Special Report

Partially Restrained Connections
### Tensile Strength of Arc Puddle Welds - Wind Uplift Forces on Roof Deck

#### Steel Design Data Sheet No. 18

![Diagram of roof deck](image)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.5</td>
<td>.625</td>
<td>.75</td>
</tr>
<tr>
<td>A446 grade A*</td>
<td>22</td>
<td>230</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>280</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>360</td>
<td>460</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>440</td>
<td>570</td>
</tr>
<tr>
<td>A446 grade C</td>
<td>22</td>
<td>280</td>
<td>360</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>340</td>
<td>430</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>440</td>
<td>560</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>540</td>
<td>690</td>
</tr>
<tr>
<td>A446 grade D</td>
<td>22</td>
<td>310</td>
<td>390</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>370</td>
<td>470</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>480</td>
<td>610</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>590</td>
<td>760</td>
</tr>
<tr>
<td>A611 grade C*</td>
<td>22</td>
<td>250</td>
<td>310</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>300</td>
<td>380</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>380</td>
<td>490</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>470</td>
<td>610</td>
</tr>
<tr>
<td>A611 grade D</td>
<td>22</td>
<td>270</td>
<td>340</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>320</td>
<td>410</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>420</td>
<td>530</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>510</td>
<td>630</td>
</tr>
</tbody>
</table>

* Roof deck is generally specified to meet ASTM A446 grade A (galvanized) or A611 grade C (painted).

(1) Single metal thickness values.  
(2) Double metal thickness values - end laps  
(3) Edge laps (at supports).

All table values are in pounds (tension) and are design values found by the formulas given in the AISI Specification for the Design of Cold-Formed Structural Members(A); the safety factor is 2.5 but the 33% increase for wind loading has been included. The edge lap values (column 3) have been reduced by 30% to adjust for eccentric loading of the weld as recommended by Tensile Strength of Welded Connections(B). AWS procedures for arc puddle welds are to be followed. A minimum electrode strength of 60 ksi is required.


(B) R.A. LaBoube and Wei-Wen Yu, Department of Civil Engineering, Center for Cold Formed Steel Structures, University of Missouri–Rolla, Civil Engineering Study 91-3
Estimating

Gives you unrivaled accuracy - and an accurate bid is money in your hand

In these days of declining profits, Structural Software's computerized Estimating gives you the accuracy you need to stay competitive. An accurate bid can mean the difference between a healthy profit and an unwelcome surprise. Plus, you're able to bid more jobs using the same personnel. Our Estimating program correctly prices all items that go into a job, from the mill to the warehouse. The only thing left for you to calculate is the savings! Almost all of the pricing levels and labor codes can be changed to suit your needs. In fact, our customers agree that Estimating's flexibility makes it the best estimating program on the market. And Estimating's unique modular design for IBM computers lets you easily add on our other programs, like Multing, Inventory and Production Control, to give you even greater accuracy and control over shop production.

"The computer saves so much compilation time and analysis time, since it groups the pieces automatically. We can bid a lot more work now, and that's really important in today's competitive market. Using the computer saves us hours, or days, on turning estimates around."

Greg Lewis
Elwell Iron Works, Inc.

"Estimating saves us the cost of one person per year. We also appreciate the consistency that computerized estimating adds to our operation. Since this program was written by a structural steel fabricator, and for a structural steel fabricator, we don't have to rethink anything to use it."

Jack Holcomb
Berlin Steel Construction Co.

"We're extremely satisfied. Estimating has enabled us to do another 20 to 35 percent more quotes and increased our accuracy tenfold. The computer eliminates the tallying errors that creep in sometimes when you're totaling up the weights. We've had our system for close to five years, and we're very happy with it."

Dave Fritzler
Coastal Steel Corp.

Call (800) 776-9118 for details on Estimating and other Structural Software programs, including:

*FabriCAD - A total unit detailing process that includes shop drawings
*Inventory Control, Production Control and Purchase Orders - Material Allocation programs that link purchasing with production to cut waste and boost profits. Structural Software Co., 5012 Plantation Road, Roanoke, VA 24019.
FEATURES

18 COMPOSITE SEMI-RIGID CONNECTIONS
Partial Restrained connections can significantly reduce deflections, increase the frequency of vibration, and provide needed lateral stiffness.

24 UNLOCKING THE INHERENT STIFFNESS OF LOW-RISE BUILDINGS
Industry standard shear connections provide restraint to columns and can be used as partial restraint connections in design.

30 INNOVATIVE STRUCTURE FOR AN AWARD-WINNING AIRLINE PAINT FACILITY
Though more attention has focused on this project's innovative mechanical system, its structural system also is noteworthy.

34 BENEFICIAL PROCRASTINATION
Delaying lead paint removal projects by upgrading the coating system can offer substantial benefits.

38 NEW COATING SYSTEMS FOR BRIDGES
The pending obsolescence of higher volatile organic content (VOC) coatings has resulted in the rapid expansion of the protective coating market in the 1980s and the introduction of many new state-of-the-art formulations.

NEWS AND DEPARTMENTS

6 EDITORIAL

9 STEEL INTERCHANGE
- Connecting wide flange to structural tubes
- Designing lateral bracing

12 CORRESPONDENCE
- Extra Credit
- Cellular Beams

14 STEEL NEWS
- New ideas In Structural Steel
- New LRFD Edition
- Steel Inspection Newsletter

16 STEEL CALENDAR

41 PRODUCTS

42 STEEL MARKETPLACE
Introducing the one steel for North America: Chaparral Steel's A36/A57250 steel. This mill-certified steel satisfies multigrade requirements in the U.S., Canada and Mexico. The A36/A57250 steel meets all the specifications of our A36, A572 Grade 50, 44W and 50W. It's everything you like about these grades rolled into one. Plus, it costs the same as the A36, and has the same carbon equivalent range, an important factor for welding and formability. It's also just as easy to get, thanks to our innovative shipping techniques and central location. Call your Chaparral representative today and order the structural steel that makes the grade a number of ways: Chaparral's A36/A57250.
Revisiting An Old Friend

In my first editorial for Modern Steel Construction way back in January 1990, I mentioned that AISC was moving its headquarters to a very suitable building—at least for a structural steel association. “Whether by chance or some pre-ordained plan,” I wrote, “we ended up in the first multi-story building to be built with high strength steel with a yield point of 50,000 psi furnished to ASTM specification A440.”

I also quoted from a USS Structural report on the building that noted the building used moment resisting beam-to-beam connections instead of diagonal bracing. “Because wind forces require moment resisting beam-to-column connections, it was considered advisable to include this restraining effect in the design of the beams for gravity loads.” In other words, the building was an early example of Partially Restrained Connections—the topic of a Special Report in this issue beginning on page 18.

In 1962, the engineer designed his innovative structure to achieve minimal interference on leasing space from structural members. Also, the use of high-strength steel in conjunction with PR Connections allowed a substantial savings in steel weight.

Today, higher fabrication labor costs further increase the advantages associated with PR connections. These include the elimination of column web stiffeners and the simplification of beam-column connections. In addition, frame erection time is quickened and the reduced weight of the frame can reduce foundation costs.

Professor Roberto Leon from the University of Minnesota begins our special report with an explanation of the principles involved in designing PR connections. His article is followed by one from Kurt Swenson, an engineer with Stanley D. Lindsey & Associates. Kurt describes his firm’s use of PR connections and sites the cost effective design used on a recently completed low-rise building in Nashville.

If you’ve used PR Connections in a recent design—or, for that matter, in an old building like One East Wacker Drive—let me know. We’re always looking for innovative steel stories to cover in MSC. SM
World Class Civil and Structural Software
See It To Believe It -- at a City Near You!

STAAD-III/ISDS - Ranked #1
By a Recent ENR Survey of Structural Engineers

CIVILSOFT - World Class
Civil Engineering Software Since 1976

You are invited to see the latest in Research Engineer's line of quality engineering software at a city near you. If you are looking for quality engineering software sign up for a free introductory seminar. Come see what Research Engineers can do for you.

Seminar Schedule

San Diego, CA.* 09/08/92
Irvine, CA. 09/09/92
Pasadena, CA. 09/10/92
Phoenix, AZ. 09/29/92
Dallas, TX. 09/30/92
Houston, TX. 10/01/92
San Antonio, TX.* 10/02/92
Washington, D.C. 10/12/92
Philadelphia, PA. 10/13/92
North New Jersey 10/14/92
Hartford, CT. 10/15/92
Boston, MA. 10/16/92
Birmingham, AL. 11/02/92
Nashville, TN. 11/03/92
Atlanta, GA. 11/04/92
Charlotte, N.C. 11/05/92
Miami, FL.* 11/12/92
Tampa, FL. 11/13/92

* STAAD Seminar will show both English and Spanish software versions

Structural Seminar to Feature
STAAD-III/ISDS Release 15!
The most powerful integrated Structural Analysis, Design & Drafting software with 2D/3D Static / P-Delta / Dynamic / Seismic analysis, STEEL / CONCRETE / TIMBER design and state-of-the-art interactive graphics.

Release 15 enhancements include: Foundation design, concrete column interaction analysis, deflection check for steel design, enhanced CAD interface and many advanced analysis / design / graphics features.

AutoSTAAD - AutoCAD based structural drafting / model generation.

CIVILSOFT Seminar to Feature
AutoCivil Release 3.01
Ten powerful design and analysis programs running inside of AutoCAD® Release 11/386 or higher in the areas of survey, mapping, and hydraulics applications.

Advanced Designer Series Programs
Ten powerful standalone products running outside of the CAD environment in the areas of survey, mapping, hydraulics.

To make your reservations for one of these introductory seminars call:
(800) 367-7373.
Make your reservations today!

Research Engineers, Inc.
1570 N. Batavia
Orange, Ca. 92667
(714) 974-2500 Fax: (714) 974-4771

Offices in U.K. (Culver) Tel: (01)783-1391 • W. Germany (Bonnstein) Tel: 06255/79577 • France (Paris) Tel: 37 47.51.63 • India (Chennai) Tel: 44-6914
**AISC Database**

The AISC Database contains properties and dimensions of structural steel shapes, corresponding to Part I of the 1st edition LRFD Manual of Steel Construction and the 9th edition ASD Manual of Steel Construction. Two versions, one in U.S. customary units and one in metric units, are available. Please specify.

The computer database, in ASCII format, contains W, S, M, and HP shapes, American Standard Channels (C), Miscellaneous Channels (MC), Structural Tees cut from W, M, and S shapes (WT, MT, ST), Single and Double Angles, Structural Tubing, and Pipe

An explanation of variables specified in each data field is included as are a BASIC read/write program and a sample search routine by which the database may be manipulated, and a routine to convert the file to Lotus 1-2-3 format. Additionally, the metric version includes a text file which cross references the ASTM designations in SI units to U.S. customary units.

Available on 3" or 5" disk. $60.00

**AISC Software**

**STEMFIRE**

STEMFIRE determines safe and economical fire protection for steel beams, columns, and trusses. STEMFIRE is based on rational procedures developed by AISC which extend the published UL fire resistive designs to other possible rolled structural shapes and common protection material requirements. For a required fire rating, STEMFIRE determines the minimum spray-on thickness for various rolled shapes as well as the ceiling membrane or envelope protection for trusses. This methodology is recognized by UL and has been adopted by the three national model building codes in the USA.

The software database contains all pertinent steel shapes and many listed UL Fire Resistance Directory construction details and fire ratings. In this manner, user search time is minimized and the design and checking of steel fire protection is optimized. Hence, STEMFIRE is easy to use with little input effort to quickly produce specific design recommendations. Two 5" disks containing executable software bearing AISC copyright and a users manual with instructions and sample problems are included with purchase.

Available on 5" disk only. $96.00

**WEBOPEN**

WEBOPEN is designed to enable engineers to quickly and economically design beam web openings. An expedient tool, WEBOPEN uses state of the art criteria and features a clear and logical data entry system with easy to use color coded input windows. Furthermore, WEBOPEN accesses a shape database allowing the selection of any W, S or M shape for use in the design procedure.

WEBOPEN was written by practicing engineers for engineers and incorporates expert design checks and warning messages which enhance the application of the AISC Design Guide to specific design problems. Using this software, unreinforced or reinforced, rectangular or round openings, concentric or eccentric, in both composite and non-composite steel beams may be designed. The design is complete with stability and proportioning checks. Additionally, the design is optimized through user interaction during the design sequence. Included with purchase are the WEBOPEN program, the WEBOPEN Users Manual and the AISC Design Guide Steel and Composite Beams with Web Openings.

Available on 3" or 5" disk. $495.00

**CONXPRT**

CONXPRT is a knowledge based PC software system for steel connections. Expert advice from long-time fabricator engineers is used to augment the design rules. CONXPRT incorporates provisions to set dimensional and material defaults for a particular project or general shop needs. Additionally, CONXPRT is menu driven and incorporates help screens designed for easy use.

*Module I: Shear Connections*  
Available in either 1st edition LRFD or 9th edition ASD format. Designs more than 80 configurations of double framing angles, shear end plates, and single plate shear connections is possible.

*Module II: Moment Connections*  
Available in 9th edition ASD format only. Provides a set of four knowledge bases for the design of strong axis moment beam-to-column flange connections; direct welded, flange welded-web bolted, flange plate welded-web bolted, and flange plate bolted-web plate bolted connections. Additionally, a knowledge base for the column side design of web stiffener plates and doubler plates is a part of the module.

Available on 3" or 5" disk. $300.00

Available on 3" or 5" disk. $550.00

Available on 3" or 5" disk. $400.00

**AISC for AutoCAD**


The program will parametrically draw to full scale the end, elevation, and plan views using the design dimensions of the shapes shown below.

Available on 3" or 5" disk. $120.00

AutoCAD is a registered trademark in the US Patent and Trademark Office by Autodesk, Inc.  
AISC for AutoCAD is copyrighted by the US Copyright Office by Bridgefarmer and Associates, Inc.

**to place an order, call**

(312)670-2400

(312)670-2400
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 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
1 East Wacker Dr.
Suite 3100
Chicago, IL 60601

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

How should I connect wide flange beams to all four faces of a structural tube column in such a way as to transfer wind moments as well as dead and live load reactions?

It must be assumed that the tube column is able to resist the bending induced by the various combinations of wind and gravity moment. The tube walls must be protected against localized buckling and stretching and the side walls must have adequate shear capacity, unless the horizontal forces are able to be carried in one face, directly through, and out the opposite face. There are several ways to strengthen a tube column.

1. Internal diaphragm
2. External diaphragm
3. Girdling or cladding
4. Through plate diaphragm.

When all four beams are the same nominal depth, through-plate diaphragms can be used. Figure A is an example of this, showing the tube severed and rewelded to the plates. Another version is shown in Figure C where external diaphragm plates are cut out to the profile of the tube and welded to the tube. The tube remains intact. Figure B shows an example of internal diaphragms. The tube is cut and the diaphragm plates installed where required and the tube rewelded. This is useful if the wide flange beams are of varying nominal depths. In Figure B the moment connection is made by field welding the beam flange directly to the face of the column. The fourth method of reinforcing the tube is by girdling or cladding as shown in Figure D. By extending the reinforcing upward and downward more bending strength can be added. Resistance to shear in the sidewalls can also be increased by girdling.

The gravity load can be resisted by a shear plate or single angle connection or, as noted in Figure E, a stiffener plate can be installed below the bottom flange connection to connect it to a stiffened seat.

Figure F shows several adaptations of external diaphragm plates and their versatility.

Modern Steel Construction / October 1992 / 9
Figure F: Adaptations of external diaphragms

This is but a brief glimpse at a complex type of connection. For further related information I suggest the following references:

5. Ricker, David T., "Practical Tubular Connections", 1985 ASCE Structural Engineering Conference David T. Ricker
Payson, AZ

Another response:

A simple connection is suggested. Details are provided in Figure 1.

Vijay P. Khasat
Ohio Edison
Akron, OH

Are there any design requirements that an engineer can follow when designing lateral bracing?

When designing lateral bracing the engineer has little in the way of guidance from the AISC Specifications although the commentary suggests referencing the Structural Stability Research Council's Guide to Design Criteria for Metal Compression Members (Wiley Interscience, New York, ISBN 0 471-09737-3). In addition the Handbook of Steel Construction published by the Canadian Institute of Steel Construction is more specific and does provide design requirements in its section 20.3 Stability of Beams, Girders and Trusses.

Frank Petriglano
The Steel Institute of New York
New York, NY

New Questions

Listed below are some 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. 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.

1. Where can I get information on stainless steel bolts?

2. Are there limits on bending a wide flange beam into a radius?
Design Data's SDS/2 Steel Fabrication System.

SDS/2 gives you the flexibility to integrate all aspects of your business with one software system. That concept is called Information Management. Each module by itself will save you time and money and by combining products to implement Information Management you receive more than twice the benefit in savings and productivity. So whether you need one SDS/2 software module or all these tools working together, Design Data can provide the most productive system for you.

For more information about SDS/2, information management in the steel industry or future product demonstrations call 800-443-0782.
AUTOMATED PRODUCTION RECORDING

Now there's an automated way to monitor and record plant production as it happens—simply as a result of using Steel 2000. What's more, Steel 2000 can do the job for you with or without a network and whether or not you have CNC fabrication machinery.

Automated Production Recording lets you capture and report plant production at as many shop locations as you desire. It eliminates the need for manual data entry and offers reporting capabilities that are limited only by your imagination.

To find out more about Automated Production Recording and Steel 2000, call 601-932-2760; Fax 601-939-9359.

CORRESPONDENCE

Extra Credit

Dear Editor:

I am in receipt of the August 1992 issue of Modern Steel Construction. While I was happy to find our article on the Old Bridge Public Library, I was horrified to find that the list of Design Team Members had been omitted.

The average reader will conclude that my role in this project was much more substantial than was, in fact, the case. You have done a terrible disservice to both our Project Architect, Michael DeBiasse, and to the Project Engineer, Sanjeev Shah, of Severud Associates.

These two individuals deserve the lion's share of the credit for the realization of this project, and you have an obligation to recognize their contributions.

Sincerely,
Eliot W. Goldstein, AIA
James Goldstein & Partners
Millburn, NJ

Cellular Beams

Dear Editor:

Terminal 1 at Chicago's O'Hare Airport, recently featured in your publication (June 1992), is a famous example of architecture using exposed steel beams with openings or apertures profiled along the web. Westok Structural Services, Ltd., based in Great Britain, has developed a technique that produces such beams with the maximum economy. Instead of simply burning disks of steel out of the web, which is both wasteful and costly, Westok's method uses a patented cutting profile similar to that used in the production of castellated beams.

The profiled tee sections are welded back together to form a beam of increased depth, thus significantly improving the beams overall strength and performance. In the case of O'Hare Airport, for example, Cellform beams would have been typically 30% lighter.
than the sections actually used.
O'Hare, like all other airports, could also make use another—and perhaps more important—application of Cellform beams. In airport terminals, the necessity for long clear spans without intermediate columns is a constant headache for structural engineers. The excellent strength/weight ratio of a Cellform beam makes it a most efficient long-span floor beam, particularly effective when designed compositely. The fact that air-conditioning ducts and other services can be passed through the cells ensure the shallowest of overall floor considerations, considerably reducing exterior cladding costs.

A final refinement can be achieved by producing an asymmetrical Cellform beam made from two tees of different mass. The lighter steel is used as the compression flange—under used in composite design—resulting in the lightest and most efficient use of steel. Again, Cellform floor beams are typically 30% lighter than solid web beams, producing construction depth reductions of up to 19" per floor.

Although not yet used in the U.S., Cellform beams are not a new concept to American architects. One example is HOK International, Ltd., whose London office has designed an Exhibition Hall incorporating more than 1,100 tons of straight and curved Cellform roof beams spanning up to 90'.

Westok operates a free design service, already used by a number of consulting engineers in the States, and expects the first Cellform project to commence here inside of six months. Engineers wishing to consider cellular beams should contact: Andy Holmes, Westok Structural Services, Ltd., Horbury Junction Industrial Estate, Horbury Junction, Wakefield, West Yorkshire, UNITED KINGDOM WF4 5ER, Tel: 0924 264121; Fax: 0924 280030.

Sincerely,
Andy Holmes
New Ideas In Structural Steel

After a one year hiatus, AISC's Lecture Series on Structural Steel is returning in 1993.

Fundamental changes in the economic and business climate are shifting the priorities of designers and fabricators. AISC's new Lecture Series, "New Ideas In Structural Steel," will cover four topics, each reflective of the most up-to-date industry practices, at each lecture.

The first subject broached is the increased emphasis on low-rise construction. While not as glamorous as designing a 100-story landmark, these structures still offer unique challenges. This part of the session utilizes AISC Steel Design Guide #5, Low- and Medium-Rise Buildings as an introduction to efficient structural steel systems for low-rise structures. Topics include live load and bay size, composite floors, vibration, wind loads, unbraced frames, and special techniques.

Next up is the new Manual of Steel Construction, Volume II. This manual is devoted exclusively to connections, and this part of the session will highlight pertinent information relative to understanding the efficient selection of connection types and critical design parameters. Particular emphasis will be placed on side-by-side comparisons of Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD) solutions.

The third subject covered in this new lecture series is Eccentrically Braced Frames. This steel innovation was created to provide a predictable and economic system for large seismic forces. But its inherent economy has also proven to be valuable in moderate seismic or even wind loadings in low-rise buildings. In addition, EBF relieves the interference problems of concentrically braced frames, while at the same time providing new opportunities for architectural expression.

The final topic to be covered is Partially Restrained Connections. This is an old idea whose time has come. For years, the idea of a more economical framing method using the principle of connection flexibility to provide more balanced designs has been the subject of much research and analysis. Now, computers have tamed the additional analytical steps to bring new, reliable information to the designer. Fundamental principles will be covered, including proposed methods.

Lectures are tentatively scheduled for the following cities: Southwest—Dallas, Houston, San Antonio, Kansas City, New Orleans, Denver; Midwest—St. Louis, Chicago, Detroit, Minneapolis, Indianapolis; Mid-Atlantic—Baltimore, Washington DC, Philadelphia, Cleveland, Cincinnati, New York, Newark; Northeast—Meriden, Boston, Albany, Rochester; Southeast—Orlando, Atlanta, Birmingham, Charlotte, Raleigh, Greenville, Miami, Knoxville, Columbia, Wilmington; West: San Diego, Irvine, San Francisco, Seattle, Los Angeles.

In addition, approximately 10 other cities are under consideration.

For more information, write: AISC Lecture Series, One East Wacker Dr., Suite 3100, Chicago, IL 60601-2001.


The new June 15, 1992 AISC Seismic Provisions for Structural Steel Buildings is now available. It contains seismic steel detailing provisions that supplement the main AISC Load and Resistance Factor Design and Allowable Stress Design Specifications. As with the previous edition, requirements for columns, ordinary moment frames, special moment frames, concentrically braced frames and eccentrically braced frames are given.

The principle changes are the conversion to the load and design format contained in the 1991 National Earthquake Hazards Reduction Program (NEHRP) Recommended Provisions for the Development of Seismic Regulations for New Buildings.

The new Seismic Provisions was developed by a subcommittee chaired by E.P. Popov, professor emeritus at the University of California (Berkeley) and with Clarkstone W. Pinkham of S.B. Barnes & Associates serving as secretary.

Copies of the 1992 AISC Seismic Provisions for Structural Steel Buildings are available for $5.00 + $4.00 shipping and handling from: American Institute of Steel Construction, Inc., P.O. Box 806276, Chicago, IL 60680-4124 (312) 670-2400 ext. 433.

New LRFD Edition Nearing Completion

In accordance with the consensus operating procedures of the AISC Committee on Specification, a draft of the updated AISC Load and Resistance Factor Design Specification and Commentary is available from Oct. 1 through Nov. 30, 1992, for public review and comment. Copies of this draft (approximately 200 pages) are available for a nominal $10 handling charge from AISC Publications (312-670-2400 ext. 433).

Any public comments must be received by November 30, 1992, and should be as specific as possible. Once the AISC Committee on Specifications completes its work and approval, the new document is...
intended to replace the 1986 LRFD Specification.

Some of the principal changes include expansion of material on stability of unbraced frames, design provisions for slip critical bolted joints at factored loads, more general \( C_b \) equation, updated criteria for slender web girders and un-symmetric members, and new web crippling limits.

Corresponding corrective revisions to the 1989 AISC ASD Specifications also are being deliberated.

The annual meeting of the AISC Committee on Specification has been scheduled for Nov. 17-18, 1992 in the Chicago area. The meeting agenda primarily will address any new and unresolved specification issues. Anyone wishing to attend is welcome. Please contact N. Iwankiw, AISC Committee Secretary, at (312) 670-5415, to indicated your interest and to request more detailed information.

### Steel Inspection Newsletter

Information on code changes, certification programs, and a variety of testing techniques is available in Steel Inspection News: an informational digest. The eight-page, bi-monthly newsletter is published by the Steel Structures Technology Center, Inc.

Topics include: structural steel materials; welding; bolting; nondestructive testing; steel bar joists; roof and floor decking; shear connectors; reinforcing steel; coating systems; tolerances and certification programs for inspectors and contractors.

A subscription costs $36 for one year, $60 for two years. For more information, contact: Steel Structures Technology Center, 40612 Village Oaks Dr., Novi, MI 48375-4462 (313) 344-2910; fax (313) 344-2911.
to provide engineers and welding inspectors a greater understanding of weld mechanics and welded engineering structures. Contact: AWS, 550 N W. Lefeleune Road, P.O. Box 351040, Miami, FL 33135 (800) 443-9353.

October 13-14. CADD Seminars, Philadelphia. Topics include: implementation & management; developing CADD standards; automating the design office; A/E CADD management; linking computers; and training & staffing for CADD. Contact: Sharon Price, A/E/C Systems (800) 451-1196.


October 27. Domestic Steel Industry Update, breakfast meeting, Jackson, MS. Contact: Jim Anders (214) 369-0664.

Eccentric-Braced Frame Technology. Breakfast meeting. Discussion includes EBFs for both seismic and non-seismic applications. Contact: Colleen Hays, AISc Marketing, Inc. (312) 670-2400 ext. 203.

Columbia, SC.................. October 14
Charleston, SC................. October 15
Wilmington, NC.............. October 16
Norfolk, VA.................. October 20
Richmond, VA................. October 21
Wichita, KS.................. November 10
Denver.......................... November 11
New Orleans.................. November 17

Structural Welding Design For Buildings. One day seminar discussing the design of shear, moment, splice and other structural connections, AISc and AWS specification requirements, and other welding issues. Contact: Robert E. Shaw, Jr., Steel Structures Technology Center, (313) 344-2910.

Chicago.......................... October 8
Costa Mesa, CA............... October 22
San Francisco.................. October 28
New York City................. December 3

Steel Buildings: Special Inspection. One-day seminar discussing code-required inspections of steel-framed buildings. Contact: Robert E. Shaw, Jr., Steel Structures Technology Center, (313) 344-2910.

Houston..................... October 1
Dallas.......................... October 2
Chicago.......................... October 9
Phoenix...................... October 19
Las Vegas.................... October 20
Costa Mesa, CA.............. October 21
City of Commerce, CA...... October 23
Sacramento, CA............... October 26
San Francisco................ October 27
Portland..................... October 29
Seattle...................... November 30
Portland..................... December 1
Cromwell, CT................. December 2
Hasbrouck Heights, NJ...... December 4

16 / Modern Steel Construction / October 1992
1 GUIDE TO LRFD
Supplies background information from ASD to LRFD and introduces LRFD philosophy. Provides simplified versions of several equations for design of simple structures or components. Intended for those not yet familiar with LRFD, or who need clarification.

2 QUALITY CRITERIA AND INSPECTION STANDARDS, 3RD EDITION (1988)
This commentary discusses the commonly accepted standards of workmanship for fabricated structural steel framing which assure satisfactory fit and appearance at minimum cost for the vast majority of buildings and bridges. AISC recommendations for clarification and solution of common problems involving fabricating tolerances and procedures are provided.

3 DESIGN OF MEDIUM-RISE STEEL BUILDINGS
The design of medium-rise steel buildings is consolidated in one booklet as a reference for all designers of these structures. This guide includes rules for economic design for engineers. Load requirements are discussed as are joint and composite floor systems.

3 FREE DESIGN AIDS WITH PURCHASE OF 1 MANUAL

AISC Manuals of Steel Construction are essential references for engineers, architects, detailers, draftsmen, contractors and building officials. Two design methods—Allowable Stress Design or Load and Resistance Factor Design—provide expanded design aids and examples which reference every phase of steel construction. Also contains the latest Bolt Specifications, 1986 Code of Standard Practice, comprehensive index, and thumb-indexing convenience.

BOTH INCLUDE:

▼ Dimensions and Properties
▼ Beam and Girder Design
▼ Column Design
▼ Connections
▼ Specifications and Codes
▼ Miscellaneous Data and Mathematical Tables

9TH EDITION ALLOWABLE STRESS DESIGN (ASD)

1ST EDITION LOAD AND RESISTANCE FACTOR DESIGN (LRFD)
Based on the 1986 Load and Resistance Factor Design Specification for Structural Steel Buildings. LRFD provides more uniform structural reliability and better economy than ASD specifications. Design aids are updated in the LRFD format. Includes a special section for composite beams and columns1192 pages. $60.00.

LIMITED TIME OFFER

ORDER BY OCT. 31, 1992

NAME/TITLE ____________________________
COMPANY ____________________________
ADDRESS ____________________________
CITY/STATE/ZIP ________________________

PLEASE ENCLOSE REMITTANCE. NO COD ORDERS. ADD $5 FOR UPS CHARGE.
FOREIGN ORDERS: ADD 10%. $10 MINIMUM FOR SHIPPING.

CHECK FOR $ ___________ ENCLOSED __ CHARGE MY __ VISA
____ MASTERCARD ACCT # ____________
SIGNATURE ____________________________ EXP. DATE ____________

RETURN TO:
AISC MANUAL OFFER
PO BOX 806276
CHICAGO, IL 60680-4124

ALLOW 4-6 WEEKS FOR DELIVERY

25% discount to AISC members
Composite Semi-Rigid Connections

Partial Restraint connections can significantly reduce deflections, increase the frequency of vibration, and provide needed lateral stiffness

By Roberto Leon, Ph.D.

Recent steel design specifications, such as the LRFD Specification from AISC or Eurocodes 3 and 4, have adopted a limit state design approach, with ultimate strength and serviceability limit states generally being the governing criteria. While a design based on ultimate strength generally results in a very economical structure, as span lengths increase and new types of loading are added to the design, drift and deflection criteria begin to govern.

For the design of multistory steel structures, two recent developments have begun to pose problems:

• For the vast majority of low- and medium-rise buildings, composite floors have become the preferred structural system for gravity loads. However, since their design is most economical when based on ultimate strength limits, the economical span-to-depth ratios have increased on all-steel construction from about 20:1 to 24:1, and on composite construction from 28:1 to 32:1. The result is slender floors prone to problems with both short- and long-term deflection, cracking and vibrations.

• Large areas of the eastern and midwestern United States have been upgraded to seismic zones with design ground accelerations as high as 0.2g. In these areas, where lateral load design was traditionally governed by wind, new construction will have to comply with both more stringent drift criteria and some minimum level of seismic detailing to ensure safety during an earthquake.

Both of these problems require that connections with additional stiffness, ductility and strength be incorporated into practice. Since connection fabrication and erection represent a significant portion of a structure's cost, neither the introduction of radically new connection technology nor a requirement for full restraint connections are practical since both would greatly increase costs.

The most logical solution, therefore, is to modify the connections commonly in use today to increase their strength and stiffness. Since partial restraint (PR, or Types 2 and 3) connections already possess some flexural strength and rigidity, it is logical to try to improve their performance rather than to promote a whole new technology. PR connections (Figure 1) can significantly reduce deflections, increase the frequency of vibration, and provide the required lateral stiffness for unbraced frames up to 10 stories.

Semi-Rigid Composite Connections

During the past eight years, the author and his co-workers at the University of Minnesota have developed the concept of semi-rigid composite connections. These connections utilize the additional strength and stiffness provided by the floor slab that is activated by adding shear studs and slab reinforcement in the negative moment
regions adjacent to the columns. This type of connection is a very logical and economical solution to the problems described earlier.

**Connection Investigations**

Four different types of connections have been investigated (Figure 2):

**Type I:** These consist of a typical seat angle, a double angle shear connection to the web, and continuous slab reinforcement across column lines (Figure 3). Under gravity loads the latter provides the tension part of the couple, while the angle in bearing acts as the compression member. Because of the increase in steel strength (Grade 60 for rebar vs. A36 or A572 for the angle) and lever arm, this connection adds significant moment capacity to the connection over a typical top and seat angle connection.

There also are significant stiffness gains because the slab steel yields in almost pure tension and at a higher stress than a top angle. Additional stiffness gains accrue from the use of slip critical bolts and, at large rotations, from the presence of web angles. Under seismic loading, however, the bottom angle will pull out at relatively low loads resulting in unsymmetrical and degrading hysteresis loops. Thus, for seismic applications the thickness of the bottom angle should be increased to yield a connection with more symmetrical moment-rotation characteristics.

Figure 4 illustrates the possible increases in strength and stiffness that can be achieved and Figure 5 shows a full-scale, two-bay, one-story subassemblage incorporating these connections being tested under a combination of gravity and lateral loads.

**Type II:** These consist of a welded bottom plate, web angles for shear, and continuous slab reinforcement. This is a very stiff, economical connection possible because a welded plate has been substituted for the bottom angle, which in Type I connections was the weak link. This plate carries the tensile and compressive forces basically as axial loads, resulting in a very stiff and non-degrading connection. The same results can be achieved by welding the plate to the column in the shop and bolting it to the beam with high strength slip critical bolts in the field. The welds must be detailed to insure full transfer of moment and to eliminate the possibility of weld fracture. This connection offers very large initial stiffnesses and symmetrical behavior under cyclic loading.

**Type III:** These consist of connections similar to Type I, except that the web angles are missing. This results in a connection with a much flatter inelastic region, because there are no web angles to provide additional restraint once the seat has yielded. In addition, careful attention must be paid to the stability of the bottom angle and the beam web. As for Type I, the thickness of the seat angle is the controlling parameter.

**Type IV:** These consist of combining the simplest shear connection used in steel frames (bolted double web angles or single plate shear tabs) with the slab reinforcement. Although the angles or plate are relatively weak, the moment capacity of the composite connection can be substantially improved by increasing the thickness of the angle and lowering its position towards the bottom of the beam web. Since the web angles are carrying both shear and moment, care must be taken to prevent any type of block shear failure.

The main advantage of semi-
Tests have been conducted on a variety of semi-rigid connections. Pictured above is a typical seat angle, a double angle shear connection to the web, and a continuous slab reinforcement across column lines.

The All New

Jobber III

Dimensional Calculator

The Calculator that does it All!

The Indispensable Tool for Everyone Who Works with DIMENSIONS Detailers, Fabricators, Foreman, Crewleaders, Layout Men, Engineers & Architects. The Worlds BEST Feet/Inches/Sixteenths Engineering Calculator that also works in Decimals & Metric (millimeters) with Instant Conversion at the touch of a button!

New Features Include:

* The only Calculator with the Jobber III patented 0/15 Keyboard that cuts keystrokes by 66%. Saving You time & entry errors over "old fashion calculators" & that Means Money to YOU!  
* 4 Memories that automatically retain your data even when the Jobber III is off.  
* Everyone who works with Dimensions needs the Power of the Jobber III.

Special Price  $ 99.95 + $4.50 S&H

Jobber Instruments  P.O. Box 4112 -C  Sevierville, TN, 37864

Order Toll-Free  1-800-635-1339

20 / Modern Steel Construction / October 1992
kept small (less than a #5), and at least three bars on either side of the column should be used. Transverse steel must be provided at each column line, and must extend at least 12" into the slab strip.

**Serviceability Considerations**

To reduce serviceability problems, a minimum of 0.1 sq. in. of steel per lineal ft. must be provided over the girders, with this reinforcement extending at least 24" on either side of the girder. Care must be taken that slip critical bolts are used everywhere, that local buckling of the beam flange or web in negative moment regions does not occur, and that yielding of the column panel zone be avoided. Full shear connection should be provided since the effect of partial connection has not been investigated.

**Performance Studies**

To study the performance of

---

**Figure 4.**

Consider a composite connection containing eight #4 bars on a fully composite W18x35 A36 beam with an effective width of 108". When transformed to an equivalent area of 36 ksi steel, the rebar steel transforms to $1.6(0.936) = 2.67$ sq. in. of steel. This is about the same area as that of the flange of the W18x35.

If a top and seat angle connection are selected, and an angle with about the same area as the top flange of the beam used, the $\mu_{ult}$, usable ultimate moment, would be about 700 kip-in. at a rotation $\theta_{ult}$ of about 24 milliradians, with an initial secant stiffness on the order of $110$ kip-in./milliradian at 4 milliradians ($\theta_{ser}$). Assuming A36 steel, an equivalent tensile stress of $15.2$ ksi or only about 40 percent $(15.2/36)$ efficiency of the material.

In contrast, a semi-rigid composite connection will have a $\mu_{ult}$ of about 2200 kip-in. at 24 milliradians, and an initial stiffness of 1200 kip-in./milliradian at 4 milliradians ($\theta_{ser}$). This results in about a 70% efficiency of the material, and in tests more than a 90% efficiency has been achieved at rotations of about 50 milliradians. Thus, the composite semi-rigid connection has an initial stiffness of almost 20 times that of the steel-alone connections, and a usable ultimate strength three times higher than for comparable amounts of connection steel.

While the gains in stiffness and strength will not always be this large, this example clearly points out the potential of the system.
structures with Type I connections, 27 fixed-base, three-bay frames having four, six and eight stories, story heights of 12', 14' and 16', and girder to column length ratios of 2:1, 2.25:1, and 2.5:1 were designed according to the LRFD Specification. Each frame configuration was analyzed with: (1) rigid connections; (2) semi-rigid connections; (3) semi-rigid composite connections and composite girders with varying moments of inertia. The frames were subjected to two load cases: (1) increasing both dead, live, and lateral loads proportionally until collapse occurred; and (2) increasing the lateral load only.

The composite frame design process was as follows: (1) design the frame as being rigid non-composite; (2) use the same column sizes; (3) replace the steel girders with steel girders capable of resisting the factored construction load case without yielding; (4) provide

**WHEN YOU BUY ST. LOUIS, YOU BUY AMERICAN!**

AND YOU GET: • FULL TRACEABILITY • LOT CONTROL • CERTIFICATIONS

Registered Head Markings on all structural and machine bolts:

- A-325 Type 1
- A-325 Type 3
- A-307-A
- A-307-B
- A-449

Products from 1/2"—3" diameter include:

- COUNTERSUNK
- SQUARE MACHINE
- BUTTON HEAD

**ST. LOUIS SCREW & BOLT COMPANY**

6900 N. Broadway • St. Louis, MO 63147

(314) 389-7500 • 1-800-237-7059 • Fax (314) 389-7510
enough shear connectors to the selected steel girders to have 100% composite action; and (5) replace the rigid connections by semi-rigid composite connections. This design method proved itself to be reliable for the vast majority of the three bay frames that were studied. Only composite frames having stories of 16' with aspect ratios smaller than 1:1 were unserviceable.

The composite semi-rigid connections and frames described here are not too different from what is being built today. The main differences are in the slab and shear stud detailing and, most importantly, in the recognition in the analysis phase of the actual behavior of the connections.

Roberto Leon, Ph.D., is a professor in the Department of Civil and Mineral Engineering at the University of Minnesota in Minneapolis.

Figure 5a.

Pictured above is another view of the full-scale, two-bay, one-story subassembly allowing the testing of a type of semi-rigid connection.

A Quick Quiz
For Structural Engineers

The more a computer program costs, the better it is.

A program that solves complex, difficult problems must be complex and difficult to use.

Structural engineering software can never be fun to use.

If you answered TRUE to any of the above, or you would like to know more about a truly innovative software program, call us!

RISA-2D

Your complete solution for frames, trusses, beams, shear walls and much more!

OMNITECH ASSOCIATES
P.O. BOX 7581
BERKELEY, CA 94707
(510) 658-8328
Unlocking The Inherent Stiffness Of Low-Rise Buildings

Industry standard shear connections provide restraint to columns and can be used as partial restraint connections in design.

---

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

Modern design specifications, such as the LRFD Specification, have created new opportunities for structural engineers to minimize steel frame costs. However, we can also learn lessons from the engineers of the past.

Before the development of advanced analysis and strict code requirements for lateral load design, most design engineers did not include lateral load analysis explicitly in their designs of low-rise buildings because they understood by experience that the inherent stiffness of the building frame was adequate to resist the small forces involved. Today, engineers tend to provide discrete lateral load resisting systems and ignore a large portion of the building in lateral load analysis. This separation of "gravity" and "lateral" systems results in a waste of material, labor and money.

By realizing that no connection is a pure pin and accounting for the inherent restraint in standard connections, the design engineer can "activate" the entire steel frame to resist lateral loads and produce a more efficient and economical steel frame for low-rise construction. Research has shown that typical shear connections provide restraint to columns and can be used as partial restraint (PR)
connections in design.

PR connections represent an area in which the structural designer may reduce the cost of a structure and decrease the construction time for the steel frame. The cost reduction is realized in several areas:

- elimination of field welded connections;
- elimination of column web stiffeners;
- reduction in foundation costs;
- reduction of frame erection schedule;
- elimination of field welding inspection;
- simplification of beam-column connections.

Further economy can be gained by accounting for restraint provided by PR connections in the design of floor systems. However, this article will concentrate on PR connections in lateral load resisting systems.

Successful Applications

Even with the challenges presented to the design engineer, it has been the experience of this engineering firm that the extra work required pays off in reduced building costs which keeps clients happy. One particular application which holds great potential is in the low-rise office market.

In most areas of the country where design wind speeds are in the 70 to 85 mph range, low rise office buildings (two to four floors) with a regular grid and a medium to large floor plan (20,000 to 40,000 sq. ft.) can be constructed without special lateral load resisting elements. By utilizing all columns in the building to resist lateral loads through PR connections, a designer can eliminate the need for any Full Restraint (FR or "Fixed") connected moment resistant frames with their requisite stiffeners and full penetration welding.

In our experience, the required increase in connection stiffness is small and can be accounted for with slightly thicker double angles and two to four additional bolts per beam-column connection. The resulting design will increase the size of columns due to the increase in K and the additional moments imparted to the columns.

By spreading the lateral overturning moments throughout the structure, there is a reduction in the total foundation costs as the whole weight of the building is used to resist the moments at the foundation level. Also, the fabrication and erection costs of the steel frame are reduced by the elimination of field welding and stiffeners. Because the lateral loads are distributed, deep beam elements on frame lines are eliminated, which could reduce the floor thickness and the building height, resulting in further cost savings. Finally, the elimination of field welding will reduce the inspection costs, the chance for errors, and the time required to erect the steel frame, which is vital in a competitive commercial office market.

Another area where our office has been successful in the application of PR connections is in the evaluation of older buildings. Many older buildings do not have the discrete lateral load resisting frames used today, but many have top and bottom flange angle connections that provide significant stiffness at the connection. If the inherent restraint of these connections can be accounted for in lateral load analysis, the designer may eliminate or reduce the need for additional bracing or other more intrusive strengthening elements.

Optimizing Stiffness

The behavior of structures utilizing PR connections under lateral loads is greatly affected by the connection restraint available in the connections.

Figure 1 shows various types of PR connections. The moment rotation curves for two types of PR connections are shown in Figure 2. The difference in the amount of continuity or restraint provided by the two connections is readily apparent. The structure using relatively stiff connections with both clip and web angle connections will drift less, have more end moments in the girders and lower K factors than a structure using relatively flexible web angle or standard shear connections.

This variation in behavior creates an opportunity for the designer to optimize the structure's resistance to lateral loads by providing only the restraint required. The designer can essentially "dial-a-stiffness" for the structure by varying the connection stiffness once the gravity load design is satisfied. For structures with longer clear spans, the designer may want to take advantage of the inherent stiffness of the floor frame with stiffer connections while a structure with light floor framing and more columns may call for connections providing less restraint.

Second Order Elastic Analysis With Factored Loads Required

Because PR connections are non-linear by nature, frames with PR connections must be analyzed under ultimate loading conditions to insure the stability of the structure. LRFD provides for this type of analysis. To predict the behavior of the structure at its true limit state, the analysis must include the non-linear moment rotation behavior for the connections specified through the range of possible factored loadings. Thus, the most practical method of analysis is to use a second order elastic analysis with the PR connections modeled as rotational springs with a known rotation curve.

Modern Steel Construction / October 1992 / 25
The General Accident Insurance (Nashville Branch Office) building was designed by structural engineer Stanley D. Lindsey and Associates using PR connection systems. Architect on the project was Robert Lamb Hart, Planners and Architects. Figures 3 and 4 show the simplified floor and roof framing for this project.

The moment magnifiers B1 and B2 contained in Chapter H of the LRFD Specification cannot model the reduction in stiffness that occurs as a PR connection approaches design loadings. The expressions for B1 and B2 were developed using connections with a constant stiffness, i.e. fixed or pinned, and should not be used when determining stability and design moments for lateral load resisting frames containing PR connections.

Since K factors are dependent on the restraint provided by the end connections and this restraint varies in PR connections, the second order elastic analysis must include a calculation of K for each load case based on the actual restraint provided by the connection at that loading. It is interesting to note that the K factor will vary not only with the lateral loads, but also with the amount of gravity load on the beams because the connection restraint is affected by the amount of moment at the end of the beams. In general, the K factors for columns will increase significantly due to the reduction in restraint at the beam-to-column joint.

**A Design Example**

The simplified floor and roof
framing for low-rise office building projects is shown in Figures 3 and 4 respectively. This project is located in Nashville and is subject to a design wind speed of 70 mph. The project contains approximately 40,000 sq. ft. on two levels with 30’ x 30’ typical bays. The floor system is a composite slab system with cellular deck designed to support a live load of 125 psf. The roof system consists of 1½” Type B metal roof deck, rigid insulation and a single-ply ballasted roof. The foundation system consists of shallow spread footings on a shot rock fill base.

Once the structural system was determined, the design of the structure developed in the following fashion:

1. Designed floor slab and beams for gravity loads;
2. Estimated column sizes for gravity loads with a K factor of 2.0;
3. Analyzed resulting frame with PR connections;
4. Increased connection stiffness as required to obtain desired drift and stability;
5. Checked member sizes and repeated steps 3 through 5 as required.

The resulting beam-column connections were double angle connections with no seat angles shown in Figure 5. The final double angle connections also are shown in Table 1 along with the connections which would be required to resist the factored shear force only. Comparison of the connections indicates that the increase in the connection material was small. Further, this increase occurred only at column connections, which reduced their impact on the total cost of the project.

Tables 2 through 4 show other properties of the structure determined during the structural analysis. Table 2 shows how the floor beam and girder moments varied from gravity to lateral load cases. The end moments are relatively small due to the somewhat flexible connections, and the lateral load case did not control the design. The comparison of frame drift in Table 3 indicates the large amount of drift that can be expected with PR connected frames when compared to FR connected frames.

From this example, it is apparent that the real economy in using PR frames is realized when more frame lines can be utilized to resist wind. Table 4 presents the K factors and column moments used to design the columns. The typical first floor column size for this project is a W10x54 GR50. If sized only for gravity loads with a K=1.0, the typical interior column would be W10x39 GR50. This appears to be a significant increase in steel weight; however, if typical frames were utilized, approximately half of these columns would increase to W12x65 GR50.

By using very flexible PR connections in this building, enough connection restraint was mobilized to resist lateral loads within serviceability requirements. Thus, the

---

**Table 1. Comparison Of Simple Shear To PR Connections**

<table>
<thead>
<tr>
<th>Floor</th>
<th>Shear Only</th>
<th>Angle Size</th>
<th>L</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>PR Connection</td>
<td>4&quot;x3½&quot;x⅛&quot;</td>
<td>16&quot;</td>
<td>5</td>
</tr>
<tr>
<td>Floor</td>
<td>Beams</td>
<td>4&quot;x3½&quot;x⅛&quot;</td>
<td>10&quot;</td>
<td>3</td>
</tr>
<tr>
<td>Floor</td>
<td>PR Connection</td>
<td>4&quot;x3½&quot;x⅛&quot;</td>
<td>15&quot;</td>
<td>5</td>
</tr>
<tr>
<td>Floor</td>
<td>Girders/Beams</td>
<td>4&quot;x3½&quot;x⅛&quot;</td>
<td>15&quot;</td>
<td>5</td>
</tr>
<tr>
<td>Floor</td>
<td>Shear Only</td>
<td>4&quot;x3½&quot;x⅛&quot;</td>
<td>10&quot;</td>
<td>3</td>
</tr>
<tr>
<td>Floor</td>
<td>Girders</td>
<td>4&quot;x3½&quot;x⅛&quot;</td>
<td>7&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Floor</td>
<td>PR Connection</td>
<td>4&quot;x3½&quot;x⅛&quot;</td>
<td>12&quot;</td>
<td>4</td>
</tr>
</tbody>
</table>

All bolts ¾” diameter A325 Bolts

**Table 2. Factored Floor Beam Moments**

<table>
<thead>
<tr>
<th>Negative Moments (K-Ft.)</th>
<th>Positive Moments (K-Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity Only W/Lateral</td>
<td>Gravity Only W/Lateral</td>
</tr>
<tr>
<td>Beams</td>
<td>Beams</td>
</tr>
<tr>
<td>W10x39 GR50</td>
<td>W10x39 GR50</td>
</tr>
<tr>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td>41</td>
<td>40</td>
</tr>
<tr>
<td>39</td>
<td>38</td>
</tr>
<tr>
<td>41</td>
<td>40</td>
</tr>
<tr>
<td>782</td>
<td>553</td>
</tr>
<tr>
<td>284</td>
<td>224</td>
</tr>
</tbody>
</table>

**Table 3. Comparison Of Frame Drift At Service Loads**

<table>
<thead>
<tr>
<th>Total Lateral Deflection (In.)</th>
<th>FR Connected Frame</th>
<th>PR Connected Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd Level</td>
<td>0.16</td>
<td>0.52</td>
</tr>
<tr>
<td>Roof</td>
<td>0.32</td>
<td>1.19</td>
</tr>
</tbody>
</table>

**Table 4. Strong Axis Column Factored Moments And K-Values**

<table>
<thead>
<tr>
<th>Column Type</th>
<th>Gravity Only Moment (K-Ft.)</th>
<th>K</th>
<th>Gravity W/Lateral Moment (K-Ft.)</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>External</td>
<td>16</td>
<td>2.16</td>
<td>45</td>
<td>2.10</td>
</tr>
<tr>
<td>Internal</td>
<td>3</td>
<td>1.81</td>
<td>56</td>
<td>1.70</td>
</tr>
</tbody>
</table>
lateral load resistance was provided with almost no increase in steel cost over a gravity load only design. In the final analysis, considerable savings were obtained and the steel frame cost almost 10 percent less using PR connections than with more traditional FR design.

**Barriers To Use**

In the design of a steel framed building, the inclusion of partial restraint connections may reduce the cost of the structure, but it also will increase the amount of work for the structural engineer. The PR connection is another variable that must be determined by analysis and then verified, designed, documented on the contract documents and inspected in the field. For this reason, many engineers do not take advantage of the economies of PR connections. It is much simpler to use a standard FR connection detail on the drawings; however, the increased cost may be the difference between a project being completed and one that is abandoned due to economic considerations.

Another barrier to the widespread use of partial restraint connections is the lack of access to moment rotation curves that are essential for the design process. To date, no industry wide organization has made the data on PR connection easily available to the design engineer. Without the available information, design engineers must take on the added burden of searching for available data from various sources. At this time, two of the best sources for a large database of moment-rotation curves for PR connections are available in the following publications:

- Kishi, N., and Chen, W.F., "Data Base of Steel Beam-to-Column Connections," Purdue University School of Engineering, 1986

These references contain valuable information concerning PR connection behavior, bibliographies for further reference, and experimental moment rotation curves for many different types of joints.

**Use In Practice**

When using a PR connected frame, the design engineer has to take extra steps to insure that the assumptions made in the design are realized in the field. This begins with the contract documents.

Each type of connection must be individually detailed, including angle sizes, thicknesses, and lengths, and it also is important to define the number of bolts, as well as the diameter, gauge, and pitch. Figure 5 provides an example of the connection details used on the project used in the example design. The location of each type of connection should be clearly marked on the plans and/or frame elevations. Finally, the engineer should include notes in the construction drawings as well as the specifications indicating the connections are not subject to redesign by the fabricator.

One main concern over the use of PR connected frames is that the in-place behavior of the connections will not match that shown in...
the laboratory due to construction tolerances and poor inspections. This is a valid concern. Improper fit-up, welding angles when bolt holes don't match, and insufficient tightening of bolts will greatly affect the connection behavior and cannot be allowed. Therefore, once the construction team is assembled, the engineer must stress the importance of the integrity of the connections, and must be involved in the construction review to insure that connections are correctly constructed.

Conclusions
In today's competitive construction environment where many projects do not reach groundbreaking because of budget constraints, an engineer must choose to use all of the available tools to reduce the steel frame cost of a building. The PR connection is a tool that allows the engineer to provide only the restraint needed by the frame, at a lower cost than regular FR connections. Many years ago engineers did not worry about lateral loads in the design of low-rise buildings because they knew, through years of experience, that the inherent stiffness of the frames were adequate. Now, our advanced analyses have begun to quantify this behavior so we can take advantage of it is modern steel design.

PR connections can be advantageous in some applications such as low rise buildings in low to moderate wind zones and during evaluation of existing buildings. However, the designer must respect the analysis required for a safe and serviceable design. The stability and drift of the frame must be verified under ultimate load conditions to insure an acceptable design. In addition, the designer must make special efforts to document the design and verify that it has been correctly executed in the field.

Kurt Swenson, P.E., PhD., is a senior design engineer with Stanley D. Lindsey and Associates, Ltd., a cutting edge structural engineering and design research firm headquartered in Atlanta.
Innovative Structure
For An Award-Winning
Airline Paint Facility

Though more attention has focused on this project’s innovative mechanical system, it’s structural system also is noteworthy

By Fred R. Schoenfeld, P.E.

When Delta Airline’s Aircraft Strip and Paint Hangar in Atlanta received an ACEC Honor Award for Engineering Excellence, the jury focused on its innovative mechanical system which can transfer over 950,000 cu. ft./minute of air through the 617,000 sq. ft. facility.

But while the advanced stripping/painting technology and complex mechanical systems of the hangar are well deserving of attention, the structural design of the facility also is due its share.

Mechanical Requirements

Eight different design concepts were analyzed by Rosser Fabrap’s architectural/engineering team and Delta, with the primary considerations being dictated by new environmental regulations, concern for employee health, and a desire for improved quality in painting and stripping operations. The final design divides the facility into 167,000 sq. ft. of aircraft bays arranged in an “L” shape and 450,000 sq. ft. of contiguous aircraft shops, specialty shops and storage areas arranged around the hangars on four floors.

Giant air handling units in the attic space of the hangar bays introduce fresh air from overhead into the bays. Air is returned near the floor at the side walls through paint arrestor dry type filters. Variable speed fan motors enable the
air flow to be adjusted for stripping (high volume) and for painting (low volume) in each of the three hangar bays. During the stripping operation, liquid stripper is applied to the aircraft body and the excess is captured in stainless steel collector troughs beneath the aircraft and disposed of as hazardous waste. Annual capacity for the $67.5 million facility exceeds 240 aircraft.

**Structural Considerations**

One of the design parameters that influenced the shape of the building and, as a result, the structural framing, was the sloping roof. Over the years, in its search for a leak-free, low-maintenance roofing system, Delta has settled on a site-rolled, continuous sheet, standing seam metal roof as its standard. But while the 1:12 slope of this roof reduces leaks and maintenance and provides an attractive aesthetic, it also presents a structural challenge.

The L-shaped arrangement of the hangar bays, combined with the direction of roof slope and the fact that the main trusses need to span from side-to-side in the bays, resulted in two different roof framing systems.

The largest hangar bay (Bay 10) has six trusses with double pitched top chords spanning parallel to the slope of the roof. These trusses all have the same depth, occur at 54' on center and have a clear span of 235'. The truss depth goes from 16'-8" to 27'-3½". The two smaller bays (Bays 11 and 12) have five trusses with flat top chords spanning normal to the slope of the roof. These trusses vary in depth, occur at 50' on center, and have clear spans of 150' and 180' respectively.

The truss spacings of 50' and 54' were developed both for economics and necessity. A value engineering study developed with input from AISC-members Steel Inc., the project’s fabricator, and Heaton Erecting, Inc., the project’s erector, concluded that larger truss spacings were more cost effective. And these larger spacings also were necessitated by the need to

The aircraft bays are designed to accommodate the wide variety of aircraft in the Delta fleet. Top photo by Jim Roof.
accommodate the huge air handling units that are located in the interstitial spaces between the top and bottom chords of the trusses.

One feature that makes this hangar different from most others is a metal panel ceiling below the bottom chords of the trusses. This ceiling separates the conditioned space around the planes from the interstitial space above. The requirement of providing support for the ceiling, support for the air handling units and service catwalks, as well as bottom chord bracing for the trusses all without many complicated connections resulted in a unique three-layered framing system at the bottom chords.

The lowest layer consists of bar joists with ceiling extensions, which support the metal panel ceiling from their bottom chords. To keep the joists shallow, they span 27' in Bay 10 and 30' in Bays 11 and 12. The joists bear on angle seats suspended below the main truss bottom chords in Bay 10 and the sway truss bottom chords in Bays 11 and 12. Additionally, in Bay 10 the joists bear on the bottom flange of W27 girders, which occur midway between the main trusses.

The intermediate layer consists of framing for the air handling units. By keeping spans short and the framing members shallow, this framing can pass above the bottom chord bracing. An exception to this is the W27 girders in Bay 10, which are a part of and contribute to all three layers. On the top layer, these girders support mechanical equipment framing flush with their top flanges.

Another feature of the hangar is the return air chases located immediately behind the metal panel walls of the hangar bays. These walls require girts and wind columns just like the exterior walls. In Bay 10, this lead to another interesting structural development. At main truss locations, two columns that occur on either side of a chase are tied together to form a vertical truss, which when joined to the horizontal truss that they support, create a trussed rigid bent. While the rigid frame action did not significantly help the horizontal span of the trusses, it did dramatically decrease lateral sway parallel to the trusses, which was very important in light of the lateral forces induced by the telescoping stacker cranes and the fact that Bay 10 was isolated from the rest of the structure by expansion joints.

The standing seam metal roof, while providing excellent protection against leaks in an unbroken field, does not work as well when it is penetrated. Therefore, to avoid penetrations, as well as giving the roof a clean, uncluttered look, all mechanical penetrations were limited to mechanical wells and vertical surfaces.

Shop Framing

While not as glamorous as the hangar bays, the shop framing deserves some mention. Floor-to-floor heights are 25' for the second floor and 20' for the third and fourth floors. The most typical bay size is 25'x40', with some 27'-6" x 40' and 30' x 40' bays. Design live load is 250 psf, but forklift traffic also had to be considered.

The slab consists of 5" of normal weight concrete on a 3" deep 18 gauge composite deck. Typical slab spans are 7'-6", 8'-4", and 9'-2". Slabs have continuous top and bottom reinforcement normal to the
Filler beams for crack control and to ensure continuing function even if loss of bond with the composite deck were to occur.

Filler beams, which span in the 40' direction, are designed as simple span composite beams, but sufficient reinforcing is provided in the top of the slab over the girders to handle full continuity under live load. Girders are designed as simple span composite members. A572 Grade 50 steel was used for both girders and filler beams after an economic study indicated it to be the most cost effective material. The project used a total of 8,500 tons of steel. General contractor on the project was Garrett-Patton Construction Co., Scottdale, GA.

Wind load design is based on an 80 mph basic wind velocity using provisions of ASCE 7. Except for the truss bents in Bay 10, lateral loads are resisted by X-type and chevron bracing, primarily at exterior walls. With so much gravity load leaning on the bracing, F-Delta effects were analyzed in the design of the bracing.

The building has a foundation of 16"-diameter augercast piles with 80 ton compressive capacity and reinforced for 20-ton uplift capacity at selected locations.

Tight Construction Schedule

As the result of a very aggressive completion schedule, the structural design of the hangar included consideration of ways to minimize construction delays. In order to facilitate field assembly of the hangar trusses and to keep field reaming of bolt holes to a minimum, truss connections were designed utilizing oversized holes, which meant the bolts had to be slip-critical.

All truss connections were made with 1"-diameter A490SC bolts using a Class A slip coefficient. Truss members received a shop coat of primer, and faying surfaces in connections were masked. Proper bolt tension was ensured through the use of snap-off bolts.

Because the heavy mechanical equipment in the interstitial space over the hangers had to go in after the truss bottom chord framing was complete, but before the roof framing was finished, some careful sequencing was required. This became doubly critical when it was decided to use the same cranes to set the equipment as were being used to erect the steel.

To facilitate the mechanical contractor's installation of equipment and ductwork, a rolling work platform was created that rested on the top chords of the ceiling support joists and moved from bay-to-bay as the work progressed.

Fred R. Schoenfeld, P.E., is a principal with Rosser Fabrap International, Atlanta, and a senior structural engineer in the firm's Aviation Group.

---

Modern Steel Construction / October 1992 / 33
Beneficial Procrastination

Delaying lead paint removal projects by upgrading the coating system can offer substantial benefits

By Eric S. Kline and William D. Corbett

During the past 50 years, millions of gallons of lead-based paint have been applied to structures throughout the world. Recent regulations, however, on the containment and disposal of lead-based paint debris have resulted in rapidly escalating costs for repainting structures. In fact, these costs have increased so much that on some projects, the facility owner can no longer afford repainting, which results in delayed maintenance and potential steel section loss due to inadequate corrosion protection.

Because of the complexity and costs of lead paint removal and disposal, considerable efforts are being made to find alternatives to total removal of lead-based paint and the postponement of coating work. One alternative is to upgrade the existing system with one of several generic coating types requiring little surface preparation. Choosing to "upgrade" the system may permit an owner to profit by "beneficial procrastination"—postponing the cost of coating removal without the possible consequences of corrosion damage affecting the integrity of the structure. This delay is designed to permit new technology to develop, which in turn should lower the costs associated with lead paint removal projects in the future.

Approaches To Upgrading

There are several techniques to achieve cost savings by system upgrading. These include: upgrading the coating system in more severely corrosive environments to reduce deterioration and to extend the service life; inspecting and repairing the coating system before extensive surface preparation is necessary; and partially removing the coating system in areas where total system removal is not required. For example, it may be as necessary to totally remove a peeling topcoat as it is to spot clean and prime isolated rusted areas.

The first approach, applying a better paint system on severely corroded areas, is not a new concept. The SSPC developed the environmental zone painting system in the early 1970s. Therefore, this article offers guidelines for the second and third approaches: inspecting and repairing a system before extensive surface preparation steps are necessary; and partial removal where total system replacement is not necessary.

Can The Existing System Be Upgraded?

Three conditions of the existing system are analyzed to determine if it can be upgraded. These include the extent of the corrosion on the structure, the total thickness of the existing coating system (including the number of coating layers), and the adhesion characteristics of the system.

To determine if a coating system can be upgraded, the coatings or corrosion engineer must first conduct a visual assessment of the amount of corrosion on the structure. SSPC-Vis 2, "Standard method of Evaluating Degree of Rusting on Painted Steel Surfaces" (also referenced as ASTM D-610), is a method commonly used to establish the amount of corrosion.

SSPC-Vis 2 uses photographic reference standards to illustrate the degree of rust on a numerical scale from 0 to 10. Note that the rust grade scale is in reverse order with a higher rating indicating less rust.

Regardless of the method employed to analyze the data, areas with 10 percent or more of the surface rusted would generally not be...
candidates for upgrading by topcoating, but rather would need extensive degrees of surface preparation, perhaps including total removal. Areas with less than three percent of the surface rusted, however, would be prime candidates for upgrading if the existing system is able to withstand the rigors of some minimal surface preparation and the contractive curing stresses and additional weight of the newly applied coating system, all of which can be determined with physical testing.

Physical Testing

Depending on the age of the structure, many different coating layers may be present, and these may vary both in thickness and generic type. The cohesive strength of the coating layers, as well as the adhesion of the coating film to the substrate, must be assessed before adding new layers and curing stresses to the existing film.

The total thickness of the existing system can be determined using a non-destructive dry film thickness gage (magnetic pull-off or magnetic flux). The Tookey Gage, a destructive film thickness gage, can be used to determine the number of layers and the thickness of each.

Perhaps one of the most critical evaluations in determining whether or not the existing system will support an additional layer is its adhesion. Coating adhesion is evaluated in accordance with ASTM D-3359 “Measuring Adhesion by Tape Test.”

The Decision Process

So when can a coating system be upgraded?

Typically, if the coating system exhibits less than 10 percent deterioration/corrosion, exhibits thicknesses in the 5- to 20-mil (125- to 600-micron) range, and has satisfactory adhesion, the engineer can be reasonably confident that the system is a candidate for applying an upgrade. However, even under these conditions test patches of the candidate system(s) should be applied before a commitment to upgrading is made on a wholesale basis on a large structure.

Alternatively, if the topcoat is peeling but layers beneath spot rust are intact (SSPC-SP2) or power (SSPC-SP3) tool cleaning may be used to prepare surfaces before upgrading.

If the coating is very thick (25-40 mils or more) and the system’s adhesion is poor to marginal, any decision to attempt recoating will necessitate the application of test patches.

Coating Selection

The selection of upgrade coating systems should focus on materials that have low shrinkage characteristics during curing and high solids content to minimize solvent penetration and softening of the underlying system.

Laboratory and six years of field testing have now been completed on the use of various high performance upgrading systems over back-to-back riveted angles removed from the steel bridge railing of the Ewing Park Bridge in Ellwood City (Pittsburgh), PA.

These angles contained a thick, lead-based alkyd coating (25-30 mils) that was brittle but otherwise mostly adherent. The angles were prepared using three different degrees of surface preparation: SSPC-SP10 (near white blast cleaning); SSPC-SP17 (brush-off blast cleaning); and SSPC-SP2 (hand tool cleaning) for the removal of obviously loose coating followed by blow-down using only compressed air.

These angles were then coated with five different coating systems:

- vinyl zinc-rich/high-build vinyl (7.5 mils);
- urethane zinc-rich/urethane topcoat (5 to 8 mils);
- zinc-aluminum-pigmented epoxy mastic/vinyl topcoat (7 to 9 mils);
- two-coat epoxy mastic (10 to 16 mils);
- two coats of an aluminum-epoxy-urethane-mastic (10 mils).

The laboratory exposure consisted of approximately 500 hours of accelerated weathering. Field exposure consisted of placing duplicate angles for each of the surface preparation/coating system variable beneath a leaking expansion dam on the Carson Street Bridge ramp in Pittsburgh. The panels were then examined by the authors visually in accordance with SSPC-Vis 2. Although the initial condition of the old alkyd presents an uncontrolled variable for panels cleaned according to SP7 and SP2 with blow down, the data suggest the following:

- All five systems performed well over surfaces prepared in accordance with SSPC-SP10. Slight evidence of underfilm corrosion (less than 1 percent rusted), perhaps due to the presence of residual chlorides from the initial field exposure, was noted on some systems with surfaces coated with the thin film systems (less than 10 mils total thickness). All of the areas cleaned in accordance with SSPC-SP10 performed better than those cleaned to SSPC-SP7 or SSPC-SP2 with blowdown.
It was apparent that areas prepared using only air blow-down performed as well or better than areas that had been Brush-Off blast-cleaned. This result was unexpected, and may be attributable to a fracturing and weakening of the old alkyd due to the impact of the abrasive.

On the blow-down and Brush-Off blast-cleaned areas, the thicker film systems performed better than the thin film systems. When the epoxy mastic or urethane mastic was used, minor defects were noted on the blow-down and Brush-Off blast-cleaned surfaces; however, the overall performance approached that of the SSPC-SP10 surface.

Other Case Studies

Additional evidence of the viability of system upgrading is found in data that a major chemical company has developed from two major bridges across the Monongahela River in the Pittsburgh area. Surface preparation involved spot cleaning of rusted areas in accordance with SSPC-SP6, followed by a complete brush-off blast in accordance with SSPC-SP7. In each of these cases, the vast majority of the old alkyd was allowed to remain on the steel surface. The coating system used on these two structures consisted of an aluminum-filled, moisture-cured urethane spot primer; a full intermediate coat of aluminum-filled, moisture-cured urethane; and a polyester-aliphatic-polyurethane topcoat.

After 13 years exposure, both bridges are in good condition and exhibit little corrosion and virtually no signs of coating disbondment with the old alkyd system.

On other projects, a 100 percent solids penetrating epoxy sealer has been used. One project, the Swinburne Bridge in the Pittsburgh area, was coated using this system in 1989. The existing coating system was a lead-based paint, greater than 30 mils thick, exhibiting cracking and marginal adhesion. The existing system was Brush-Off Blast-Cleaned (SSPC-SP2) to removed loose, old paint. After Brush-Off Blast Cleaning, hundreds of thousands of coating islands remained. In addition to the 100 percent solids penetrating epoxy primer that was applied, an epoxy intermediate and urethane topcoat also were applied. After three years, the coating remains intact and adherent, and no spontaneous disbonding within the old coating layers is occurring, even in areas abraded by the impact of gravel or stones.

Conclusions

The overall advantage of upgrading the existing system is reduced maintenance costs now; with the hope that the coating system life will be extended. In addition, our study suggests that simply coating over the old system after removing obviously loose paint by hand tool methods (SSPC-SP2) may be an effective approach. Total lead paint removal may cost as much as $5 to $10 per sq. ft. It becomes apparent that minimal surface preparation, followed by upgrading with one or more of the materials discussed, would provide substantial cost savings by reducing coating costs to approximately $2 per sq. ft.

However, it must be recognized that each project is unique. The physical characteristics of the existing system must be carefully evaluated to determine whether it is a candidate for upgrading.

This article is condensed from an article appearing in the March 1992 issue of the Journal of Protective Coatings & Linings and was reprinted with permission. Eric Kline is a senior coatings consultant with KTA-Tator, Inc., and is the SSPC representative to the Council for the Advancement of Steel Bridge Technology. William Corbett is marketing manager at KTA-Tator.
Working together, AISC and CNA help keep losses under control to keep your premiums down.

The AISC business insurance program offers you a very important benefit: A loss control program that not only helps keep premiums down, but also is available at no extra cost. Only the close working relationship between the CNA Insurance Companies and AISC makes this possible.

By listening to your association, we understand the risks of the structural steel fabricating business. As a result, the CNA Insurance Companies can offer you a loss control program that may help reduce injuries and may ultimately reduce premiums. We are proud to say this program has been endorsed with the AISC "Seal of Approval."

Take advantage of this comprehensive insurance program designed especially for and endorsed by AISC. Call 1-800-CNA-6241.
New Coating Systems
For Bridges

The pending obsolescence of higher volatile organic content (VOC) coatings has resulted in the rapid expansion of the protective coating market in the 1980s and the introduction of many new state-of-the-art formulations.

By Tom Calzone

Most everyone involved with new bridge construction coating projects has seen changes in the nature of products they apply and specifications for coating work. Generally, polymer technology used for VOC compliant coatings formulations has resulted in improved performance. And along with this you get different application properties that affect the way steel is painted in the shop.

But in addition to the changes in formulation, the variety of products and systems has increased several fold since 1980. (Currently specified, new construction, shop-applied bridge coating systems are described in Table 1.) Multi-coat shop systems, cleanliness requirements, materials costs and inspection scrutiny have dramatically increased the cost of shop coating. Now more than ever, fabricators must get a handle on their coating related costs.

VOC compliant formulations of the common generic types are accomplished in two ways. Via water based technology or by increasing the solids content. In most cases both approaches require formulation of entirely new products to replace noncompliant technology.

Inorganic zinc remains the predominant shop construction primer. The reasons for its growing popularity as a shop primer through the 1970s make it the product of choice today even with the advent of many new options. Among the benefits of inorganic zinc:

• Unsurpassed corrosion resistance.
• Inorganic zinc primed steel can be handled quickly with minimal damage in the shop, in transporting and erecting.
• Undercutting corrosion from damage points, abraded edges or holidays is virtually nonexistent.

Inorganic zins are considered to be permanent primers and expected to last for the design life of the structure. Remedial maintenance of topcoats may be necessary over that period but should not entail blast removal.

• Traditional formulations can weather for years in the yard or at the erection site with no special preparation prior to topcoating.
• Inorganic zins are compatible with a variety of finish coats.
• They achieve Class B friction ratings according to the “Specification for Structural Joints using ASTM A325 or A490 bolts.” This high friction value remains during long weathering periods prior to erection and fastening.

The traditional inorganic zinc

Table 1:

<table>
<thead>
<tr>
<th>System Specified For Shop Application</th>
<th>VOC Compliance</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic zinc, solvent based</td>
<td>Compliant and noncompliant</td>
<td>Predominant system</td>
</tr>
<tr>
<td>Inorganic zinc, water based</td>
<td>Compliant</td>
<td>Zero VOC content</td>
</tr>
<tr>
<td>Inorganic zinc / high build urethane</td>
<td>Compliant and noncompliant</td>
<td></td>
</tr>
<tr>
<td>Inorganic zinc / epoxy / urethane</td>
<td>Compliant and noncompliant</td>
<td></td>
</tr>
<tr>
<td>Inorganic zinc / vinyl</td>
<td>Noncompliant</td>
<td>Vins cannot comply</td>
</tr>
<tr>
<td>Epoxy zinc rich / epoxy / urethane</td>
<td>Compliant and noncompliant</td>
<td></td>
</tr>
<tr>
<td>Epoxy mastic / epoxy mastic / urethane</td>
<td>Compliant</td>
<td></td>
</tr>
<tr>
<td>Alkyds - 2 or more coats</td>
<td>Compliant</td>
<td></td>
</tr>
<tr>
<td>Acrylic latex - 3 or 4 coats</td>
<td>Compliant</td>
<td>Mostly used as zinc topcoats</td>
</tr>
<tr>
<td>Epoxy zinc rich - 2 coats</td>
<td>Noncompliant</td>
<td>One state</td>
</tr>
</tbody>
</table>
formulations do not comply with solvent emissions (VOC) regulations in many states and therefore fabricators are applying VOC compliant inorganic zinics. However, compliant formulations cost more than their noncompliant predecessors.

There are two methods to formulate VOC compliant inorganic zinics: high solids-solvent based and water-based. Both approaches result in inorganic silicate binders holding zinc particles on the steel. Each formulation will behave differently in application than the classic solvent based zinc.

**High Solids Solvent Based Inorganic Zinc**

Naturally, each manufacturers' high solids formulation is different. There are some commonalities, however, that affect application. A painter using traditional techniques will tend to build extra coating thickness with the high solids products. Resistance to mudcracking (a function of thickness) varies between manufacturers, however, with all products thicker films mean more consumption. For the most part the high solids, solvent based materials will behave in familiar fashion.

**Water Based Inorganic Zinc**

While water-based inorganic zinics are not new, they had seen little if any use as bridge primers prior to the restrictions imposed by VOC legislation. Water based inorganic zinics have significantly different application requirements and curing properties. While the solvent based inorganic zinics require atmospheric moisture to cure, the water based products rely on evaporation of moisture from the coating to proceed with the curing reaction. Water based inorganic zinics contain no co-solvents and will dry at the rate of water evaporation. This rate may vary greatly with temperature and relative humidity. The solvent-borne materials contain co-solvents of varying evaporation rates and may be thinned with fast or slow solvents as needed. This provides for a more consistent application throughout a wide climate range. These differences are readily apparent to the painter.

The fabricator must approach surface preparation and cleanliness differently with water-based inorganic zinics. These primers require a jagged profile as produced by a steel shot/grit blast mixture. This presents a lot of surface area for adhesion. Reduced adhesion will occur on flame hardened edges due to their resistance to blast profiling.

Some fabricators will perform an additional blast on these surfaces to promote adhesion. Also, traces of oil contamination will prevent adhesion. Oil and water don't mix. A trace of oil which would have no effect on solvent based products prevents water borne inorganic zinc from effectively wetting out the steel and adhering. Solvent wiping blasted steel will only spread the affected area. Steel must be thoroughly degreased prior to entering the blast cabinet so that it comes out with no traces of contamination and does not contaminate the abrasive. After blasting, the steel must be primed immediately or protected from contamination from adjacent painting and other sources of organic contamination (Salamander heaters, hand prints, etc.).

Table 2 shows the similarities and differences between traditional inorganic zinics and low VOC formulations.

The low VOC formulations of other shop coatings types also differ from their predecessors. These

<table>
<thead>
<tr>
<th>Table 2: Traditional Inorganic Zinc Vs. Low VOC Formulations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VOC Content</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
</tr>
<tr>
<td><strong>Mudcracking resistance</strong></td>
</tr>
<tr>
<td><strong>Surface preparation</strong></td>
</tr>
<tr>
<td><strong>Application</strong></td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
</tr>
<tr>
<td><strong>Humidity</strong></td>
</tr>
<tr>
<td><strong>Topcoat time</strong></td>
</tr>
<tr>
<td><strong>Hardness</strong></td>
</tr>
<tr>
<td><strong>Topcoat compatibility</strong></td>
</tr>
<tr>
<td><strong>Friction</strong></td>
</tr>
<tr>
<td><strong>Salting</strong></td>
</tr>
</tbody>
</table>

**Note 1:** At low humidities, dry spray tendency increases dramatically. High humidity may retard cure, effect adhesion and early rain resistance.

**Note 2:** Low humidity applications will lengthen cure time.
differences are summarized.

**Epoxy Primers And Intermediate/finish Coats**

New resin technologies have enabled manufacturers to comply with VOC regulations while improving chemical resistance, corrosion resistance and adhesion. The cost of new products (on a square foot basis) is the same or slightly higher than old technology.

The newer, high solids formulations are made with lower molecular weight resins more easily reduced to a sprayable consistency. However, pot life is reduced and drying is slowed. Fortunately, recoating of low VOC epoxies may occur earlier, since in some products a “wet-on-wet” second coat is acceptable due to a reduced tendency to trap solvent.

Again, with the newer coatings the painters natural habits will result in thicker films. Some adjustment will be necessary to realize economy from the solids content. It is very important that the thinner used be matched to the solvents and resins in the product. The lower solvent content in the material leaves less room for marginally compatible thinners and following manufacturers recommended thinning practices is crucial.

**Polyurethanes**

Aliphatic polyurethanes are being specified more frequently for shop applications. The primary purpose of the urethanes is gloss and color retention. The performance of various VOC compliant formulations varies greatly and may be better or worse than earlier products used. Note also that there is a wide spread in cost between the VOC compliant products, and invariably they cost more than the old products.

High solids formulations are more difficult to apply in a car-like finish. Reduced solvent levels effect levelling and flow properties and can result in more of an “orange peel” appearance in the surface. This can be particularly evident in high gloss products.

Again, as with other high solids types, painters must adjust for the improved coverage rates to keep material consumption down.

**Acrylic Latexes**

Several states are specifying acrylic latex products for their VOC new construction coatings, and several others are considering the move. House paint is typically an acrylic latex and considerable research has been done to improve weathering and color stability in latex resins for this huge market. Industrial formulations provide excellent adhesion, and corrosion protection as well.

The most common use of acrylic latex bridge coatings is for topcoating inorganic zinc, e.g. on Alabama, Florida and Virginia specifications. Acrylic latex formulations are compatible with a number of primers including epoxy zinc rich, epoxy mastics and even old lead bearing oil alkyd coatings.

Acrylics are significantly different from other coatings. The rheology, or appearance in the can, looks thick and fluffy. The unfamiliar painter will be inclined to thin the material (with water). This may not be necessary because the thick appearing latexes are often sprayable as is, perhaps with some equipment modifications. A small amount of water can go a long way thinning latex products and too much can ruin the film-forming and curing properties.

Acrylic latex will become tough and have excellent adhesion. Unfortunately their adhesion and damage resistance develops more slowly than most solvent based products. High humidity will retard the cure by slowing water evaporation. Cold temperatures, 45°F being about the coldest allowable, do not substantially increase the dry to touch time but will greatly extend the full cure period. Acrylic latex has a lower tolerance of thick films. Applications of five or even four mils dry film thickness can cause the coatings to dry from the outside-in. The impermeable surface skin that forms will then crack as it shrinks with water and co-solvent trapped within the material. Special care is needed around fillets and stiffeners to avoid heavy build.

**Summary**

There are two approaches to VOC compliant coatings, via water based or high solids, solvent based technologies. The differences between familiar materials and new VOC compliant formulations are summarized:

**High Solids Coatings**

- Reduced working time from old formulations (pot life)
- Longer cure time (relative to pot life)
- Fast film build
- Less slickness in finish. Tendency to show “orange peel”
- Quicker recoatability, often “wet-on-wet”
- Thinning procedure is more critical

**Water-Based Coatings**

- Provide a long working time (pot life)
- Rheology differences may effect equipment used
- Prone to cracking at excess thickness
- Cure time in high humidity is extended

As always there are growing pains in assimilating new technology. These can be overcome with relatively small investments in equipment and training. Your coating supplier is trying to formulate user friendly products within the limits of the raw materials. Rely on your coating supplier to help with these new products. The manufacturer can reduce your routine headaches and costs and perhaps prevent a catastrophe from occurring. The supplier can also familiarize your inspector to the differences with the new technology, and as a team, put out a quality product of reasonable cost while complying with environmental mandates.

Tom Calzone is Highway Market Manager for Carboline. This article is adapted from a paper presented at the 1992 National Steel Construction Conference.
Corrosion Resistance

A high performance, single-component urethane coating from Wasser High-Tech Coatings eliminates most application restrictions for temperature, humidity and dew point. The company's coatings will cure as quickly as four hours in temperatures down to 15 degrees F, can be applied in humidities of 6 to 99 percent, and can be wetted or immersed after as little as 20 minutes after application. The coatings offer superior corrosion resistance and can be used to encapsulate red lead. They have been specified by more than a dozen state DOTs as well as more than 10 major utilities.

For more information, contact: Wasser High-Tech Coatings at (800) MC-PAYNT.

Cold Galvanizing

Zinc. Cold Galvanizing Compound stops rust and rust creepage on ferrous and nonferrous metal surfaces.

For more information, contact: ZRC Products Co., 21 Newport Ave., Quincy, MA 02171-9975 (617) 773-1180; fax (617) 328-5304.

Fast-Curing Epoxies

Tnemec Co. has introduced Series 160 Tneme-Fasprime and Series 161 Tneme-Fascure. These fast-curing, high-performance coatings can be handled in two hours and recoated in three, making them ideal for shop applications. Tneme-Fasprime is a rust-inhibitive primer for steel where extra corrosion resistance is needed.

For more information, contact: Tnemec Co., Inc., P.O. box 411749, Kansas City, MO 64141-1749 (816) 483-3400; fax (816) 483-1251.

Environmentally Conscious Coatings

Southern Coatings, a subsidiary of Pratt & Lambert, Inc., is a leader in providing environmentally conscious primers and topcoats for the steel fabricator and joist manufacturer. The Enviro-Guard line offers lead- and chromate-free primers and coatings offering superior protection against rust and corrosion.

Complete information on Enviro-Guard VOC compliant primes, as well as Chemtec 606 Water Base Epoxy Zinc Rich Primer, Chemtec 608 Inorganic Zinc Rich Primer and Dura-Pox 646 Epoxy Mastic High Build system, is available by contacting: Southern Coatings, Inc., P.O. Box 160, Sumter, SC 29151 (800) 766-7070; fax (803) 254-4833.

Rust Overcoating

PRE-PRIME 167 from Devoe Coatings is a rust penetrating sealer designed to wet, strengthen and seal porous rust. The product is a 100 percent solids, two-component epoxy. This thin coating wets and wicks its way through rust.

For more information, contact: Devoe Coatings Co., 4000 Dupont Circle, P.O. Box 7600, Louisville, KY 40207 (502) 897-9861.

Low VOCs

Available from Glidden and ICI Paints is Lifemaster Pro, a waterborne acrylic enamel with a low-level of VOCs. The coating is ideal for both structural steel and metal siding.

For more information, contact: Glidden Industrial Coatings, 801 Canterbury Road, Westlake, OH 44145 (216) 892-5341.

Coating Thickness Measure

A new range of Coating Thickness Gauges has been introduced by Elcometer Instruments Ltd. The Elcometer 345 is pocket-sized, yet offers a number of advanced features, including an angled screen with backlighting, so that even in the darkest corners these instruments can be easily read. Options include the entry of limits for tolerance checking and the ability to average readings. Also, one model offers memory for up to 10,000 readings.

For more information, contact: Elcometer Inc., 1893 Rochester Industrial Dr., Rochester Hills, MI 48309 (800) 521-0635; fax (313) 650-0500.

Steel Maintenance

Carbosmatic 15 Low Odor from Carboline is recommended for the maintenance painting of rusty steel or for upgrading old coatings on steel bridges, metal buildings, and exposed structural steel. Only a single coat is required for most applications and hand or power tool cleaning often is acceptable. The product has excellent immersion resistance to both salt and fresh water and resists acid, alkali and solvent spillage.

Carbo Zinc 11 is used as a single coat protection of steel structures in weathering exposure and as a base coat for organic and inorganic topcoats in more severe services. The self-curing, inorganic base coat protects steel galvanically, eliminating sub-film corrosion.

For more information, contact: Carboline, Technical Service Department, 350 Hanley Industrial Circle Ct., St. Louis, MO 63144-1599 (314) 644-1000; fax (314) 644-6883.

Technical Information

The Technical Information Packet Service (TIP) from the Journal of Protective Coatings & Linings provides a collection of photocopied information previously published in the magazine. A typical TIP runs 50 to 100 pages. Subjects include: Achieving VOC Compliance; Cleaning and Painting; Weathering Steel; Lead Paint Removal; Generic Coating Types and Their Uses; Coating Economics; and total Shop Painting. The base cost is $5 + $0.20 per page. Customized TIPS also are available.

For more information, contact: TIPS, (800) 837-8303.
Steel Marketplace

Two Great Opportunities

Steel Inspection News
This bi-monthly newsletter keeps you informed on quality and inspection issues for steel framed structures. Specifications, codes, quality criteria, inspection and industry practices are discussed in a direct and practical manner for the inspector, engineer, fabricator, erector, contractor and code official.

For more information, contact Bill Dave at:
40012 Village Oaks, Novi, MI 48375 phone: (313) 544-2810 fax: (313) 544-2811

Steel Structures Technology Center, Inc.

Steel Buildings: Special Inspection
This one-day seminar, now being conducted across the country, covers the inspection of steel, bolts, welds, joints, deck and shear studs to meet code-required special inspection requirements. Geared for both inspectors and engineers. Call for dates and locations.

Help Wanted—Chief Estimator
Rapidly growing Southeast structural steel fabricator seeking highly experienced estimator with a minimum of fifteen (15) years experience working with major steel fabricator to head estimating department. Top salary.
Send resume to:
Sales Manager
P.O. Box 940038
Maitland, FL 32794-0038

HELP WANTED—STEEL FABRICATOR
Well-established, (29 years), medium-size structural/miscellaneous fabricator recruiting experienced personnel for all departments. Located near Kennedy Space Center in Florida.
No phone contact please.
Mail resume to: Industrial Steel, Inc.
P.O. Box 346
Mims, Florida 32754-0346

Help Wanted—Senior Estimator Position
Versatile Structural Steel Fabrication Facility located in Tigard, Oregon, is seeking an experienced Senior Estimator with a minimum of six years experience in take-off, laboring and complete job costing. Computer experience is a plus! We offer a competitive salary and broad-based benefit program.
Please submit your resume with references to:
P.O. Box 23759
Tigard, OR 97281

ELITE BEAM COPING MACHINE
The CM-2044/3 Beam Profile Cutting Machine is the economical alternative to much higher priced CNC machinery with the advantage of 90's technology. With over 80 machines sold in 17 countries worldwide, and a price below $40,000.00, this machine not only produces all your end operations, but also can be used in place of a saw for cut-to-length operations.
For further information, shop-layout and Consulting, contact:
ELITE EQUIPMENT INC.
P.O. Box 5417, Tustin, CA 92681
Tel: 714/569-1050 Fax: 714/569-1009

CLASSIFIED ADS
Reach 35,000 engineers, fabricators, architects, contractors, bridge officials and building owners inexpensively with a classified advertisement in Modern Steel Construction. It's fast and easy—we'll even do the typsetting for you at no charge.
For rate and placement information, call:
Marci Lynn Costantino or Greg Poland at (705) 679-1100.
Or fax them a note at (705) 679-5926.

Free Software Catalog
For Structural Steel Detailers & Fabricators
Quality - Affordable - PC Software
Steel Detailing with or w/out a CAD interface, 10 integrated calculator programs designed for detailers & checkers, job estimates, bills of materials, length cutting lists, shipping lists & nesting, residential and light commercial structural design, analysis of continuous beams (steel, wood or concrete), finite element analysis, project management, accounting
NES, Inc., P.O. Box 2014, El Segundo, CA 90245
800-637-1677 (phone) - 310-546-7158 (fax)

BDS STEEL DETAILERS
Having trouble finding good detailers? Ask our overseas clients what they thing of us!
"They have submitted prices consistently which are economic and have aided us to obtain a substantial share of the market!"
"They are used to working with companies at a fair distance away from their home (BDS) base."
For complete steel detailing, contact:
BDS Steel Detailers
8925 Folsom Blvd., Suite T
Sacramento, CA 95826
916/368-1666  214/541-1065

Advertiser's Index
AISC Free Design Guide Offer.................................17
Nicholas J. Bouras ..............................................CII
ITW Buildex .......................................................15
CNA Insurance ....................................................37
Chaparral Steel ....................................................5
Chief Industries ...................................................29
Computers & Structures, Inc. ............................CIV
Design Data .........................................................11
EJE Industries ......................................................12
Jobber III .........................................................20
Magni .............................................................33
Omnitech .........................................................23
RISA .............................................................23
Research Engineers ............................................7
St. Louis Screw & Bolt .......................................22
Southern Coatings .............................................13
Steel Solutions ...................................................12
Steelcad International .........................................21
Structural Analysis, Inc. .................................29
Structural Software .............................................5
Wasser Hi-Tech ..................................................CIII
Let Wasser Solve Your Bridge-Coating Blues.

PAINT IN INCLEMENT WEATHER

ASTORIA BRIDGE, Oregon Coast. Only Wasser MC-Coatings can be applied in these conditions and still yield corrosion resistance superior to all other high-performance coatings.

ENCAPSULATE RED LEAD

PUYALLUP RIVER BRIDGE, Tacoma, WA. Amazingly painted at night (Oct.-Dec.) in the wet Pacific Northwest climate, this bridge is still a showpiece of lead encapsulation.

TOUCH-UP AND REPAIR

AISEA BAY BRIDGE, Oregon Coast. Wasser's MC-Coatings are used to repair or complete dozens of projects stopped or delayed because of field problems with inorganic zinc (including NASA) and plural component epoxy and urethane coatings.

BEST CORROSION RESISTANCE

PUYALLUP RIVER BRIDGE, Tacoma, WA. Amazingly painted at night (Oct.-Dec.) in the wet Pacific Northwest climate, this bridge is still a showpiece of lead encapsulation.

Only Wasser Has All These Advantages.

1. Industry's BEST Corrosion Resistance.
2. Single Component
3. No Application Restrictions for Humidity, Dewpoint, or Temperature (20° F)
4. Micaceous Iron Oxide
5. Industry's First Urethane Mastic (Solves Epoxy Mastic Problems)

CALL TOLL FREE
800 MC-PAYNT

WASSER
HIGH-TECH COATINGS

CALL TOLL FREE
800 MC-PAYNT

Circle 311 on Reader Service Card.
STATE OF THE ART

STRUCTURAL STEEL DESIGN
SOFTWARE

STRUCTURAL ENGINEERING • EARTHQUAKE ENGINEERING
AISC ASD '89 • AISC LRFD '86 • UBC '91

INTEGRATED ANALYSIS & DESIGN SOFTWARE
FOR STEEL STRUCTURES

By: Ashraf Habibullah & Edward L. Wilson

For more information:
Computers & Structures, Inc.
1995 University Avenue
Berkeley, California 94704
TEL: (510)845-2177
FAX: (510)845-4096

ETABS is a registered trademark of CSI.
SAP90 is a trademark of CSI.