with the World's Leading Architects."

And if one of those architects wants to write a book on "My Experience with the World's Greatest Engineers," Cohen is sure to be included.

Cindi Crane is a freelance writer formerly based in Evanston, IL.

THE LRFD (R)EVOLUTION

In addition to providing more uniform reliability, analysis shows LRFD can save an average of 5% of total steel tonnage on mid- and high-rise projects



Aine Brazil, P.E., and Thomas Scarangello, P.E. are senior associates with Thornton-Tomasetti Engineers in New York City.

LIKE PAUL REVERE'S FAMOUS RIDE, the release of the First Edition of the Load and Resistance Factor Design (LRFD) Manual of Steel Construction in 1986 was expected to signal a revolution. Many in the engineering community braced themselves for a remarkable change in the way steel structures would be designed. And given that engineers were already comfortable with the strength design method through ACI 318, the changes should have been painless. Indeed, many leading engineers believed that the new LRFD Manual would, in just a short time, relegate allowable stress design to the dusty shelf of the reference library along with the Three Moment Equation and the Williot-Mohr Method.

Unfortunately, it hasn't quite happened that way.

The intent of the new specification was to simplify the design of structures, provide uniform reliability for the various loading conditions that a steel structure would experience in its lifetime, and improve overall economy—all laudable goals. So why then, more than eight years after the introduction of LRFD, is the engineering community still struggling with the schizophrenic approach to steel design?

A portion of the blame can be placed on human nature: People resist change and are slow to adapt to change. A look at the history of the ACI strength approach reveals that it took 15 years (from 1956 until 1971) for the working stress method to be relegated to an "alternate method." And it wasn't until 1977 that the working stress was placed in an appendix, signaling the widespread acceptance of and preference for the strength method by the engineering community.

Human nature and historical parallels, however, are not the whole story. Many other elements have contributed to the slow acceptance of LRFD by the engineering design community—miscommunication, bad timing, technological advances, and the confusion caused by LRFD's different load factors.

Miscommunication has been a serious problem. When AISC released the 9th Edition of the ASD Manual of Steel Construction, it sent a signal to many engineers that the ASD approach was not being phased out. The updating of the 8th Edition to include the latest research reinforced many engineers justification for not "retooling."

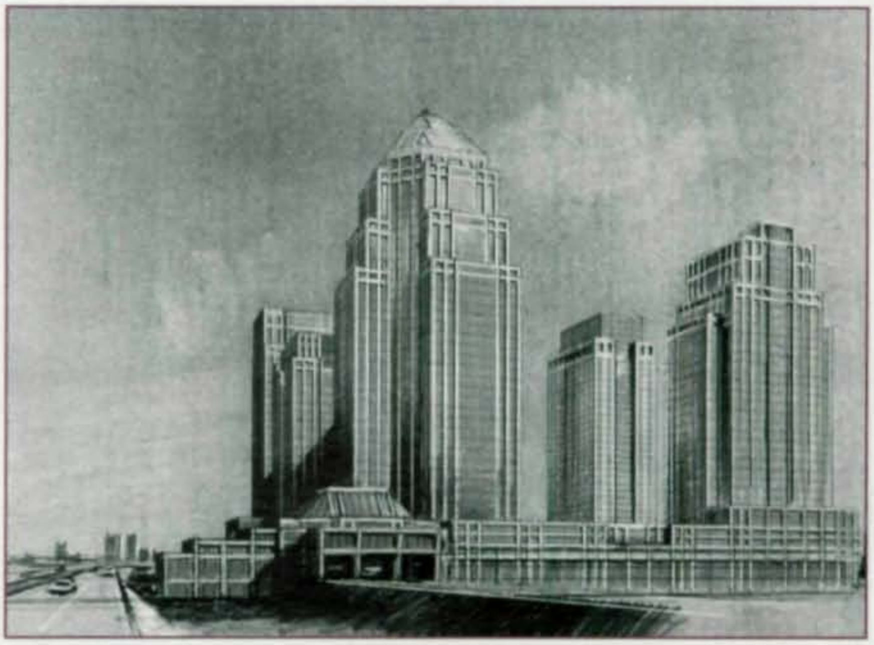
Poor timing and the growth of computer technology also had a negative influence on the adoption of LRFD. When the ACI strength approach was introduced, computer routines were in the infancy. However, when the LRFD Specification was introduced, most offices had already invested considerable time and money in either in-house and/or off-the-shelf steel design programs. The problem was even worse on the fabrication side. Many engineers employed by steel fabricators had codified their connection design approach through the use of proprietary programs that incorporated the working stress design. And since LRFD offered little or no savings—and in some cases actually increased connection requirements—there was little incentive to switch. LRFD arrived just when design engineers were beginning to reap the benefits in savings of time and money from working stress programs—programs with which they had grown comfortable and confident in their day-to-day design process and use.

Another perceived obstacle to the widespread acceptance of LRFD is the different load factors between ACI 318 and the LRFD Specification. Regardless of their basis in solid research, the LRFD load factors have been met with confusion and skepticism by both engineers and code authorities. Further, the difference between the ACI 318 and LRFD Specifications have negated the benefit of consistent and easily translatable design forces from concrete to steel (and vice versa) in a strength design approach to a given structure.

While these problems continue to slow the transition to LRFD design, the good news is that these problems are being overcome. The LRFD Manual has been adopted by most local governing agencies as an alternate to ASD. Acceptance of LRFD is now the rule, rather than the exception.

In one of the most promising trends towards acceptance of LRFD as the preferred design standard, academia has wholeheartedly embraced it. Almost universally, engineering colleges and universities teach LRFD in their steel design course. In many cases, LRFD is the exclusive steel design method taught to undergraduates. As these students graduate and enter the workforce, their experience with—and knowledge of—LRFD will ease the transition to LRFD-based designs in offices around the country.

Another factor that bodes will for the eventual universal adoption of LRFD is the widespread recognition of LRFD for seismic design in codes throughout the country. Most seismic source



420 Fifth Ave. (left), a 30-story steel-framed office building designed in 1988, was one of the first buildings in New York City to utilize LRFD.

The Allied Junction / Secaucus Transfer Station (above) includes four 20- to 40-story office towers. The use of LRFD results in savings in steel weight in the gravity controlled columns, the baseplates and the 30-ft. span composite steel girders.

Utilizing LRFD for 546 Fifth Ave. in New York City resulted in a reduction of approximately 15% of total steel tonnage for the building's columns.

documents have adopted (or will soon adopt) the strength design approach, since the nature of seismic design requires quantifying and enhancing the ratio of ultimate strength to elastic strength or ductility of structures. The basic need to understand the behavior of systems and elements in their ultimate state of deformation makes the LRFD approach the logical choice when designing for seismic forces.

Case Studies

Back in 1991, Thornton-Tomasetti Engineers evaluated the impact of having utilized LRFD in the design of two New York City mid-rise buildings. The first was 420 Fifth Ave., a 30-story steel-framed office building. Designed in 1988, it was one of the first buildings in New York City to utilize LRFD. Also studied was 546 Fifth Ave., a 150-ft.-by-100-ft.-by-50-ft.-wide L-shaped, 23-story office building. The building is comprised of 170,000 sq. ft., with floor plates that step back every few levels and vary from 10,000 sq. ft. at the lower levels to 6,000 sq. ft. at the uppermost floor.

In what has proven to be the case for most typical mid-rise office buildings, these designs illustrated that utilizing LRFD results in significant economies while, at the same time, providing a more uniform level of reliability.

The use of LRFD-based design for these two buildings resulted in savings for gravity columns and base plates since the New York City building code, like most building codes, recognizes significant live load reductions for columns supporting multiple stories. This, in turn, leads to favorable dead load to live load ratios. Savings for columns were approximately 15% of the total column tonnage, with an additional 25% savings in base plate tonnage.

Given the ability of steel to span long distances, and thereby resulting in girders with large tributary areas, live load reduction again is a factor for girders and especially for transfer girder design. A reduction of approximately 10% in transfer girder weights resulted from the use of an LRFD design.

Also, although most of the lateral load resisting system elements were governed by drift control, utilizing LRFD for lateral load resisting systems provided benefits, albeit minimally.

However, while the use of the LRFD Specification for the typical office floor construction (30 ft. to 45 ft. bay sizes) results in economies when the design is based only upon strength considerations, deflections, vibrations and other service related criteria tend to minimize or eliminate any savings in typical floor beam design.

Overall, the incorporation of LRFD in the design of these two buildings resulted in a savings in total steel tonnage of between 4.2% and 4.4% when compared to an equivalent ASD design.

LRFD Today

Thornton-Tomasetti, which now routinely uses LRFD, has a number of projects currently underway.

Representative of our larger commercial high-rise projects is the Allied Junction/Secaucus Transfer Station, a mixed-use commercial development above a rail transfer station located in the Hackensack Meadowlands, NJ. The complex of 3.6 million sq. ft., currently under design, will consist of four 20- to 40-story office towers, a 600-room hotel, retail concourse, and a 4,400-car parking garage. The structural system for the office buildings and basic station concourse will be steel framed. Floor framing with a typical bay size of 45-ft.-by-30-ft. will consist of composite beam construction with concrete slab-on-metal deck. Lateral load resistance will primarily be provided by braced cores with outriggers. Exterior moment frames will be used to supplement the cores.

In the office building structures, the use of LRFD is effecting savings in steel weight in the gravity controlled columns, the baseplates and the 30-ft. span composite steel girders. However, the design of the 45-ft. span floor beams in the office areas will be controlled by vibration considerations. In addition, design of both the columns and braces in the lateral system will be controlled by drift limitations and will not yield savings in steel weight.

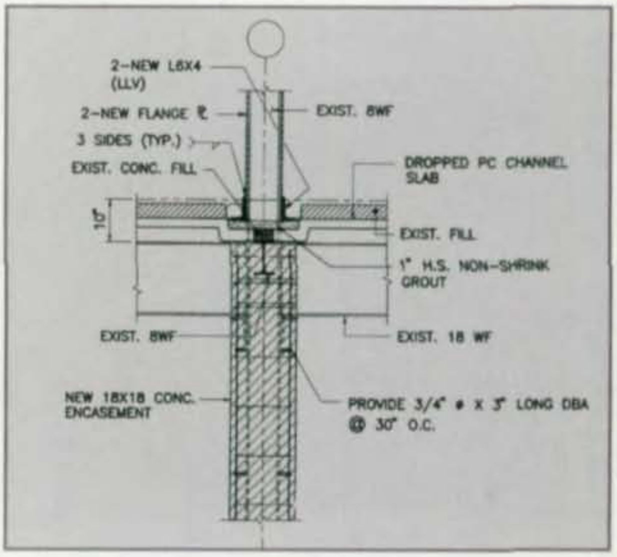
The introduction of composite design guidelines and design aids has simplified the design effort required when incorporating composite columns in a building system. For the Secaucus Transfer Station, utilizing this feature of the LRFD manual helped satisfy specific requirements driven by the platform design constraints: high headroom in the track area mandates floor-to-floor heights of up to 25 ft, with some columns unbraced for 45-ft., and the overall finished column dimensions are limited to 36 in. in diameter. The design solution utilizes concrete-encased steel columns to satisfy strength, stiffness, fireproofing and finish requirements. The provisions in the LRFD Specification greatly simplified the implementation of these components in the design, resulting in efficient column sections and minimizing design effort.

Overall evaluation of current high-rise projects shows that LRFD continues to yield average savings of 5% of the total steel tonnage.

Renovation Activity

In the current market economy, Thornton-Tomasetti Engineers has seen a marked increase in renovation and the expansion of existing buildings. With these types of projects, LRFD is an indispensable tool in maximizing the existing structure's capacity and minimizing the extent and cost of the design.

The Phase III renovation and vertical expansion of the Roosevelt Field Shopping Mall in Garden City, NY, is representative of this type of project. Built in 1955 as an open air mall of approximately 650,000 sq. ft., the two-story steel frame construction is currently undergoing a major expansion, which will double the retail space in the area under renovation. A significant portion of this expansion will result from the addition of a new retail floor at the level of the existing roof.



The use of LRFD for the Roosevelt Field Shopping Mall expansion reduced the impact of construction on stores operations.

In this project, the vertical expansion resulted in the evaluation and reinforcing of existing columns for the additional loads of the added retail level. Floor construction in the existing mall was very heavy, since the original mall was an open-air design. The resultant high dead load to live load ratios of between 1.0 and 2.5 led to a significant advantage of LRFD over ASD. Three basic categories of column treatment were developed for this project using LRFD. First, the existing columns were investigated to determine if the increased capacity under the LRFD Specification provided sufficient additional load-carrying capacity. If reinforcing was required, one of the following two methods was implemented: When space constraints were a factor, the existing W8 column sections were reinforced by cover-plating to form a box section; otherwise, the columns were made composite by encasement in concrete. Load transfer through the column-to-floor joints was critical and use of LRFD eliminated the need for intricate "watch-making" type field work.

Since the retail spaces of the mall continue in full operation during the expansion, it was imperative to minimize the extent and complexity of the structural reinforcing. By using LRFD in evaluating the capacity of the existing columns and in developing the reinforcing details, it was possible to reduce the impact of the construction work on the retail spaces.

Owners and developers of existing buildings continue to look for ways to expand and modify their properties in an effort to retain their existing tenants and to attract new tenants. The use of the LRFD method is a tool that engineers can use to effectively cut the costs of major structural renovations.

Conclusion

Although adoption of LRFD by the engineering community has been slow, we are confident that recognition of the advantages of this approach will continue to erode resistance and promote its acceptance as the preferred design approach. This evolutionary process is far from complete. But as its utilization on more and more projects continues to confirm LRFD's advantages of uniform reliability, consistency and improved economy, extinction of the ASD method is only a matter of time.

1994 T.R. Higgins Lecture: COMPOSITE FRAME CONSTRUCTION

By Lawrence G. Griffis, P.E.

ALTHOUGH MANY MODERN STUDENTS AND PRACTITIONERS OF STRUCTURAL ENGINEERING tend to think that composite construction is a product of recent design and construction practice, it actually began just prior to the start of the twentieth century.

In the U.S., some early uses of composite construction appeared in the year 1894 when both a bridge and a building were constructed. The bridge was the Rock Rapids Bridge in Rock Rapids, IA. After submitting calculations to verify his composite design, a Viennese engineer named Joseph Melan obtained a patent for bending I-beams to the curvature of an arch and then casting them in concrete. The composite building constructed the same year was the Methodist Building in Pittsburgh, which was built using concrete-encased steel floor beams. In 1897, a fire in a nearby building spread to the Methodist Building. While the contents were destroyed, the frame was not—demonstrating one of the advantages of composite frame construction.

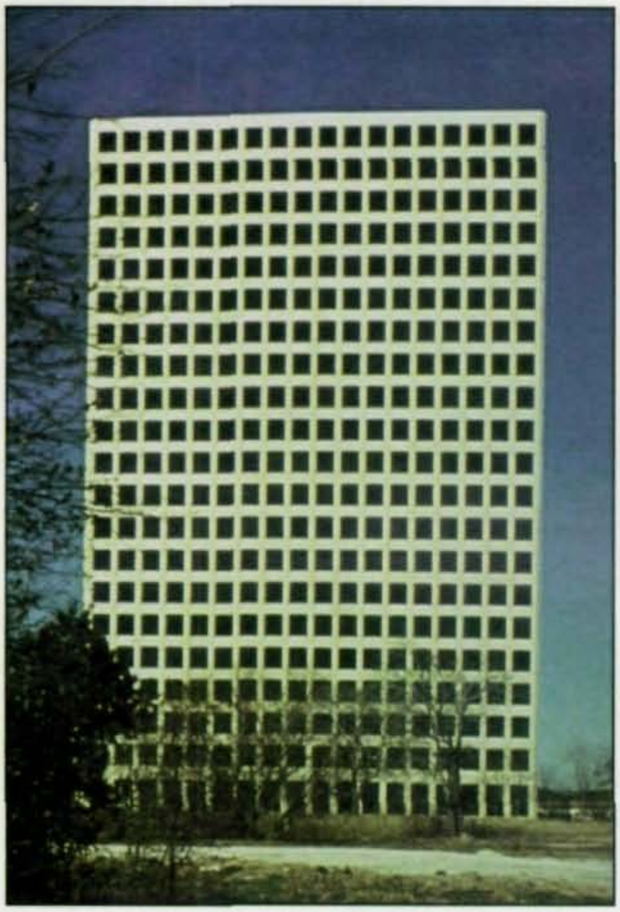
Figure 1: The Methodist Building in Pittsburgh was an early example of composite construction.

As additional buildings and bridges were constructed using steel wrapped in concrete toward the end of the nineteenth century, a need for research testing arose to better understand the behavior. A set of systematic tests for composite columns was begun at Columbia University's Civil Engineering Laboratories in 1908. This was followed by tests of composite beams in the Dominion Bridge Company's fabrication shop in Canada by Professor H.M. McKay of McGill University in 1922-24.

An early record of composite construction appearing in a U.S. building code is found in the 1930 New York City Building Code, which allowed extreme fiber stresses of 138 MPa (20 ksi) rather than the 124 MPa (18 ksi) value traditionally allowed for noncomposite beams.

Shear connectors also were recognized in this early composite construction as an effective means to enhance the natural bond between steel and concrete. In 1903, Julius Kahn received a U.S. patent on composite beams where shear tabs in the beam flanges were bent upward to project into the slab. Different types of shear connectors have been proposed over the ensuing 90 years, including some types still documented in AISC's Manual of Steel Construction.

In 1954, welded headed metal studs were first tested at the



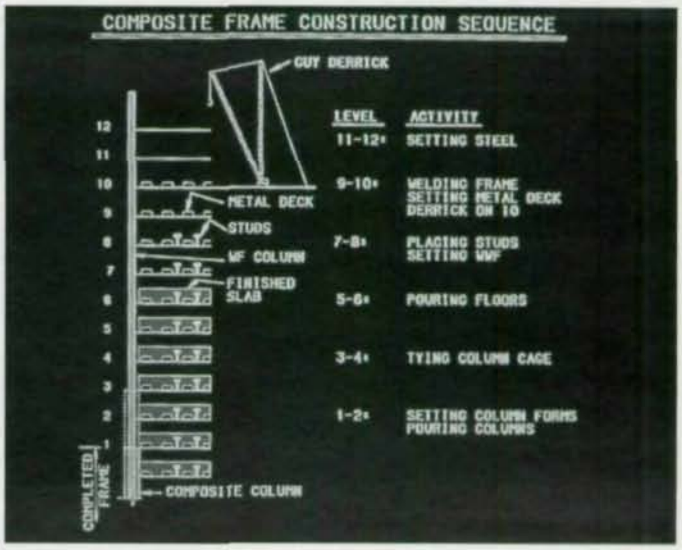


Figure 2 (left): Fazlur Kahn's 1970 Control Data Building used composite construction.

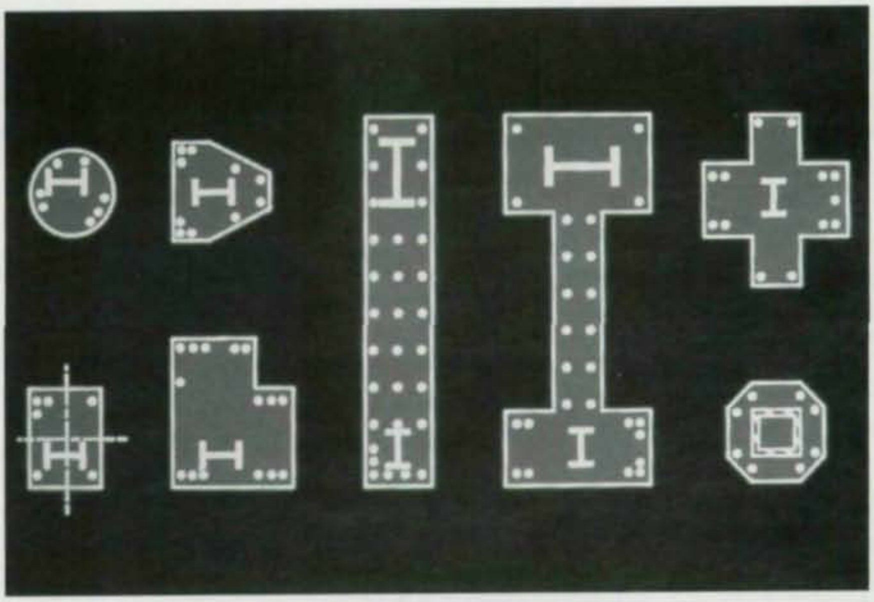
Figure 3 (above): Composite Frame Construction Sequence. The floor number refers to the number of levels above which concrete has encased the erection columns.

University of Illinois. At the completion of the tests, in 1956, a formula for the design capacity of these connectors was published. The welded headed metal stud has now become the dominant method of transferring shear between steel and concrete. The first bridge to use these connectors was the Bad River Bridge in Pierre, SD, which was built in 1956. Also in 1956, IBM's Education Building in Poughkeepsie, NY, became one of the first buildings to use headed stud connectors. The second floor was formed with a 38 mm-deep, 0.6 mm-thick composite deck, using wires welded to the top flutes of the deck to achieve composite action between the metal deck and the hardened concrete.

The widespread use of composite metal decks began to flourish in the 1950s in building construction. The metal deck acted as a form for the wet concrete, thus reducing concrete formwork costs. The deck was shaped in such a manner as to ensure composite action so that it could serve as the positive one-way reinforcement for the final hardened concrete slab.

Composite action was first achieved through the use of wires welded to the deck. The standard today, however, is through embossments manufactured into the deck. One of the first modern buildings using this technique of construction was the Federal Court House in Brooklyn, NY, which was designed in 1960. The composite metal deck and welded headed stud have gained such widespread popularity in modern building construction that it has become virtually the only floor system for steel and composite frame buildings during the past 25 years.

The first tall building boom occurred in the U.S. in the 1920s and 1930s when high-rise structures such as the Empire State Building and the Chrysler Building were constructed. Many of these early vintage steel frames utilized the protection that the concrete afforded the frame when it was cast around it for resistance against fire and corrosion. Not until the 1960s with the advent of modern composite frame construction have engineers actively sought rational methods to take advantage of the stiffening and strengthening effects of reinforcing bars and concrete on the capacity of the embedded steel frame. The late Fazlur Kahn, in his early discussion of structural systems for tall buildings, first proposed the concept of a composite frame system in the Control Data Building in Houston in 1970. Since that time, composite frame construction has been utilized on many high-rise buildings all over the world and its usage, with a composite column as the key element, is well documented in the work of the Council on Tall



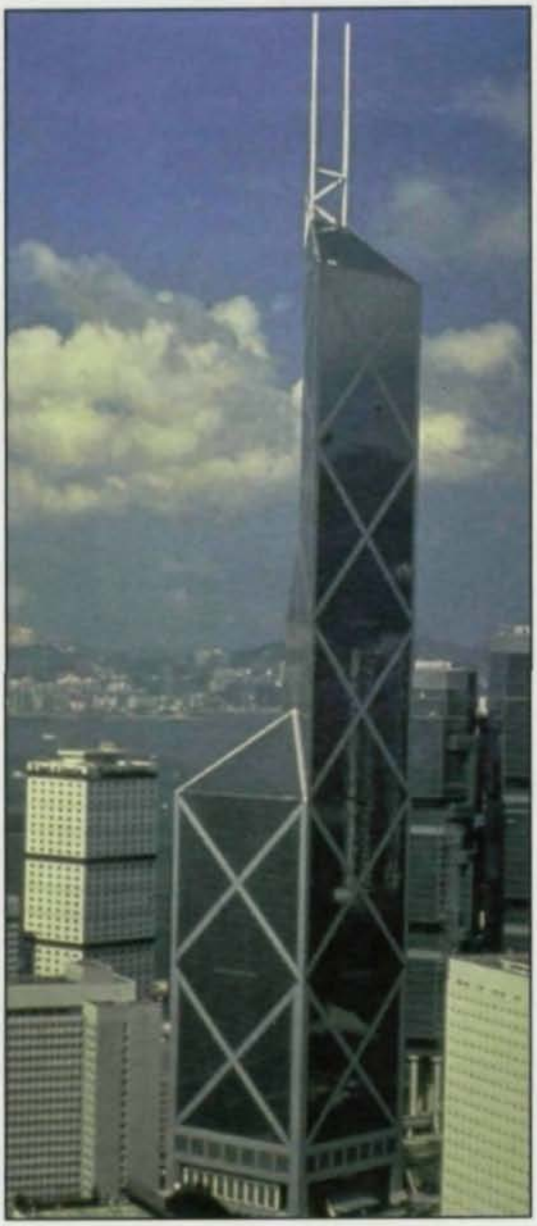


Figure 4 (above): Composite Column & Wall Shapes.

Figure 5 (left): The Bank of China in Hong Kong.

Buildings and numerous other publications.

WHY COMPOSITE?

Composite frame construction is a marriage of steel and concrete. As in any successful marriage, each partner must contribute to its success. Structural steel provides high strength, longspan capability, light weight, and quick speed of construction. Concrete provides economy in carrying large vertical loads, stiffness fire resistance and damping. In high-rise building design, this synergism is particularly beneficial because composite frame construction has allowed for rapid construction by spreading construction activity over many floors, allowing work to proceed faster and more economically.

In Figure 3, the floor number refers to the number of levels above which concrete has encased the erection columns. With the erection guy derrick or crane positioned on the 10th level, steel for levels 11 and 12 is being set. On levels 9 and 10, the frame is being welded or final bolt tightening is occurring and metal deck is being placed. On levels 7 and 8, studs are being welded to the top of composite beams and welded wire fabric is being laid on the floor deck. At levels 5 and 6, concrete is being poured for the floor. On levels 3 and 4, composite column reinforcing cages are being erected and tied. On levels 1 and 2, column forms are being placed and concrete is being poured for the composite column. Finished concrete floors are needed ahead of composite column and shear wall pouring in order to have a finished surface for stacking tieing reinforcing steel and setting the column forms.

Experience gained from this type of construction indicates that, depending on the individual contractor, there exists an optimum construction sequence and spread in the various construction activities. If this relative staging is not maintained, then problems can occur. For instance, when the gap between setting steel and placing concrete beams becomes too wide, an overload of the erection columns can occur since they have been designed for a certain number of floors of construction loading or have been sized to limit column shortening to a predetermined amount. Also, frame stability can start to be of concern.

If the gap becomes too close, then construction activity becomes congested with a resulting loss of construction time and efficiency. Obviously, close coordination and control of the construction process is required for this type of construction.

Furthermore, the moldability of concrete has allowed structural steel erection shapes to be

Figure 6: Moffitt Hospital in San Francisco

embedded at strategic locations within variable and complex composite column and wall shapes (see Figure 4). This unique and important feature accommodates the free form architectural designs common in tall buildings today, while at the same time greatly simplifying connections of beam, column and brace elements.

However, composite frame construction has not been without its problems. Because of the use of steel and composite vertical carrying elements in the same building, designers must be cognizant of differential column and wall shortening that can lead to problems in floor levelness. Erection constraints are sometimes forced on the contractor when he is required to erect the steel frame within a predetermined number of floors behind which concreting of the composite elements is taking place.

There can be constructibility problems at complex joints where structural steel, reinforcing steel and concrete must all fit together. The contractor and engineer must work as a team to ensure stability in the erection frame until final concreting takes place. Also, until recently, there has been no widespread building code acceptance of this form of construction, hampering its use particularly in seismic zones.

And finally, a general lack of research has contributed to many engineers' reluctance to embrace the concept of composite frame construction.

Economic Considerations

The economy of composite frame construction in practical cases of high-rise building design is often made apparent in the value engineering phase.

The general contractor will oftentimes figure the total cost of concrete, reinforcing steel, forms and steel frame. This total frame cost is then divided by the building square footage and the erected structural steel price to determine "equivalent" structural steel unit weight. When compared to the unit weight of an all-steel building, it is not uncommon to see a 10% to 20% reduction in steel weight with composite construction.

Part of this economy can be attributed to the fact that composite vertical load carrying elements typically realize an 11-fold cost advantage (steel/composite cost approximately equal to 11.0) when comparing strength and an eight-fold advantage when comparing axial stiffness. Perception to motion, as measured by building acceleration of the top most occupied floor, oftentimes controls the design of lateral load resisting frames in tall, slender buildings. Crosswind acceleration is oftentimes the most predominant component of acceleration and its relationship to the building properties can be defined by the following proportionality:

Cross Wind Acceleration:

$$\alpha \frac{(\text{Wind Velocity})^{3.54} \times (\text{Period})^{1.54}}{(\text{Damping})^{0.5} \times \text{Mass}}$$

Because of the inherent advantages of composite frames over all-steel frames as shown above, it is not uncommon for composite building accelerations to be as little as 50% of all-steel building accelerations. When building motion controls the design in tall buildings, as it often does, there is a very powerful incentive for engineers to use composite frames. Indeed, in looking at most of the super-tall buildings being considered around the world today, it can readily be said that "When engineers build tall, they build with composite."

Perhaps the most spectacular example of composite frame construction that exists today can be found in the Bank of China Building in Hong Kong (see Figure 5). Designed by architect I.M. Pei and engineered by Leslie Robertson, this sleek and graceful tower exhibits all the attributes of composite frame construction. Its five composite columns form a megastructure of concrete filled steel tubes that together provide the lateral load resisting frame in one of the windiest cities in the world—all for a mere 23 psf of structural steel.

Figure 7: Renovation of a high-rise building frame

RENOVATION/STRENGTHENING

While composite construction in the U.S. has flourished in the area of new construction for high-rise buildings, its use has also grown in the area of retrofitting of existing structures. Recent experience has shown that various combinations of steel and composite elements—whether steel angle bracing, composite columns (concrete filled tubes or concrete encased rolled shapes), steel plate composite shear walls or concrete encased steel beams—are ideal for bringing older structures in conformance with modern building codes.

It is very likely that this usage of composite frame structures will expand in the future. All three model building codes in the U.S. now require seismic design. There is a move to standardization of seismic requirements by incorporation of NEHRP seismic provisions in the model codes as well as in the new ASCE 7 document. As seismic awareness spreads eastward from California and seismic design is required by national and local codes, can it be very long before the federal government and thus the private sector requires (demands) seismic safety in building design?

Composite shear walls have been used in California in hospital design. The Moffitt Hospital in San Francisco, designed by J.J. Degenkolb Associates, is an 18-story building that utilized steel plate shear walls wrapped in concrete (see Figure 6). Although the steel plate shear walls were used in this hospital as part of the original construction, the application is well suited to retrofit. In this case, the steel plates were designed to carry all the lateral loads and the concrete was used for fire resistance. The 1994 NEHRP provisions will permit designing this type of frame as a composite system. Composite shear walls can be an excellent method for retrofitting older structures because of the high-strength, high-ductility, and the limited space requirement within existing cavities and inherent fire resistance.

High-rise buildings, designed for older wind code provisions, can be upgraded by wrapping existing steel columns in reinforced concrete and welding headed stud shear connectors to the columns. Additional wind bracing can be added between the new composite columns to strengthen the lateral load resisting system in order to bring it under compliance with modern wind codes (see Figure 7).

Research has been completed at the University of Texas at Austin under the direction of

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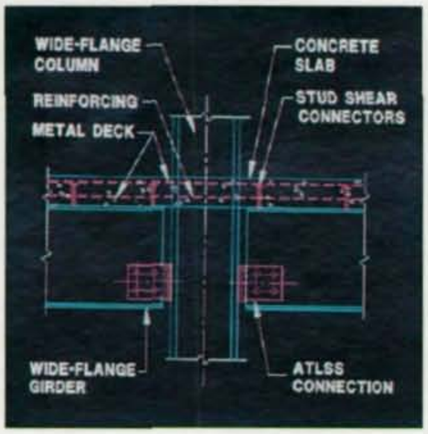


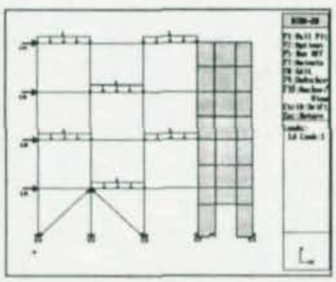
Figure 8: ATLSS connector / semi-rigid composite joint detail

James Jirsa and Michael Englehardt to strengthen non-ductile reinforced concrete frames with a steel bracing system. This work involved the jacketing of concrete columns with steel plates and developing existing bottom reinforcing bars through the beam column joint with through bolts. This reinforcing provides a means for retrofitting existing concrete buildings with steel to form a composite frame.

Composite Joints

Clearly, the lack of experimental research required to develop accurate strength models for the transfer of forces between steel and concrete at composite frame joints in one obstacle that has deterred the use of composite frame construction. However, recent research in this area should help change this situation.

Research on the design and behavior of composite moment frame joints by Gregory G. Deierlein, first at the University of Texas at Austin and now at Cornell University, has provided new insight for engineers using composite frame construction. Bahram Shahrooz at the University of Cincinnati has performed experimental research on coupling of concrete shear walls with steel coupling beams. This research should aid practicing



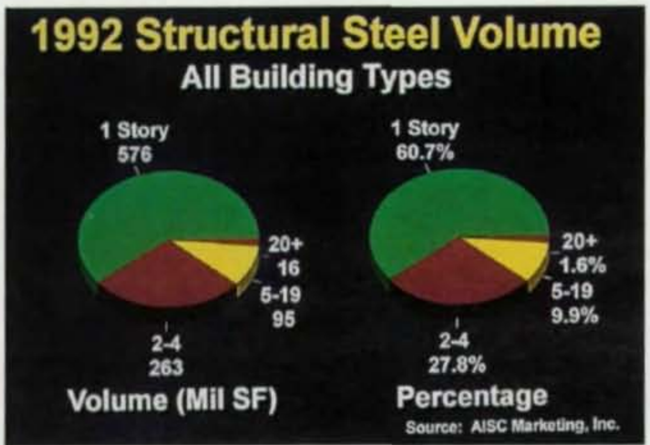


Figure 9: Steel in construction

engineers in designing for this practical condition under both wind and seismic loads.

Motivated by the use of large scale thin walled circular composite columns in high-rise buildings in Seattle, Atorod Azizinamini has performed experimental research and developed design criteria for the use of steel wide flange beams moment connected through large diameter steel pipes filled with high-strength concrete. Research at Lehigh University under James M. Rickles has provided new insight on the behavior of high-strength concrete encased steel H shapes under seismic loads. Other research at Lehigh includes the development of the ATLSS Connector (see December 1993 MSC). One version of this connection is applicable to semi-rigid moment connections as shown in Figure 8.

This and other research expected to come out of the Phase 5 U.S./Japan Cooperative Research Program discussed later in this article should provide needed information to enhance the usage of composite frame construction in the years ahead.

Codes/Specifications/ Literature

The 1994 edition of the NEHRP (National Earthquake Hazard Reduction Program) "Recommended Provisions for the Development of Seismic Regulations for New Buildings" has completed final balloting and will be published soon.

For the first time ever, this important document, prepared by the Building Seismic Safety Council, will contain a new chapter devoted strictly to composite elements structural systems and connections.

This chapter is clearly a milestone in the evolution of composite frame structures. For the first time guidelines will be available to the practicing engineer to utilize composite frame construction. This new chapter is particularly important because the NEHRP provisions serve as a resource document to the model building codes. It is hoped that this widespread coverage will encourage the use of composite construction and serve as a catalyst for new research in this area.

There have been other important developments as well. The ASCE Committee on Composite Construction has been very active in preparing design guidelines in the field of composite construction. Included are the following:

- *Guidelines for Design of Joints Between Steel Beams and Reinforced Concrete Columns*
- *Specification for Composite Joists and Trusses*
- *Guidelines for Design of Composite Semi-Rigid Connections*

These documents will soon be available to the profession.

AISC has published another

in its series of design guides—this one dealing with composite columns. Entitled "Load and Resistance Factor Design of W-Shapes Encased in Concrete," it is based on the new AISC LRFD provisions for composite columns. It contains much practical information, including construction details, and design tables. An accompanying computer program also is available.

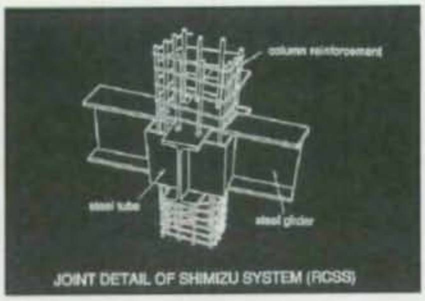
Other publications also are available. A comprehensive new text entitled "Constructional Steel Design—An International Guide," edited by Patrick Dowling, John Harding and Reidar Bjorhovde and published by Elsevier Applied Science contains several chapters on the subject of composite construction. A recently published text describing European practice as defined in the new Eurocode 4 is entitled "Designers Guide to Eurocode 4" by R.P. Johnson and D. Anderson, published by Thomas Telford Services Ltd. is now available.

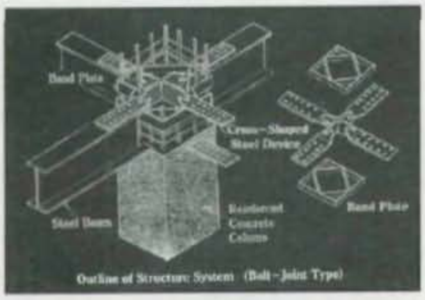
Two recent international conferences, sponsored b the Engineering Foundation, have been held recently. Proceedings from both the Henniker, NH, conference in 1987 and the Potosi, MO, conference in 1992 are available from ASCE. A third international conference is planned.

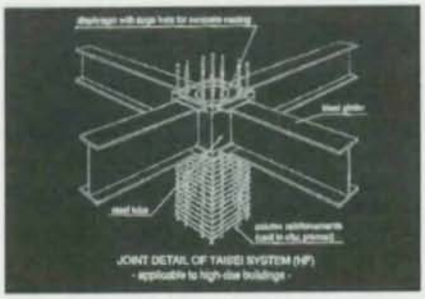
RESEARCH

Some of the recent research on composite joints and columns was briefly described earlier. Other important work has been done or is now ongoing. Most readers are aware of the pioneering work done by Roberto Leon (see March MSC). Subash Goel has recently tested steel joist encased in plain and fiber reinforced concrete. This work could offer a practical composite system applicable not only to new construction but also to retrofit existing structures.

Perhaps the most significant work in the field of composite construction is yet to come. The U.S.-Japan Cooperative







Figures 10 & 11 (left): Fujita System from Japan
Figure 12 (top right): Shimizu System from Japan
Figure 13 (middle right): Kajima System from Japan
Figure 14 (bottom right): Taisei System from Japan

Research Program is now about to enter Phase 5. This phase deals with Composite and Hybrid Structures and promises to provide insight into the behavior of composite elements, systems, and connections. The focus of this research effort will be in the following areas:

1. New materials, elements and systems
2. Concrete filled steel tube (CFT) systems
3. Reinforced concrete (RC)/steel reinforced concrete (SRC) systems
4. Reinforced concrete (RC)/steel reinforced concrete (SRC) wall systems

Research in these four areas will include the following topics:

1. Material and component studies
2. Subassemblages
3. Complete structure
4. Analytical studies
5. Design studies

A common theme structure for the joint research effort in the two countries will be used to facilitate comparisons between various system types identified for research and to derive structural elements and subassemblages for detailed studies. Component and subassemblage studies will probably preceded testing work on full systems. Physical research specimens will be not less than one-half full size. It is envisioned that five years will be needed to fulfill the major objectives of this research program.

Low-Rise Construction

In comparing U.S. and Japanese practice in composite construction, it is interesting to see the difference in focus, emphasis and thrust of research and applications. In the U.S., the emphasis has been on high-rise construction where composite construction has allowed economy of materials, speed of construction, and maximum utilization of labor trades. Applications have been mostly in non-seismic zones where wind loads have controlled the design. In Japan, however, composite construction has expanded because of the perceived advantages it has in high seismic zones where the increase in stiffness, ductility and fire resistance is important. Also, most of the Japanese applications are in low-rise and mid-rise construction.

Perhaps, however, the U.S. can learn from the Japanese experience in low-rise construction. It is interesting to examine the usage of structural steel in U.S. building construction (see Figure 9). AISC Marketing, Inc. reports that for calendar year 1992, more than 60% of the steel volume is contained in one-story buildings, nearly 90% in buildings less than or equal to four stories, and less than 2% in high-rise buildings over 20 stories. This leads to a significant conclusion for the future of composite frame construction: "The glamour is in high-rise, but the volume is in low-rise."

Perhaps, however, the U.S. can also learn from the Japanese experience in high seismic zones. In Japan, the numerous large construction companies are well equipped and funded for research in structural components and systems. As a result, numerous proprietary components and systems have bee developed. Systems with long-span steel beams connecting to concrete filled steel tubes or to steel reinforced concrete columns or walls are very common in Japan. Clever connection details have been developed to make these systems practical (Figures 10 through 14). These systems are designed according to structural standards published by the Architectural Institute of Japan and the Building Research Institute of Japan. However, many of the new components and systems developed are not covered by the existing standards and so the composite research on the Japanese side is motivated to develop new standards.

The challenge for U.S. designers, builders and researchers is clear. We must develop new composite frame systems for low-rise construction, suitable also for seismic zones. New composite materials, elements, systems and connections will likely take advantage of the ductility, toughness and redundancy that are inherent in steel and concrete composites. As we look back on our experience in the U.S. with high-rise composite construction, the road to successful applications is evident. First, we must develop new low-rise systems, starting in non-seismic zones. Here, as in the high-rise arena, designers and builders should collaborate on the development of practical, economical systems. Then, we need the researchers to conduct physical and analytical tests to enhance our understanding of the behavior of such systems and to refine the simplified theories used in the early development. Subsequently, with the experience of practical applications in low and moderate seismic zones and a newly refined design theory, we are in a position to apply these systems to high seismic zones. And lastly, we must codify the practice.

Although this may seem a somewhat backwards approach, it is borne out of necessity and certainly worked well for U.S. high-rise development. This procedure will allow new composite systems to successfully compete with existing steel, composite and concrete systems in the marketplace.

Lawrence G. Griffis, P.E., is senior vice president of structural engineering with Walter P. Moore and Associates in Houston. The author wishes to acknowledge the assistance of Ivan Viest, who furnished much of the early history of composite construction usage in the U.S., Isao Nishiyama of the Building Research Institute in Tsukuba, Japan, and the researchers named in the article.

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Circle no: 90

Product: E-Size Plotter
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Fax: 805/389-6993
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Fax: 905/566-0181
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