STEEL CONSTRUCTION PROCESS STUDY

Study funded by:

American Institute of Steel Construction
One East Wacker Drive, Suite 3100
Chicago, IL 60601-2001

Submitted by:

David I. Ruby, P.E., S.E.
Ruby & Associates, P.C.
30445 Northwestern Highway, Suite 310
Farmington Hills, MI 48334-3102

April 16, 2004

EXECUTIVE SUMMARY

The purpose of this study was to identify areas within the steel industry construction process that have the potential for process modifications resulting in increased productivity or quality improvement. The areas identified for further study, evaluation or research are those that have the potential to impact productivity or quality and may be implemented within the next five years.

Six areas have been identified as having the potential for significant process improvement within the steel industry. Each of these areas will require additional investigation, study or research to fully develop and implement. The areas are as follows:

- Construction Process Integration
- Industry Standards
- Material/Piece-mark Tracking
- Welding Advances
- Tolerances – Acceptable Variations
- Coatings

Present day design models contain most of the information necessary for a fabricator/erector to prepare an accurate and competitive proposal. The options presently being generated by AISC CIS/2 interface have introduced the concept of information sharing to the design industry. Recent advancements in Building Information Modeling (BIM) technology provide a potential vehicle for total process integration. AISC should establish of a task group consisting of fabricators, erectors, detailers, and structural engineers (representing SEI, NCSEA and CASE) to explore BIM technology and its possible implementation. This task group would be charged with the responsibility to explore the interface process, prepare essential requirements, develop a means to utilize BIM as a process which will allow the steel industry to utilize technology for the benefit of the ultimate consumer, the owner.

The AISC is able to bridge the gap between members of the construction community to develop industry standards for the steel construction industry. The removal of repetition and redundancy in the connection design process, collaboration on uniform graphic standards and incorporation of BIM technology in the CIS/2 interface would allow the steel construction process to realize quality improvement and process efficiencies necessary to compete in the global economy.

Material tracking has also been identified as an area needing process improvements. The AISC has been instrumental in working to create a bar code standard for the computerized tracking of steel from the mill to the jobsite. Since survey responses indicated that as many as 2 or 3 man-hours per ton are spent in looking for material at the job site, it is recommended that this program be expanded to include piece-mark tracking for field operations.

The fabrication and erection processes were reviewed considering the impact of computer detailing and fabrication technology as well as the advancements in welding processes and controls. In addition, through visits to several allied industries, it became clear that process improvement revolved around the same four items; 1.) Limited material variations, 2.) Automated welding processes, 3.) Extensive use of jigs and fixtures, and 4.) Standardization. These specific aspects of the fabrication/erection processes were considered to be essential for quality improvement and cost reduction.

While the fabricators are comfortable with the current tolerances specified in ASTM A6, the greater construction community feels differently. Structural steel variations are costly to the contractor and the owner. Steel fabricators need to realize their comfort with the current state directly impacts the image of the steel industry and jeopardizes the future of steel as the material of choice. The full benefit of industry advancements cannot be realized until tolerances are addressed.

Cost benefits may be realized with an in-depth review of the painting and coatings segment of the steel industry. While there are several obstacles to implementing, pre-primed structural shapes may prove to be an economical part of the fabrication process.

Through our review of the steel construction industry, we identified several areas where there may be considerable benefit to the industry provided additional resources are applied toward implementation. These items may not come to full fruition in the next five years; however, we believe that these areas will increase productivity and should be given consideration for their long-term benefits.

- Global Standards
- System Design vs. Component Design
- Continuing Education of the Design Profession
- Development of Design Guides
- Increased Funding for Research
- Body of Knowledge
- Industry Collaboration
- Alternative Connections

This report contains detailed descriptions of the immediate impact areas and the long-term areas as well as information on the entire scope of the review.

ACKNOWLEDGEMENTS

The author wishes to thank Tom Schlafly and Duane Miller for constant encouragement and technical input and Brian Volpe, P.E. and Jamie Fox, P.E. for their countless hours of research without which this study would never have been completed.

In addition, this study would have been incomplete without the valuable input from the following companies:

- Caterpillar Tractor
- Colasanti Construction
- Douglas Steel
- Interstate Steel
- Alberici Constructors – Hillsdale Fabricators
- Lincoln Electric Company
- Midwest Steel
- Peterson Beckner
- Steel Dynamics
- Steel Service Corporation
- Turner Construction
- Vulcraft
- University of Arizona – Dr. Robert Fleischman
- Lejeune Steel

TABLE OF CONTENTS

INTRODUCTION

PROBLEM STATEMENT

Production processes, measurement techniques and equipment have significantly improved over the past 30 years. Technological innovations have been utilized to create more efficient processes in allied industries, such as shipbuilding and heavy equipment manufacturing. However, the structural steel fabrication industry has been reluctant to implement such changes. Even though there have been significant advancements in the manufacturing process, the acceptable variations allowed by ASTM A6 and AISC "Code of Standard Practice" have not been changed or modified to reflect these innovations.

Over the past several decades, manufacturers, through the use of technology, have made great strides in improving quality, reducing rework and cutting cycle time. These improvements were required to stay competitive in a global economy. The U.S. steel fabrication industry faces a similar challenge to remain competitive with the ever-increasing number of foreign fabricators entering the domestic market.

Automated fabrication is commonplace in allied industries. Welding processes augmented by computer controlled power supplies produce quality welds in less time. Reduced variations in material tolerances and the implementation of technology have resulted in improved quality along with significant savings.

For the steel construction industry, can similar technological improvements be integrated into the process to create a more efficient process?

STUDY OBJECTIVE

The objective of this study is to conduct a preliminary survey of the steel construction process and identify areas with the potential for process modifications resulting in increased productivity or quality improvement. The improvements could result in increased productivity, lower costs, higher quality, or more effectiveness. The immediate charge is to identify areas for further study, evaluation and/or research for implementation within the next five years. Additional areas where implementation may be many years down the road will be noted, however the focus of the study is on the short-term.

INVESTIGATION PROGRAM

Our investigation covered the entire steel construction industry, from design to installation. We began with tolerances and design standards. The fabrication and erection processes were reviewed considering the impact of computer detailing and fabrication technology as well as the advancements in welding processes and controls.

A document review entailed looking at publications, research reports, articles and websites to evaluate where the industry stood in comparison to the rest of the world in our process and material tolerances.

Interviews were conducted with parties that spanned the spectrum of the industry, starting with the producers and going through fabricators, erectors and general contractors. These discussions gave tremendous insight and data for the current status of the industry. Many of the questions asked in the interviews were answered with more questions that broadened the scope and depth of the investigation.

Existing software was reviewed to see how it could integrate with current technology. A main focus was whether or not the products available today fully utilize the available technology to increase efficiency or productivity. The ability to communicate with other programs and its compatibility with the 3-D process and the CIS/2 standard was also important.

Allied industries were investigated to determine where their process improvements recently made could be beneficial to the steel construction industry. Some of the efficiencies realized by equipment manufacturers in the fabrication process apply to the steel construction industry.

The domestic steel construction process was compared to the overseas competition. Advances in technology are used in different degrees in other parts of the world. Other countries have significant differences in the overall process. These differences were reviewed to determine if there was anything to learn from the competition.

The key areas identified as short-term for productivity and quality improvements should be evaluated by the industry and the AISC with the intent that further research will produce a methodology for application. These applications will provide the opportunity for process improvements to maintain steel as the material of choice in the future.

SHORT-TERM AREAS FOR PRODUCTIVITY AND QUALITY IMPROVEMENTS

CONSTRUCTION PROCESS INTEGRATION

The structural steel construction industry has been successful in the past through the melding of experience and knowledge with advancements in technology. Rivets gave way to H. S. bolts, weldments replaced castings and computer-aided drafting has become the norm. However, the construction process remains very fragmented. Professional structural engineers design structures with sophisticated software, fabricators utilize the computer to assist in making take-offs and developing costs, the sales department uses a spreadsheet for final pricing, the detailer models the structure for shop and erection drawing preparation, the shop combines manual and computer-aided tasks to fabricate the product, while the field forces continue to work from paper erection drawings and hand written shippers.

In the process outlined above, Designers, Fabricators and Erectors act independently to develop their understanding of the project. In doing so, each individual continues to recreate project knowledge for his own use without establishing a retrievable project knowledge base. Such redundant and inefficient practices negatively affect project quality, labor requirements and schedule thus increasing the total cost of construction. Manufacturers have eliminated these redundancies and enhanced process control by partnering with their suppliers and using enabling technology. Manufacturers view their process as a whole, beginning with the raw materials through the finish product. Viewing the construction process as a manufacturing process is a paradigm shift that would aid the steel construction industry. We should look at the process as a manufacturing process that would be enhanced by process control, reduced duplication and a common objective.

A Stanford University study released in 2000 demonstrated that there are significant redundancies and bottlenecks in the steel construction industry. This study was based on a small change to a floor opening in a steel framed building. The delays were tracked through the normal construction process and then compared to the possible scenario using electronic data exchange through CIS/2. A small change that could have been conveyed electronically in minutes ended up resulting in a total delay of 40 days due to the time it took to communicate the change through the issuing of a revision (architect to engineer, engineer to architect and general contractor, general contractor to steel contractor) and the obligatory resubmittal of shop drawings. The additional cost was estimated at $55,000 due to modified connections in the field and the delay impact on the project (Fischer, 2000). This was a small scale study but one that sheds light on the big picture. Utilizing technology, seamless exchange of information on a real time basis will result in process improvements and significant savings. In short, integration is the key!

It is possible today to integrate the design/construction process through the utilization of Building Information Modeling (BIM)* technology. Such technology would allow for the total integration of the steel construction process. The current CAD model used in the design of a building is not an intelligent model. BIM technology actually maintains and models data representing the entire building. The BIM technology may be able to be expanded to include the information necessary to integrate the fabrication and erection process. The use of BIM technology would increase efficiency by reducing tedious tasks, allowing users to share information efficiently with all associated parties, aligning the information so that all parties are aware of all progress or changes, and cutting down on errors in the process. A single model would be used from the initial concept through completion of the project. Tasks that are repetitive in today's design and fabrication process would soon be eliminated; thus reducing man-hours and improving reliability. The full utilization of BIM technology would enhance the design, fabrication and erection process and would allow structural steel to continue to be the material of choice.

One example of integrated manufacturing success is in the design and manufacture of the Boeing 777. The 777 was 100% digitally designed and preassembled on the computer. By using this system, Boeing was able to detect over 10,000 part interferences in the initial modeling. The data from the system was shared among

* BIM Technology is presently available from Bentley Systems, Inc's Microstation and Autodesk, Inc's Revit

suppliers so that parts could be manufactured to exacting standards. When those 2 million parts, built all over the world, were assembled in Seattle, they fit perfectly the first time. Not only did this integration help in the manufacture of the aircraft, but in the design as well, including a 90% reduction in engineering change requests, a 50% reduction in cycle time for engineer change requests and a 90% reduction in material rework. (Intelligent Manufacturing 1996).

Two recent high-profile projects in Chicago demonstrated what can be done with a minimum amount of process integration. The construction schedule for the reconstruction of Soldier Field was reduced by four to six months primarily due to the ability of all to utilize the shared 3-D model. Following award the structural engineer and the steel fabricator agreed to share the 3-D model in order to provide a single point of reference for all communications. While the process was not without some problems, the benefits of integrating design and fabrication through utilization of a 3-D model became very evident (ENR, Post, 4/14/03). The Millennium Park amphitheater project also realized a significant reduction in the number of requests for information by conducting net meetings, where each party could view and discuss the 3-D model in real time from their own office (ENR, Post, 2/9/04). These meetings kept the shop drawing phase from becoming the critical path for the project. Due to the complexity of the Millennium Park structure, which exists only because of 3-D modeling technology, completion of the project in a 2-D environment would not have been feasible.

Caterpillar utilizes available technology to improve its manufacturing process. The FASIP (Fabrication of Advanced Structures using Intelligent and Synergistic Material Processing) program, developed by Battelle in Columbus, Ohio, is used to predict weld heat input and control plate distortion during production. This control enables Caterpillar to produce a final product with minimal variations. Control of material and fit-up tolerances allows extensive automation in the assembly and manufacturing process. Individual plates are fabricated with installation tabs, holes and scribed lines to assist with proper fit-up, allowing direct assembly of material. Significant production savings have been achieved through limiting material variations, reducing handling time and automating the welding process. Caterpillar estimates that 35 to 40 percent of all welding procedures are fully automated.

The opportunity for coordination and cooperation is only possible when all parties have a shared vision of the project. Teamwork is essential in ensuring a successful project; however, all team members must be confident that their ideas and intellectual property will remain well-maintained and secure and that neither will be compromised in the process of collaboration. A common BIM model would allow open discussion and reduce the time spent waiting for responses. Through this process all parties involved would have a mutual understanding of the changes in real time.

The benefits of integration through technology have been successfully demonstrated by numerous industries. The next step for the structural steel industry is two-fold. 1.) Internal - Review present fabrication and installation practices and develop a means to integrate the manufacturing process. 2.) External - Form a task group with practicing structural engineers to study 3-D modeling practice and options for usage during the bid and subsequent construction stages. There should be consideration of BIM technology as the next step for the construction industry through a paradigm shift in basic business practice; i.e., total integration of the construction industry for the 21st Century.

INDUSTRY STANDARDS

The steel construction industry should create industry standards for use by designers, as well as fabricators, in order to promote economy and efficiency within the steel construction industry. Using standards would reduce design, detailing, fabrication and erection costs. Detailed graphic standards would assure uniform shop and field documents, in both appearance and content. Industry standards would allow the industry to focus on important matters within the construction process and not on the routine and repetitive tasks inherent in each project. An AISC task group is in the process of developing industry standards. It is recommended that this process be expanded as discussed below.

Standard Connections

Standard connections were used in the past by American Bridge and Bethlehem Steel and they served the construction community well; however, over the past 30 years the industry has slowly drifted away from this practice. The current wide variety of shear connections and the associated approval process has created connection design costs and an approval process that is essentially not required.

AISC standards are required to economize the design and construction process. Having a standard set of connection details for use throughout the industry will simplify connections, improve the design process and reduce overall costs. Standards should be available for double angles for both welded and bolted conditions, for single angles, and for shear tabs using an array of bolt sizes. This library of standards would serve all types of connections.

Presently, the typical shear connections and their supporting calculations are recycled and resubmitted for approval each time. Having a standard connection set would eliminate or minimize the connection design and approval process. Shop drawings could be produced earlier in the process and the type of connections would be known prior to commencing the project. Computer generated detailing programs could be programmed to follow these standards. In summary, standards will simplify the process and reduce the cost of connection design, approval, fabrication and erection.

Detailed Graphic Standards

Detailed graphic standards would provide a valuable guide for the development of design and shop detailing software. The shop detailing software that is presently available is powerful and versatile, but it has been developed outside the industry without a guide or standard. Today's computer generated details often lack differentiation in line type and necessary checking information and dimensions. Some fabricators that have been interviewed expressed that they will not allow certain detailing programs to be used on their projects due to the visual quality of the output and its consequences on the shop floor. Illegible drawings or incomplete information have lead to errors, and errors cost money and affect the bottom line. In order to effectively use the software, shop procedures must be altered, individual shop drawings reviewed for clarity, piece marks corrected and erection plans manually modified. An industry graphic standard would establish an acceptable guideline for shop erection drawing presentation and preparation. This graphic standard would control the appearance of the details, including the size of text, line weight, piece mark protocol, skewed dimensions and bevels and shop bill requirements, just to name a few. An AISC developed detailed graphic standard would provide the guidance necessary for the shop detailing program developers to provide a more consistent product and thus serve their fabricator customer base more efficiently.

Standard 3-D Models

The use of 3-D modeling within the industry could be simplified with the development of a standard format for the appearance and content. With the immense amount of information that is contained in the model and the number of team members who must access the model, some uniformity of presentation is required. The present CIS/2 protocol, which allows for communication between several design and detailing software packages, is a start. However, standardization of the modeling process would allow for an error-free communication between the various software packages and increase the power and accessibility of the 3-D model. This standardization does not mean that individual software companies need to stop being innovative and creative, but would keep the basics the same.

The AISC brings together members of the construction community to develop industry standards for the steel construction industry. The removal of repetition and redundancy in the connection design process, collaborating on uniform graphic standards and incorporating BIM technology in the CIS/2 interface would allow the steel construction process to realize quality improvement and process efficiencies necessary to compete in the global economy.

MATERIAL/PIECEMARK TRACKING

The National Institute of Standards and Technology (NIST) research related to automated steel erection still lies much further down the road. The use of robots to automate the steel construction industry may be a reality in the future but in the meantime, the use of electronic tracking technology would provide the steel industry with the tools to enhance the field operations.

Material tracking is an area where process improvements are possible and in some cases absolutely necessary. Currently many fabricators track items internally, but once the piece leaves the shop, identification looses its effectiveness. Keeping track of material from the time it is produced until it is installed at the jobsite would increase the efficiency of the industry.

Steel is identified as it is produced. Mill producers identify material with a mark that is applied at regular intervals. This is normally a stencil noting the size and the heat number. Each bundle of material is labeled with a bar code that can then be tracked to the mill certifications. Based on discussions with steel producers, bar coding steel as it is produced is possible, however it involves stopping the production line. Since producers are not willing to stop the production line to mark the bar code onto the material, a system must be developed that will allow individual members to be bar coded during production, if it is going to happen at the mill. The bar code by the bundle may be acceptable if steel service centers and fabricators who receive the bundles from the mill are able to bar code the material at their facilities.

The AISC has been instrumental in working to create a bar code standard for the computerized tracking of steel from the mill to the jobsite. In association with the Metals Service Center Institute and Technical Committee on Structural Shapes, they have formed a committee to provide for more cost effective and automated ways to ship and receive material. Computers will be able to track material, how it was sent and when it was received. This would greatly improve material tracking during shipping and receiving at the mills, service centers and fabricators. Prior to shipment, the mill would notify the receiver as to exactly what material was shipping and when the material would be delivered. The focus of the industry committee is presently addressing receiving operations in order to create shipping efficiencies (Marti, 2003). This program should be expanded to include piece-mark tracking for field operations.

Such an extension of the piece-mark tracking for field purposes could prove to be a more efficient process. Recent discussions with erectors have indicated that as many as 2 or 3 man-hours per ton are spent in looking for material at the job site. Reducing this cost to essentially the price of a simple scanner should provide immediate benefits. Having the computer model include the erection sequence and/ or procedure would simplify field operations. Daily printouts following the erection sequence, shipping schedule and material locations would increase the effectiveness of the field operation. Remote job sites would be able to communicate with the central office and share erection information electronically. All of this could be tracked in real time.

The initial drawback will be the costs associated with implementation. Extensive training for the field personnel and the cost of the technology may be too great to realize cost-effective improvements in the process. Further review can quantify the magnitude of the associated costs and determine the effectiveness of wide spread computerized jobsite tracking.

There would be substantial benefit to computerized material tracking from the mill to the job site. The work already underway by the AISC committee for shipping and receiving bar coding and the potential to use this in erection as well, make this a very attractive opportunity for additional research into its economies.

WELDING ADVANCES

The technological advances in welding should be continually reviewed by the steel construction industry. While robotic welding in the field may be years off, the use of robots in the shop could be a reality today. Advances in welding equipment and robotic technology can change the way today's fabrication shop operates.

Robotics provide extensive automation opportunities. Welding robots that have been used widespread in manufacturing processes have started to become practical in steel fabrication. The Japanese fabricating industry has been using automation for many years. Several of the larger fabricators here in the U.S. have been using programmable robotic welding equipment for some time. Programmable robots can replace those processes that require significant manual hours. Robots equipped with laser sensors and touch probes can determine their position and perform quality welded joints with efficiency. This may be especially useful in the heavy girder fabrication segment where stiffeners may be welded automatically with little human input. There are likely other repetitive tasks such as welding beam clip angles and column base plates that could be performed by robotic equipment. The versatility of the modern welding robot has a place in the future of the U. S. steel fabrication industry.

New welding equipment has the capability to deposit weld faster and with less hear input. Through the use of multiple wire electrodes and improved power control technology, welding can be performed with increased efficiency and effectiveness. Today's computer controlled electrical power sources allow high quality welds to be performed more consistently and in less time.

Advances in welding can reduce the number of hours required in fabrication. With rising material and labor costs, automation makes sense. When welded joints can be completed twice as fast with new technology, shop and/or field labor would be reduced. Whether the welds are done manually or with automation, the equipment available today can do the job more effectively than the welding equipment of old. Man-hours saved in the shop reduce costs and deliverable time, which are important aspects to efficient and effective fabrication operations.

Cutting edge welding technology makes welding an attractive method of joining members. Modern welding provides a better joint than in the past. Improved power supply technology allows for higher deposition rates and better control of weld quality. Full control of the current is now available to create a smooth, more stable arc with consistent penetration and deposition. Technology exists today that allows welding operations to be controlled to provide consistently high-quality results.

The initial costs of new technology welding equipment will require fabricators to evaluate their present operations. The efficiencies of purchasing new equipment must be weighed against the inefficiencies that it will replace. The new technology may not be the right fit for every fabricator but there will be many who will be able to use the new products to increase the productivity of their operation.

The potential benefits to the steel industry from improved welding technology and practices are great. The welding industry has embraced technology and has developed products that will greatly reduce the fabrication time and also provide a high quality weld. With the focus on economy and reducing costs, welding and its recent advances will allow the U. S. steel construction industry to benefit immediately.

TOLERANCES – ACCEPTABLE VARIATIONS

The accepted variation from the specified norm is what we know as *tolerance*.

The mill tolerances as prescribed by ASTM A6 have been the guide to acceptability for mill product for some time. These acceptable variations that govern sweep, camber, out-of-square, over thickness, off-center web and flange rotation were developed by U. S. Steel and Bethlehem Steel in the early 1950's. Structural steel erectors have installed the fabricated product and have continually provided a final facility within the standards of acceptance as outlined in the "Code of Standard Practice" . However, even within the prescribed tolerances anchor rods are miss-located, column grids are in disarray, bearing surfaces are out-of-level and columns are out-of- plumb.

In the past thirty years, process controls and computer technology have made dramatic in-roads in the industrial and manufacturing processes across the world. In the same time frame, the steel fabrication industry has attempted to improve its processes while utilizing material supplied to ASTM A6. The structural steel industry has introduced new technology to improve the fabrication process through the use of material handling, beamlines, cold saws, semi-automatic and automatic welding, CNC equipment and others. It is common knowledge that process improvement is a function of input as well as output. Therefore, as long as the input is governed by acceptable variations as prescribed in ASTM A6, the output improvements will be limited.

The interviews within the steel construction industry have revealed a reluctance for reducing the acceptable variation on mill material, fabricated structural steel or final erected tolerances. The industry is satisfied with the product as presently furnished. The steel industry consensus opinion is that reducing tolerances would increase the cost of structural steel without any guarantee of a reduction of costs or improved quality for the remaining construction community.

The greater construction community has a different view. Structural steel variations are costly to the contractor and the owner. Automated and robotic welding processes require a more uniform material in size and shape; therefore, if the steel industry is to fully utilize the advances in welding and automation, the acceptable shape variations must be significantly reduced.

If the steel construction industry believes that they have achieved the optimum product, then investing in variation enhancement would be a waste of time and money. However, if they believe that they have only scratched the surface in technology and automation, then they must invest in further study in this area.

COATINGS

Cost benefits may be realized with an in-depth review of the painting and coatings segment of the steel industry. The primary product received from the structural steel mills is unpainted structural shapes. The fabricators must clean and paint the material prior to sending it to the jobsite. European countries use painting systems far more advanced than those in the United States, which include pre-primed material.

Cleaned and pre-primed material presently exists in the hollow structural shapes (HSS) segment of the industry. Copperweld is the only producer who presently utilizes this technology in the United States. The trade name is KLEENKOTE®. They have the exclusive license to the technology in the United States. The steel is mechanically cleaned and degreased in-line, and the pre-primer is electrostatic ally applied.

Many equipment manufacturers have realized significant cost benefits through increased productivity and reduced costs due to pre-primed HSS material. The tube material arrives ready for fabrication and the coating does not impact the welding process. Copperweld reports that an independent study of several customers showed cost savings of as much as $112 per ton (Copperweld). This savings is significant for the HSS industry and could be potentially viable for structural steel as well.

One of the major challenges facing mill-primed steel is applying the coatings in-line. Unlike hollow structural shapes, which are cold-formed, structural steel is hot-rolled. The temperature during production may be as high as 1800°F. This temperature is too high for paint application. However, later in the rolling process when the temperature is much less, application of the paint may be ideal. Paint will adhere and dry much faster when heat is present. Heat is already present in the process and this could be advantageous to making the process cost-effective. The process required for making pre-primed structural steel a reality is worth an in-depth look by the industry.

Another major obstacle is the mindset of the steel industry. While reducing the costs at the fabrication shop, the cost of the material from the mill would increase. Presently, the industry does not see the advantages in increasing the up-front cost of the material to save costs in the fabrication process. There are structural steel fabricators who have spent time researching whether pre-primed wide flange material could be of benefit to their individual operations. So far, it appears that none has deemed it worthwhile. Meanwhile, steel producers are not rushing to produce painted material because there is no demand from the consumer base. Producers that were interviewed had not given much thought to painting material at the mill but would readily jump at the opportunity if it would prove to be economical.

Before pre-primed material can be integrated into the steel industry, there are issues that must be addressed. The formation of mill scale in the steel rolling process is a major obstacle. The compatibility of pre-primer with some of today's specialty and epoxy paints is a potential concern. Research into whether special paints or fireproofing will work with this system is necessary. There are quite a few issues to be reviewed in making pre-primed material a quality improvement tool for the steel construction industry.

Pre-primed structural shapes may prove to be an economical part of the fabrication process. If the industry would look at the issue as a whole rather than as individuals looking for a competitive advantage, pre-primed material may become an efficient cost-effective process that would benefit the entire industry. It is recommended that pre-primed structural steel be considered for further study.

LONG-TERM AREAS FOR PRODUCTIVITY AND QUALITY IMPROVEMENTS

These items, which were identified during the study, are offered here in no particular order.

GLOBAL STANDARDS

It is only a matter of time until a global industry standard will be developed. The AISC, in concert with ISO, should take the lead in the development of relevant global industry standards. Past discussions with Canada and Mexico to explore such options may not have been as effective as hoped but this should not be a deterrent. Global standards will likely not be a major requirement in the next few years but in time, globalization will be a reality.

SYSTEM DESIGN VS. COMPONENT DESIGN

The steel construction is directly impacted by the capability of the design team, which in-turn is a direct reflection on the quality of the final design. The education of professionals and the design process as a whole must be reviewed. The primary structural design is often developed from basic architectural concepts without addressing finish, exterior treatments, building use, etc. All aspects of the facility must to be taken into account. The structure must be viewed as a system, not as components. Too often, steel designers will focus only on the design of the steel, while the total facility suffers. The foundations, the exterior fascia, the roof, means of egress and life safety are all important considerations in the design of a facility. In addition, the structural system must be defined and properly integrated; such activities will positively impact the final constructed product. AISC should expand its educational offering in building systems to practicing professional organizations.

CONTINUING EDUCATION OF DESIGN PROFESSION

Many engineers do not possess an adequate knowledge for the design of constructible steel facilities and those few who have the hands-on knowledge are leaving the industry. Practicing engineers must be educated on the many aspects of steel fabrication and constructibility so they may understand the consequences of their decisions. This is not a call for advanced degrees; it is a call for the education of the practicing structural engineer on the fundamentals of constructing with structural steel. AISC should initiate a task group with practicing structural engineers and fabricators for the purpose of developing a continuing education program directed towards all aspects of fabrication and constructibility.

DEVELOPMENT OF DESIGN GUIDES

The industry would benefit from the development of additional design guides by industry experts. Many engineers simply do not understand key areas of critical issues when designing. Our discussion with Vulcraft steel joist engineers uncovered that the improper specification of joists by the engineer of record creates a substantial cost. A joist design guide could be developed with input from the Steel Joist Institute that would help the design industry properly communicate the required needs to the joist manufacturer. Other areas where design guides could be very beneficial are:

- Building Systems
    - Mid-rise
        - Slab-Girder
        - Staggered Truss
        - PR Framing
    - High-rise
        - Braced
        - Tube
        - Bundled Tube
        - Moment Frames

    - Braced frames
  - Long spans
  - Lateral load systems

- Roof and Floor Systems
- Cable Structures
- Post-Tensioned Steel
- Truss and Beam Reinforcement
- Heavy Long-Span Truss Concepts, Details & Connections
- Steel-Concrete Interface and Connections
- Composite Systems
- Blast Resistant Construction

These design guides could be developed in the upcoming decade for the benefit of the industry. There are likely other topics for design guides. Recent design guides for steel-framed open-decked parking structures and high strength bolts both serve to provide insight in areas where the design industry requires additional direction.

INCREASED FUNDING FOR RESEARCH

Today in Japan, a percentage of the construction costs of all building projects is retained for construction research and testing. The same desire for advanced research must be evident here in the U.S. With technology advancing so rapidly and the rest of the world trying to break into our domestic market, further research spending on new technologies and concepts is required to keep pace. Finding how to fund additional research will be a critical task of the AISC in the upcoming years.

INDUSTRY COLLABORATION

The domestic steel industry must learn to work together in order to continue to be competitive in the 21st century. Foreign competition is present on projects throughout the U. S. New technology that can help the industry prosper must be shared within AISC to allow domestic steel fabricators to be competitive in the global economy. Keeping the status quo method will result in a downturn for the domestic industry and allow additional foreign competition. Continuation and expansion of the AISC Roundtable to encourage joint industry activities and research is required and the ongoing efforts by the AISC to foster this collaboration will assist in maintaining a strong and vibrant industry. However, an AISC fabricator task force must be organized to address the issues of collaboration and technology sharing in order to better arm the industry.

BODY OF KNOWLEDGE

The days of the regional fabricator are disappearing. Fabricators from Mississippi and Montreal are actively bidding projects in Chicago and Miami, against fabricators from Japan and Korea. The members of the American steel construction industry must leverage their knowledge base, continue to support steel related research and embrace technology development to create a strong, cost effective national industry that can compete on a global scale and thus allow its members to provide the quality of service to which the nation has been accustomed. The Body of Knowledge that veterans of the drawing board era can offer must be captured and put to work in design and construction industry. These efficiencies and truths learned over time must to be made available to the next generation of the steel industry. AISC is in the best position to assemble and disseminate this knowledge before it is too late. Individuals, such as, Omar Blodgett, Bill Milek, Art Arndt, Dave McQuaid, Bob Freeland and Farnam Garrard could add significantly to the Body of Knowledge. In addition, legends, such as Yura, Galambos, Fisher, and others could provide a resource for future research and advanced planning. Preserving this Body of Knowledge is essential so the American fabrication industry can continue to be competitive in the world market.

ALTERNATIVE CONNECTIONS

The steel industry must continue to direct research efforts towards developing more effective alternate connections. If technology exists to create alternate methods of connecting that may reduce the amount of time required to erect a structure, or make erection safer, it must be pursued. (Work performed at Lehigh University in the 1990's on steel castings and automated construction to replace conventional connections and construction as we know it today has not made significant strides toward reality.) Recent research at the University of Arizona has focused on developing modular connections for seismic resistant steel moment frames through the use of castings. With seismic design spreading throughout the country due to recent code changes, such connections may be useful to the entire industry.

The use of steel castings in non-seismic applications has become more prevalent in Europe. Several U.S. fabricators have replicated castings by fabricating weldments which are subsequently milled to the proper formation. New technology in the casting industry may, again, make the use of castings a suitable alternative in the near future.

Recent earthquakes have provided the impetus for Seismic Analysis Code (SAC) and industry funding for seismic connection testing. Further research may find that castings have their place in the construction of steel buildings. In addition, other new, innovative connections will continue to be developed through industry-funded research.

CONCLUSION

The steel construction industry has been slow to embrace technology and reluctant to change its old habits. Generally, the industry has used technology to mechanize manual tasks. Engineering and estimating departments use CAD in lieu manual drafting, computer-generated summaries in place of manual take-offs, and spreadsheets instead of the calculator. A few fabrication shops are using CIS/2 data transfer, CNC equipment and beamlines with material handling tables. Automated welding is primarily used for large girder fabrication, while semi-automatic welding use has increased due to its portability. However, minimal integration of the steel construction process has taken place. The industry as a whole has not attempted to adopt and integrate the information, design and manufacturing technology that is available today and therefore is unable to reap the benefits attributed to such advances. The remainder of the world began several years ago; they embraced new technology. Unencumbered by old habits, they funded research in new methodology and they were fueled by a desire to succeed in the world economy. Our industry must meet the world challenge in order to remain a vital, functioning contributor to the U. S. and world economies. Technology, and those that embrace it, will be the force that drives the future success of the construction industry. The structural steel industry and its members must develop the means and methods to integrate technology and fabrication within the next ten years in order to move the U. S. steel industry into the 21st century.

WORKS CITED

Boykin, Danielle. "Building Information Modeling: The Next Stage in CAD?" NSPE Engineering Times, Volume 26 Number 3, March 2004.

Copperweld. "KLEENKOTE® Cleaned and Pre-Primed Structural and Mechanical Tubing." Brochure, <http://www.copperweld.com>.

Fischer, Martin and Khanzode, Atul. "Potential Savings from Standardized Electronic Information Exchange: A Case Study for the Steel Structure of a Medical Office Building." Technical Report #121, Center for Integrated Facility Engineering, Stanford University, July 2000.

Intelligent Manufacturing, Volume 2 Number 12, December 1996.

Marti, Chris. "Scanning Steel." Modern Steel Construction, AISC, January 2003, p. 40.

Post, Nadine M. "Chicago Team Struggles To Impose Order on Chaos." Engineering News-Record, McGraw Hill, February 9, 2004.

Post, Nadine M. "Stadium Engineer Drives Toward 'Paperless' Project." Engineering News-Record, McGraw Hill, April 14, 2003.

WORKS CONSULTED

Argiris, Leo, et al. "Steel Goes Global." Modern Steel Construction December 2003.

Bergsma, Gus, Michael El Markovitz, and Steven E. Hamburg. "Strucutral Steel Software: Building the Future".

Bernstein, Harvey M. "Measuring Productivity: An Industry Challenge." Civil Engineering December 2003.

"Code of Standard Practice for Steel Buildings and Bridges." American Institute of Steel Construction, Inc. 07 March 2002.

"Cost of Steelwork From Feasibility Through to Completion." Steel Construction – Journal of the Australian Steel Institute Vol. 30, Number 2 June 1996.

Eckmann, David, et al. "On the Horizon." Modern Steel Construction January 2003

Garvin, Edward E., and Beth S. Pollak. "3 Schools + 2 Years =." Modern Steel Construction October 2003.

"Information Technology in the Australian Steel Construction Industry." Steel Construction – Journal of the Australian Steel Institute Vol. 33, Number 2 June 1999.

Jeffords, Larry W. "Conventional Steel Construction vs. Pre-engineered." 1997 NSCC Proceedings AISC.

Khanzode, Atul R, and Martin Fisher. "Potential Savings from Standardized Electronic Information Exchange: A Case Study for the Steel Structure of a Medical Office Building." Center For Integrated Facility Engineering Stanford University July 2000.

Kunz, John, et al. "Integrated & Automated Project Processes in Civil Engineering: Experiences of the Center for Integrated Facility Engineering at Stanford University." Center For Integrated Facility Engineering Stanford University February 2002.

Melnick, Scott L. "Engineers and Fabricators Turn to EDI for Cost Savings." Structure December/January 2001.

Marti, Chris. "Scanning Steel." Modern Steel Construction January 2003.

Muller, Joann "How to Build A Mountain." Forbes 05 February 2004.

"An Overview of Recent Research in Steel Structures in Australia." Steel Construction – Journal of the Australian Steel Institute Vol. 35, Number 4 December 2001.

Post, Nadine M. "Chicago Team Struggles to Impose Order on Chaos" Engineering News Record 09 February 2004.

Post, Nadine M. "Houston Stadium is Open and Shut Case." Engineering News Record 01 July 2002.

Post, Nadine M. "Movie of Job that Defies Description IS Worth More Than A Million Words." Engineering News Record 08 April 2002.

Post, Nadine M. "Seattle's Eccentric 'Book Behemoth' Shatters Stereotypes." Engineering News Record 03 November 2003.

Post, Nadine M. "Stadium Engineer Drives Toward 'Paperless' Project." Engineering News Record 14 April 2003.

Post, Nadine M. "Steel Sector Plans Paradigm Shift." Engineering News Record 14 April 2003.

Post, Nadine M. "To Help Save Time, Structural Engineer Wears Harder Hat." Engineering News Record 02 February 2004.

Rees-Evans, D. "'W' Shape Dimension Nomenclature." Tolerance Study AISC C.O.S. Meeting 16 November 2001.

Roe, Andrew. "Building digitally Provides Schedule, Cost Efficiencies." Engineering News Record 25 February 2002.

Roe, Andrew. "Cleveland Gets A Case of Gehry's Totally Unreserved." Engineering News Record 27 May 2002.

Sawyer, Tom. "Industry Firms Cash In on the Value of Their Expertise." Engineering News Record 13 August 2001.

"Scenario Planning for the Australian Steel Construction Industry." Steel Construction – Journal of the Australian Steel Institute Vol. 36, Number 1 March 2002.

Schwegler, Dr. Ben, Martin Fischer, and Kathleen Liston, Ph.D. "New Information Technology Tools Enable Productivity Improvements." 2000 NASCC Proceedings AISC.

Stroud, Roger G. "Electronic Data Interchange Liability Issues." 1998 NSCC Proceedings AISC.

"Structural steel Part 1: Hot-rolled bars and sections." Australian/New Zealand Standard.

"Updating Standard Shape Material Properties Database for Design and Reliability (k-Area 4)." American Institute of Steel Construction, Inc. 04 December 2001.

APPENDIX A TOLERANCE STUDY

Rolling Tolerances – Comparison of U.S., European, Japanese and Australian Standards

Pertinent Standards

U.S.
ASTM A6

Germany

DIN EN 10 024 (1995)	Taper Flange I-Sections - Tolerances
DIN EN 10 034 (1994)	I & H Sections - Tolerances
DIN EN 10 055 (1995)	Equal Flange Tees – Tolerances
DIN EN 10056-2 (1994)	Equal/Unequal Leg Angles - Tolerances
DIN EN 10 279 (2000)	Channels - Tolerances
DIN 18203-2 (1986)	Building Tolerances - Prefab. Steel Components
DIN 18800	Steel Construction (General)
DIN 18802	Construction Tolerances (General)
DIN 18201	Tolerances - Definitions and Terms (for use w/ 18202/18203)
DIN 1025-1	I & H Sections - Properties (tolerance section moved to EN 10 034)

UK

DIN EN 10 024 (1995)	Taper Flange I-Sections - Tolerances
BS EN 10034:1993	I & H Sections - Tolerances
BS EN 10055:1996	Equal Flange Tees - Tolerances
BS EN 10056-2:1993	Equal/Unequal Leg Angles - Tolerances
BS EN 10279:2000	Channels - Tolerances

Japan

JIS G 3192:2000	Dimensions, mass, tolerances - hot rolled sections

Australia

AS/NZS 3679.1:1996	Structural steel - Hot-rolled bars and sections Amdt 1:1997, Amdt 2:2000

Note: German and UK EN Standards are European standards and identical.

Wide Flange Shapes – Observations on Tolerance Specifications

Size

- U.S. ASTM A6 is only code that does not have direct tolerance spec. for t_f and t_w
- Japanese JIS 3192 consistently more restrictive than European Code
- European EN 10024 more restrictive than ASTM A6 for smaller shapes, identical or less restrictive for larger shapes
- Australian AS/NZS 3679 overall slightly less restrictive than JIS 3192, more restrictive than EN 10024 & ASTM A6
- AS/NZS 3679 shapes only to max d=24"± & b_f=12"
- Mass tolerance ASTM A6 (2.5%) most restrictive
- Individual thickness tolerances when given exceed mass tolerances (especially for small sections), therefore actual thickness tolerances would be expected to be well within specified tolerance as governed by mass tolerance

Web Off-Center

- EN 10034 most restrictive for common smaller shapes
- for heavier shapes in each series EN 10034 equal or less restrictive then ASTM A6
- AS/NZS 3679.1 more restrictive than ASTM A6 for small shapes, equal for W8 and up
- JIS 3192 data not available

Out of Square

- EN 10034 most restrictive, up to 4 times as restrictive as ASTM A6 for small shapes, approaching ASTM A6 for larger shapes
- AS/NZS 3679.1 more restrictive than ASTM A6 for small shapes, equal to ASTM A6 for all others
- JIS 3192 data not available

Size Tolerance Specifications
All dimensions in mm

Criteria	Condition	EN 10034	as %	ASTM A6	as %
d	100<d=180	+3/-2	+1.67 to 3.0/-1.11 to 2.0	+4/-3	+2.22 to 4/-1.67 to 3
	180<d=400	+4/-2	+1.0 to 2.2/-0.5 to 1.11	+4/-3	+1.0 to 2.22/-0.75 to 1.67
	400<d=700	+5/-3	+0.71 to 1.25/-0.43 to 0.75	+4/-3	+0.57 to 1.0/-0.43 to 0.75
	700<d	+5/-5	<±0.71	+4/-3	<+0.57/-0.43
bf	50<bf=110	+4/-1	+3.6 to 8/-0.91 to 2	+6/-5	+5.45 to 12/-4.54 to 10
	110<bf=210	+4/-2	+1.9 to 3.6/-0.95 to 18.2	+6/-5	+2.86 to 5.45/-2.38 to 4.54
	210<bf=325	+4/-4	±1.23 to 1.9	+6/-5	+1.85 to 2.86/-1.54 to 2.38
	325<bf	+6/-5	<+1.85/-1.54	+6/-5	<+1.85/-1.54
tw	tw<7	0.7	10+	2.5% nominal	2.5
	7=tw<10	1	10 to 14.3	mass tolerance	2.5
	10=tw<20	1.5	7.5 to 15		2.5
	20=tw<40	2	5 to 10		2.5
	40=tw<60	2.5	4.17 to 6.25		2.5
	60=tw	3	<5		2.5
tf	tf<6.5	+1.5/-0.5	+23/-7.7	2.5% nominal	2.5
	6.5=tf<10	+2/-1	+20 to 30.8/-10 to 15.4	mass tolerance	2.5
	10=tf<20	+2.5/-1.5	+12.5 to 25/-7.5 to 15		2.5
	20=tf<30	+2.5/-2	+8.33 to 12.5/-6.67 to 10		2.5
	30=tf<40	2.5	±6.25 to 8.33		2.5
	40=tf<60	3	±5 to 7.5		2.5
	60=tf	4	<±6.67		2.5
Weight			4%		2.50%

Data from Trade Arbed Chart/ASTM A6M

	JIS 3192	as %
100<d<400	2	0.5 to 2
400<d<600	3	0.5 to 0.75
600<d	4	<0.67
50<bf<100	2	2 to 4
100<bf<200	2.5	1.25 to 2.5
200<bf	3	<1.5
tw<16	0.7	4.38+
16<tw<25	1	4 to 6.25
25<tw<40	1.5	3.75 to 6
40<tw	2	<5
tf<16	1	6.25+
16<tf<25	1.5	6 to 9.38
25<tf<40	1.75	4.38 to 7
40<tf	2	<5
4 - 5%		

Data from AISC Graphs (Fax. 11/24/03)

		AS/NZS 3679.1	as %	
d	150<d=180	+2.5/-1.5	+1.39 to 1.67/-0.83 to 1	UB Shape - Universal Beam (150 & 180)
	180<d	3	<1.67	UB Shape - Universal Beam (200 & up)
bf	75<bf=90	3	3.33 to 4	UB (150 & 180)
	90<bf	+6/-5	<+6.67/-5.56	UB (200 & up), UC (all)
tw	tw=15	0.7	4.67+	UB (all), UC (all except 310 UC 158)
	15<tw	1	<6.67	310 UC 158
tf	tf=15	1	6.67+	UC, UB (varies)
	15<tf	1.5	<10	UC, UB (varies)
Weight			2.5% (see code)	

Size Tolerance Specifications
All dimensions in inches

Criteria	Condition	EN 10034	as %	ASTM A6	as %
d	4<d=7	+1/8 / -5/64	+1.67 to 3.0/-1.11 to 2.0	5/32 / -1/8	+2.22 to 4/-1.67 to 3
	7<d=15 3/4	+5/32 / -5/64	+1.0 to 2.2/-0.5 to 1.11	5/32 / -1/8	+1.0 to 2.22/-0.75 to 1.67
	15 3/4<d=27 1/2	+3/16 / -1/8	+0.71 to 1.25/-0.43 to 0.75	5/32 / -1/8	+0.57 to 1.0/-0.43 to 0.75
	27 1/2<d	+3/16 / -3/16	<±0.71	5/32 / -1/8	<+0.57/-0.43
bf	2<bf=4 5/16	+5/32 / -3/64	+3.6 to 8/-0.91 to 2	1/4 / 3/16	+5.45 to 12/-4.54 to 10
	4 5/16<bf=8 1/4	+5/32 / -5/64	+1.9 to 3.6/-0.95 to 18.2	1/4 / 3/16	+2.86 to 5.45/-2.38 to 4.54
	8 1/4<bf=12 13/16	+5/32 / -5/32	±1.23 to 1.9	1/4 / 3/16	+1.85 to 2.86/-1.54 to 2.38
	12 13/16<bf	+1/4 / -3/16	<+1.85/-1.54	1/4 / 3/16	<+1.85/-1.54
tw	tw<1/4	1/32	10+	2.5% nominal	2.5
	1/4=tw<3/8	3/64	10 to 14.3	mass tolerance	2.5
	3/8=tw<13/16	1/16	7.5 to 15		2.5
	13/16=tw<1 9/16	5/64	5 to 10		2.5
	1 9/16=tw<2 3/8	3/32	4.17 to 6.25		2.5
	2 3/8=tw	1/8	<5		2.5
tf	tf<1/4	+1/16 / -1/64	+23/-7.7	2.5% nominal	2.5
	1/4=tf<3/8	+5/64 / -3/64	+20 to 30.8/-10 to 15.4	mass tolerance	2.5
	3/8=tf<13/16	+3/32 / -1/16	+12.5 to 25/-7.5 to 15		2.5
	13/16=tf<1 3/16	+3/32 / -5/64	+8.33 to 12.5/-6.67 to 10		2.5
	1 3/16=tf<1 9/16	3/32	±6.25 to 8.33		2.5
	1 9/16=tf<2 3/8	1/8	±5 to 7.5		2.5
	2 3/8=tf	5/32	<±6.67		2.5
Weight			4%		2.50%

Data from Trade Arbed Chart/ASTM A6M

	JIS 3192	as %
3 15/16<d<15 3/4	5/64	0.5 to 2
15 3/4<d<23 5/8	1/8	0.5 to 0.75
23 5/8<d	5/32	<0.67
2<bf<3 15/16	5/64	2 to 4
3 15/16<bf<7 7/8	3/32	1.25 to 2.5
7 7/8<bf	1/8	<1.5
tf<5/8	1/32	4.38+
5/8<tw<1	3/64	4 to 6.25
1<tw<1 9/16	1/16	3.75 to 6
1 9/16<tw	5/64	<5
tf<5/8	3/64	6.25+
5/8<tf<1	1/16	6 to 9.38
1<tf<1 9/16	1/16	4.38 to 7
1 9/16<tf	5/64	<5
4 - 5%		

Data from AISC Graphs (Fax. 11/24/03)

		AS/NZS 3679.1	as %	
d	5 7/8<d=7 1/16	+3/32 / -1/16	+1.39 to 1.67/-0.83 to 1	UB Shape - Universal Beam (150 & 180)
	7 1/16<d	1/8	<1.67	UB Shape - Universal Beam (200 & up)
bf	2 15/16<bf=3 9/16	1/8	3.33 to 4	UB (150 & 180)
	3 9/16<bf	+1/4 / -3/16	<+6.67/-5.56	UB (200 & up), UC (all)
tw	tw=9/16	1/32	4.67+	UB (all), UC (all except 310 UC 158)
	9/16<tw	3/64	<6.67	310 UC 158
tf	tf=9/16	3/64	6.67+	UC, UB (varies)
	9/16<tf	1/16	<10	UC, UB (varies)
Weight			2.5% (see code)	

Web Off-center
All dimensions in mm

Condition		EN 10034	Condition	ASTM A6	Condition	AS/NZS 3679.1
tf<40	bf=110	2.5	w<426 plf	5	180<d	2.5
	110<bf=325	3.5	w>426 plf	8	200<d<612	5
	325<bf	5				
40=tf	110<bf=325	5				
	325<bf	8				

	EN 10034	ASTM A6	AS/NZS 3679.1
W4	2.5	5	2.5
W5	3.5	5	2.5
W6x9-16	2.5	5	2.5
W6x15-25	3.5	5	2.5
W8x10-15	2.5	5	5
W8x18-67	3.5	5	5
W10x12-19	2.5	5	5
W10x19-112	3.5	5	5
W12x14-22	2.5	5	5
W12x26-152	3.5	5	5
W12x170-210	5	5	
W12x230-336	8	5	
W14x22-82	3.5	5	5
W14x90-193	5	5	
W14x211-426	8	5	
W14x455-730	8	8	
W16	3.5	5	5
W18x35-158	3.5	5	5
W18x175-311	5	5	
W21x44-182	3.5	5	5
W21x201-248	5	5	
W21x275-402	8	5	
W24x55-117	3.5	5	5
W24x131-192	5	5	
W24x207-408	8	5	
W24x450,492	8	8	
W27x84-129	3.5	5	
W27x146-217	5	5	
W27x235-407	8	5	
W27x448-539	8	8	
W30x90-148	3.5	5	
W30x173-235	5	5	
W30x261-391	8	5	
W30x433-581	8	8	
W33x118-169	3.5	5	
W33x201-241	5	5	
W33x263-424	8	5	
W33x468-619	8	8	
W36x135-210	3.5	5	
W36x230-260	5	5	
W36x280-393	8	5	
W36x439-848	8	8	
W40x149-183	3.5	5	
W40x199-268	5	5	
W40x277-397	8	5	
W40x436-655	8	8	
W44x198,224	3.5	5	
W44x248,285	5	5	

40 mm = 1.57 in
110 mm = 4.33 in
325 mm = 12.80 i
180 mm = 7.09 in
612 mm = 24.09 i

Out of Square
All dimensions in mm

Condition	EN 10034	Condition	ASTM A6	Condition	AS/NZS 3679.1
bf=110	1.5	h=310	6	180=d	2.5
110<bf	0.02*b	310<h	8	200=d<250	6
	(max. 6.5)			310=d	8

	EN 10034	ASTM A6	AS/NZS 3679.1
W4	**1.5**	6	2.5
W5	**1.5**	6	2.5
W6x9-16	**1.5**	6	2.5
W6x15-25	**3**	6	
W8x10-15	**1.5**	6	6
W8x18-67	**2.7-4.2**	6	6
W10x12-19	**1.5**	6	6
W10x22-112	**2.9-5.3**	6	6
W12x14-22	**1.5**	6	8
W12x26-336	**3.3-6.5**	**6**	8
W14+	**0.02 bf<6.5**	8	8

110 mm = 4.33 in
310 mm = 12.20 in (nom. 12 in)
180 mm = 7.09 in

APPENDIX B ALLIED INDUSTRY SITE VISITS

STEEL DYNAMICS

November 5, 2003

Ruby & Associates, P.C. (R&A) visited the Steel Dynamics Structural and Rail Division Mill in Columbia City, Indiana on November 5, 2003. A discussion was followed by a walking tour of the plant. Participants were Dave Ruby, Jamie Fox and Brian Volpe of R&A, Tom Schlafly of AISC, and Doug Rees-Evans and Ken Reid of Steel Dynamics.

Discussion Items:

1. Plant Capabilities were discussed. Currently producing W6x9 through W30x148. Shapes wider than 12" nominal width are not yet being produced. W33 and W36 sizes will be produced in the near future. S shapes are produced from 6" to 24". M shapes from 8" to 12". Channels from 6" to 15" and miscellaneous channels from 6" to 9". Sheet piles PZ22 through PZ35 and HP8 through HP14 are also produced. As are standard angles, Z3 and Z4, and a variety of car-building shapes. The rail capabilities are starting to be utilized. Not all shapes are being produced due to market conditions and corporate planning. The rolling schedule is about six weeks to work the entire production line.
2. Caterpillar's tolerances were discussed. The tolerances are so tight that there is a significant premium in the production of the steel. Stricter tolerances increase the cost of production. They were compared to the Cadillac of the heavy equipment industry. Steel Dynamics has not been approached to be a supplier to Caterpillar.
3. When checking production for compliance with tolerances, the first couple pieces produced will be check and scrapped. Regular checking will follow at 20 to 30 minute intervals.
4. At Steel Dynamics, in the production of ASTM A992 steel, a target for the average yield strength is 55 to 60 ksi. In order to get the yield up from a scrap of approximately 40 ksi, Manganese and Vanadium are added to increase the yield. The scrap composition is sampled and a metallurgical recipe is followed. The recipe will depend on the sizes that are to be created and the area reduction from the base casting. As many as 4 dozen recipies exist that produce acceptable A992 material. The production process is heavily based on chemistry and metallurgy.
5. Reduction has major influence on the recipe required for production. Higher reductions create higher strengths.
6. There is less chemistry involved in producing smaller sections. Higher strengths are more easily obtained. Larger sections require more chemistry. Lower strengths are more likely. This is based on the reduction in the rolling process.
7. Steel Dynamics uses an electric furnace for all operations. By blowing O8 carbon into the mix, unwanted miscellaneous components can be oxidized out.
8. The steel is 55-60% post-consumer, 30% post-industrial and 10% virgin steel composition
9. Steel Dynamics currently uses four different blooms to produce all of their structural shapes. Each family of sizes is derived from one of the blooms. A fifth bloom will be added to create the 33" and 36" shapes.
10. Steel Dynamics uses twin furnaces in the melt shop. Casting temperature effects the density of the mixture, may create buldging and create additional wear on the mold.
11. Producing a 65 ksi yield steel is relatively easy for smaller sections. The larger sections are much more difficult. In general, the more reduction, the higher the strength.
12. The hot-rolled production process makes it very difficult to produce 65 ksi yield material. Temperature control throughout the process is essential. The QST process is required, or at

least makes it easier. ARBED uses this in their facility in Belgium. It is an inline process that provides control over the finishing of the steel. How the steel is treated and the temperature it is finshied at allow for the higher strengths. A major downside to the QST process is the costs of water and electricity to perform the process. The chemistry is not as important as the process and the finishing. How the steel is finished greatly affects the strength.

13. ASTM A992 requirements keep steels in the 50 to 65 ksi range. The material compositions make higher yields difficult provided the chemical makeup. Increasing manganese and microalloys will allow for higher strength steels. The increase of carbon however creates weldability concerns.
14. Nucor-Yamato did not see the demand in the United States for higher strength steel. It decided not to go ahead with licensing the QST process here in America. Is there the demand now? Given recent construction using large members in tension, maybe there is the interest to make domestic 65 ksi material a reality.
15. Ron Hamburger has been doing a study on the industry requirements for 65 ksi and 100 ksi materials. Contact should be made to see what he has been able to find out on the topic.
16. Production tolerances were discussed. Mill operations produce potential imperfections in the dimensional properties (flange width, thickness, out of square) and handling and storage imparts sweep and camber. Flange out of square is a major issue in the mill. Sweep and camber are also involved in the cooling process so it is not restricted to a handling issue only. Most of the sweep and camber issues, however, are caused after the steel is produced.
17. Improper handling of steel is a major issue. Stacking must be done properly to avoid sweep and camber issues. Steel Dynamics has an issue with stacking in the yard and the sweep that may be induced by improper storage.
18. No customers have approached Steel Dynamics for tighter tolerances on their material.
19. Steel Dynamics has internal tolerances which are stricter than ASTM A6. Little of what they produce does not comply with the internal standards. This would infer that ASTM A6 could be tightened.
20. Producing the H shape for wide flanges is a complex process. As one dimension is modified, it affects other dimensions. It is not as simple as it appears.
21. Steel Dynamics believes that eliminating families will create a cost savings. W14 shapes are produced in seven different families, including six in the commonly used sizes. In contrast, W12 shapes have the same family from 65plf to 212plf. Changing weight in a family is not really an issue as it is a function moving the rolls. When the family changes, the rolls must then be changed out, which creates downtime.
22. The Steel Dynamics mill is one of the most modern steel production facilities in the world. Changing rolls can be done in as little as 40 minutes. Casters can be changed in as little as two hours. The changeover procedure is also automated.
23. The mill uses a tandem mill system with a universal rougher, which gets the material close to shape and then the finishing rolls for final shaping.
24. A6 does not address roll location in the standard. Misaligned rolls could result in flanges that are not centered on the web that still are within tolerance. Doug is on a committee looking into the A6 standard. He feels strongly about this not being in the standard and that the subject must be addressed.
25. Given the sophistication of the facility, Doug was asked if alternate shape production would be a possibility. The Girder-slab system currently uses a hybrid composite shape. Information will be forwarded to Doug to see what he thinks about the possibility of it being formed monolithically.

26. Steel Dynamics largest customer base is the steel warehouse and distributor end of the business. Individual fabricators and end users are not a large segment of the clientele. Their target industry right now is small building fabrication and construction, not large fabricators.
27. Redcoat, the process currently being used by tube suppliers where the product leaves the mill painted and ready for fabrication, was discussed. Steel Dynamics would be interested if the demand was there and if it would be a profitable venture. They presently have a state of the art paint system for sheet rolling.
28. Steel Dynamics utilizes a universal tracking system. Each piece is stenciled at 15 foot intervals with the size and heat number. Each bundle is labeled and that can be tracked to the mill certification. The bar code for the bundle contains the ID for the bundle and the Duns #.
29. A bar code can be stenciled presently. However, it stops the line. Stopping the line is not acceptable. If a piece specific marking system is to be used, it must function without stopping the line and slowing production.
30. The mill has the capability to produce custom fit, custom cut, custom length members. Is this realistic? Would the demand be there? This topic would be reviewed in depth.
31. At Steel Dynamics, time is the limiting factor. The mill can run as much as needed, yet time is the limiting factor.

VULCRAFT
November 5, 2003

Ruby & Associates, P.C. (R&A) visited the Nucor-Vulcraft Group facility in St. Joe, Indiana on November 5, 2003. A walking tour of the plant was followed by a discussion. Participants were Dave Ruby, Jamie Fox and Brian Volpe of R&A, Tom Schlafly of AISC, and Jim Ronner, Mark Johanningsmeier and John Grayson of Vulcraft.

Discussion Items:

1. Plant contains many automated fixtures designed to speed up the fabrication process. Plant personnel working on the floor who thought of potential process improvements normally designed those fixtures.
2. The joist fabrication industry uses trends to determine what sizes will be used. Angle sizes of many different custom thicknesses are used. Design is based on what angles are available and not necessarily for strength only. Many factors affect the size used, including the season and availability of stock on hand.
3. The plant tries to turn over their inventory on a monthly basis.
4. The steel used is dual certified and can be used in Canada. Normally 50 ksi steel is used but 55 ksi is used for Canada. The SJI does not formally recognize 55 ksi steel in their specification.
5. Vulcraft prefers human production to robotic because the robot does not have a brain, and because they have such an efficient operation as is, a robot would not really be a benefit.
6. Vulcraft has reviewed automated welding for many years. The tolerances required for robotic welding are much tighter than the current fabrication tolerance at the plant, which is +/- ¼". They can't justify the additional expense of robotic equipment.
7. Welding in fabrication is done using tack welds initially to set up the geometry and then moving down the line for final welding.
8. Most all detailing is done as text on 8 ½" x 11" paper. Welds are given as lengths only and normally the lengths listed are very short. No size is given.
9. The fabrication and layout process is fairly standardized where panel points are standardized. Normally at 4 foot on center, the layout of material does not follow set work points but operates on a close enough type setup. Joist seats, spacers and miscellaneous pieces are all fairly standard to speed up the fabrication process. Oddball type construction is not a frequent occurrence.
10. Vulcraft does participate in design/build activities. They normally enter in only with trusted firms they have had success working with in the past. It has to be a system they are comfortable working with and in.
11. Vulcraft prefers electronic file transfer. They will strip files down to the base and layout their material from there. It saves them from reinventing the wheel, which results in a lower end cost.
12. Vulcraft does not use CIS/2. They are really not that familiar with it either. Based on their segment of the industry and how specialized joist design and fabrication is, it is not really all that practical right now. They would need loading criteria, bridging requirements and miscellaneous items that does not appear in CIS/2.
13. Vulcraft will participate in the redevelopment of the steel construction industry through the SJI. The SJI will have to lead in the effort, but Vulcraft will help the SJI do what needs to be done.

14. Communication is a major problem in the joist industry. Engineers of Record normally do not want to answer questions in a responsive manner so joist design is often as is. Value engineering only exists where the EOR has an interest. Additionally, normal joist design criteria are often not presented to the joist fabricator at the time of bidding. This creates a higher cost due to the uncertainty. Following the design criteria required by the joist supplier, as indicated in most all suppliers literature, will create an ideal situation where the joists can be designed in the most efficient manner.
15. Poor construction documents increase costs. Proper documents can really decrease the cost.
16. Standard unit opening setups for mechanical units could allow for joists to be designed prior to equipment selection, speeding up the process and reducing the opportunity for field issues. Vulcraft sees value in this.
17. Standard procedure of processing an order is first detailing. This involves showing end connections, bracing standards, etc. Approval drawings are then submitted. Calculations will be submitted if required, but normally they do not get any comments. The approvals are then checked and engineering produces a bill of materials and shop fabrication sheet for production.

CATERPILLAR
November 20, 2003

Ruby & Associates, P.C. (R&A) visited the Caterpillar facility in Peoria, Illinois on November 20, 2003. A walking tour of the plant was followed by a discussion. Participants were Dave Ruby, Jamie Fox and Brian Volpe of R&A, Tom Schlafly of AISC, Karen Huber of Caterpillar Inc., Frederick Brust of Battelle, and Duane Miller of The Lincoln Electric Company.

Discussion Items:
Dave Ruby: Presentation on Steel Construction Process and Related Tolerances Overview
The presentation consisted of an overview of the project scope and objectives. The intent of the overview was to make sure that all of the participants in the roundtable conference held at the Caterpillar plant could hear the scope and objectives prior to any discussion. This would allow them to identify relationships in the material that was to be discussed for the rest of the day.

Duane Miller: Presentation on Construction and Material Tolerances – The Effect on Welding Cost
The presentation covered conceptual weldment cost increases when taking all or parts of the ASTM A6 tolerances to their maximum allowable values. Five questions that were posed at the end of the presentation were:

1. What is real variation (versus ASTM allowed variation)?
2. What are the variations that are most costly?
3. What requirement in AISC and AWS cause the biggest cost increases?
4. How is the overall cost of a structure affected if construction tolerances are increased?
5. How is the overall cost of a structure affected if construction tolerances are decreased?

Bud Brust: Presentation on FASIP (**F**abrication of **A**dvance **S**tructures using **I**ntelligent and Synergistic Material **P**rocessing)
The presentation covered the control of plate material during its production life cycle by predicting weld distortion and developing weld sequencing and prefabricated pieces that will produce an end product with very tight tolerances. The tight tolerances make the fabricated fixture able to be used in follow up mass production using automated welding. FASIP, the program developed by Battelle for this process, is being used to replace the "rule of thumb welding procedures" that have been used by craftsmen over the last century.

Karen Huber: Presentation on the production process and the intensive R&D at Caterpillar.
The presentation covered the production process used at Caterpillar. Caterpillar uses 35-40% automated welding procedures in the production of their equipment. Each weldment is analyzed prior to production using the FASIP program in order to maintain control of the final product. This control of material tolerances and final weldment tolerances is essential when all of the pieces of the final product come together.

Karen Huber also led the group on a walking tour of the Research & Development facility. During the walk thru we viewed the some of the plate products being plasma cut with the Caterpillar installation tabs. We also viewed a tack welded assembly that was put together from 20-25 prefabricated plates. Each of the plates was fabricated with the required tabs, holes and scribe lines required to assemble the weldment. The assembly could be put together and tack welded in 10 minutes.

APPENDIX C QUESTIONNAIRE & SURVEY RESPONSES

TOLERANCE STUDY – FABRICATION

1. Do the current ASTM A6 rolling tolerances affect your fabrication process? Explain.
   - Yes. Due to depth over runs beyond A6, when using wing plate moment connections, we are required to space the plates ½ inch further apart than the tabulated depth of the beam. AISC recommends 3/16 inch further apart. When using AISC recommendation we have discovered that the beams bind up during erection so we have increased the depth to ½ inch instead of 3/16 inch. This may be due to a combination of depth overrun and out of square flanges. This problem seems to become more significant as the beams become deeper.
   - Very little for typical structural shapes but has an effect when we are doing structural that is either architectural or connects to other material.
   - Yes

2. Approximately how much of your material does not comply with ASTM A6 tolerances?
   - 20% but is more significant in deeper members
   - 1% Quality of rolled shapes have improved with continuous casting and near shape blanks.

3. What do you do to correct out of tolerance material?
   - Make adjustments in detailing members and case by case sometimes straightening and other times replacing the member.
   - Typically heat straighten or when there are stiffeners we may jack and install fitted stiffeners.
   - Call the mill for replacement or credit.

4. Does the material tolerances listed in ASTM A6 reflect the current steel mill product that you purchase?
   - Most of the time but there are some exceptions in members 16 inches and deeper.
   - It might be possible to tighten mill tolerance but we would be reluctant to do this if fabrication tolerances are tied to the same standard.
   - Yes

5. Do tolerances influence the quality of the fabricated product?
   - ASTM A6
     - i. Yes
     - ii. This is the primary tolerance that governs not only the mill tolerances but also our fabricated material.
     - iii. Yes
   - CSP
     - iv. Yes
     - v. The tolerances for beam and column length in the CSP are often exceeded by fabricators.
       1. Columns – Typical shop tapes are calibrated in 1/16-inch and it is virtually impossible to verify column length to 1/32-inch. It would be extremely rare to measure all 4 corners and not find some variation. Column variations up to 1/8 inch are not a problem in most structures although in tier building it is necessary to monitor column lengths.
       2. Cambered beams – Most shops use cut to length and punch holes before cambering. The CNC machines has varying tolerances. After cambering the center to center of top connection holes can grow up to 3/8-inches depending on the camber. This normally is not a problem if short slotted holes are used in the connections or if there are only 3 beams or so in the line.
       3. Truss cambers – The cambers listed in the CSP are partially based on a proposal I made to the Committee on Design of Steel Bldg Structures except that the tolerance is based only on the span even when the specified

cambers could vary substantially. For example at a point 30ft from the support the tolerance is 7/16-inch if the camber is 1-inch or 3-inches.

- Temperature differential
    - vi. No
    - vii. This is a design and detail issue and not really a fabrication issue
    - viii. Yes

- Column shortening
    - ix. No
    - x. This combines with column fabrication tolerances and the effect of erection build out to require monitoring and adjustment during the construction stage. This becomes a problem when working with concrete shear cores, moment frames designed for drift, and mullion type columns with no real gravity loads. It takes cooperation between the designer, fabricator, erector and concrete contractor to make all of the necessary adjustments to achieve level floors in high rise structures.

6. When laying out a column do you use a theoretical centerline?
    - Yes
    - We attempt to compensate for any column sweep by clamping the column at the saw and at the tail to a straight datum line.
    - No

7. Do you mill or use a cold-saw to square the end of a column?
    - Use dual column band saw
    - We try to only saw cut all of our columns. We do monitor diagonal dimensions to see of the column is square. If the saw does drift we will then mill and shim to adjust for length on gravity column
    - Perpendicular to the end.

8. Is this cut perpendicular to the end of the column or the theoretical centerline?
    - Theoretical centerline
    - On heavy sections under certain conditions the saw may drift slightly. We evaluate if it is necessary to mill. Note even when columns are cut perfectly square the splice often open up to field plumbing operations. This is easily handled with mild steel shims so it does not seem reasonable to fixate over the perfect splice.
    - No

9. Are the existing ASTM A6 and CSP tolerances a hindrance to process improvement?
    - Yes. If A6 tolerances were tighter it would eliminate shimming and adjustments such as blocking during fabrication.
    - I would not recommend changing ASTM tolerances unless it was clear this applied only to mill material and not welded and fabricated material. The CSP member tolerances need to be reviewed for cambered members and the use of CNC sawing and punching.

AUTOMATED SHOP FABRICATION

1. What new technology would you like to implement into your shop? Why?
    - CNC drill line
    - We already extensively use CNC equipment in the shop. I think the addition of bar coding for material control is the next major improvement we need to implement.
    - We have the latest technology.

2. How would the above technology improve your process? Your productivity?
    - Eliminate laying out and hand drilling heavy members making the process much faster and more accurate.

- It would help our inventory control, our status reporting on the shop floor and reporting of none conformances.

AUTOMATED WELDING – SHOP & FIELD

1. Have you considered weld automation equipment for use?
   - Nothing beyond what we already have.
   - We use automatic SAW welding for built up member fabrication.
   - Yes
   - Yes

2. Have you implemented any weld automation?
   - Yes.
   - We use automatic SAW welding for built up member fabrication.
   - Yes
   - No

3. If so, what process is it being used for and what are your productivity improvement expectations? If not, why not?
   - Automated Sub-Arc. Used for continuous weldments such as plate girders.
   - We use automatic SAW welding for built up member fabrication.
   - We've not found any automated equipment that is light enough to carried up on the steel.
   - Plasma cutting tables 25% and semi automated (track) as needed.
   - We've not found any automated equipment that is light enough to carried up on the steel. Also, setup in the field is neither in a controlled nor a standard environment. Therefore, every setup is different and every application is exposed to the elements (wind, rain, cold), making automated welds difficult in the field

PAINTING

1. Would using pre-primed material (Redkote from the tube industry) be beneficial? Would you be interested in purchasing slightly more expensive material already painted and ready for fabrication?
   - Not interested. By the time touch-up was done after fabrication is complete the member could have been totally painted.
   - We have done cost studies on Redkote and have not found it to cost effective

2. Are your additional painting costs currently a hindrance to your productivity?
   - Unpainted members are completed more quickly than painted members
   - The major problem with painting is poor specifications requiring over building and top coating of inorganic zincs in the shop. Often special paint jobs are not properly design for painting.

3. Have you ever using pre-primed material? If so, were you satisfied?
   - No.
   - We have used it and it was nice but not cost effective.

3D DESIGN/ DETAILING/ ERECTION COMPUTER VISUALIZATION

1. How would a 3D presentation of a job effect the industry if you were able to access it at bid time?
   - If the 3D model were CIS/2 compatible the model would be able to be input into an estimating program for a more accurate estimate that could be prepared more quickly. This would reduce costs in bidding and speed up the ordering of material and detailing after the project was awarded.
   - It would be very helpful is the design was complete enough that we could download it into a detailing and estimating program. Most designs are not simple enough and complete enough to do this.
   - Assist in material takeoff.
   - Would be helpful, in that it would allow quicker visualization of the project, but I don't think it would have a major benefit unless it automatically provided quantity takeoffs.

2. Would earlier interaction with designers help make the process more efficient? What advantages would be realized?
   - Guidance could be given by the fabricator and erector to the designer to help him to understand the fabrication and erection process when completing designs. Help could be offered in selecting member sizes and framing configurations to minimize costs. Fabricators and erectors understand construction costs and designers understand design. With both parties communicating early a more economical complete design can be completed prior to the issuing of a contract. This would reduce RFI's and Change Orders.
   - Yes. We often find that member size and arrangements need to be modified for cost effective and safe connections.
   - Yes, but only if we had already been awarded the project. If not, we spend our time helping the competition if we work out cost-saving details, but are not the successful bidder. We can minimize erection difficulties and erection costs by optimizing the connection details, providing for needed erection aids and erection safety aids, eliminating "non-erectable" conditions, etc.

3. What features would you want included in the software programs of the future?
   - More extensive CIS/2 interface including detail material and not just beams, columns and braces. All pour stops, stairs and handrail and miscellaneous steel items should transfer from model to model.
   - It would be great if the structure design program included a connection design module so that anytime the connection design module was unable to produce a design the engineer would be required to review and modify the structure.
   - Connection Design
   - Piece marks like in the old days, with C being a column, B a beam, D a diagonal member, etc.

4. Would this improve quality? Reduce costs? Improve customer satisfaction?
   - This would improve quality since each model will match exactly. No manual input would be required eliminating the chance of a human inputting data incorrectly. This would reduce costs by reducing detail drawing production time and thereby reduce construction time improving customer satisfaction. Some to this saved time could be used to refine the design before issuing the model for construction thereby reducing bulletins.
   - It would certainly reduce the adversarial relationships that develop over RFI's and same time in the long run.
   - Improve quality
   - Yes to all. Potential to reduce erection errors, reduce time hunting for members during unload and shake out procedures (thereby reducing schedule), all of which would increase customer satisfaction.

5. How does your internal fabrication process differ between CAD detailing programs vs. the manual detailing process?
   - We have been using CAD virtually exclusively for the past 10 years. Because we are using SDS/2 all of our drawings look consistent. No unique style of drawing or lettering is evident. Since the entire structure is modeled in 3D we are able to see the structure as it will be erected prior to detailing. This has produced more accurate detail and erection drawings, which has virtually eliminated questions from the shop during the fabrication process and questions from the field during erection.
   - We can detail 85% of the material in about 5% of the time using software. The last 15% has to be done manually and takes 95% of the time.

6. Is your process for fabricating detail material different with CAD detailing and manual detailing?
   - No
   - No although if we used electronically downloaded it would save time.
   - No

7. Is your detail material and main material being produced from separate shop data and married with an assembly drawing?
   - No

- No
- Yes

8. Do you feel you fully utilize the technology available today in your operations?
   - No
   - We do not link operations satisfactorily.
   - Yes
   - Yes

STANDARDIZATION OF DESIGNS

1. Have you had to modify your process or procedures to accommodate computer generated shop drawings?
   - Yes. Our shop people had adapt to the style of detailing used on the CAD drawings which differed in style from the way it would have been presented by hand. All essential information was the same but some minor presentation items were different. Major processes and procedures in our shop did not need to be changed from hand detailing to CAD detailing.
   - General no.

2. Is there a significant difference between the automated detailing programs available today? Are there any that you would prefer not to work with?
   - Yes, definitely. The only CAD program we would consider using is SDS/2. All others we have reviewed do not have the capabilities of this program. SDS/2 is an intelligent program that understands the steel design, fabrication and erection processes. All other programs are mostly line drawing programs without any internal intelligence.
   - We are basically an SDS2 firm with autocad for standard details. We have used Xsteel on one occasion and it was the only program capable of the geometry and interactive design that would have worked. We have not tried it ourselves because we do not see an advantage for most projects.

DISTORTION CONTROL

1. How big an issue is weld shrinkage control for shop prepared moment connections?
   - This is a major issue.
   - This is not really a problem as long as you understand what the structural requirements are and plan your welding accordingly.
   - To control shrinkage, you have to control the amount of weld you put in at a time. Let it cool before putting another pass.

2. How does the process differ for field welded moment connections?
   - In the field the members are usually pinned in place prior to welding and will not distort as much in the field.
   - This is a question of knowing what is going to happen and planning your work accordingly. We have had erectors that have had major problems until we explained to them what was required.
   - No Difference.

3. Would automation be of any benefit in controlling shrinkage and improving productivity?
   - Unknown
   - I doubt it.
   - No, if anything, it would make it worse.

ERECTION

1. Do you detail your column bases with a leveling plate? Have you ever used leveling nuts?
   - Yes. We would not consider leveling nuts since the diameter of the oversized hole in the base plate is very close to the maximum outside dimension of a nut. This presents an unsafe condition in the field (the nut may punch through the anchor rod hole). Also, it is difficult to set the nut to the proper elevation and keep it at that elevation without it being bumped in the field prior setting of the

column. The use of leveling plates eliminates two failure modes in evaluating erection stability: Bending Failure of the Base Plate and Buckling of the Anchor Rod. If leveling plates cannot be used we prefer to use shims with a hole punched in them to drop over the anchor rod. The shims are set prior to erection beginning to the proper elevation. Since they are dropped over the anchor rod they cannot be knocked over and are very stable.

- Almost never. They are expensive and do not allow for plumbing requirements. We use leveling nuts on light 1 & 2 story structures otherwise we provide shims.
- No and Yes
- Not usually.

2. What is the cost of using leveling plates as opposed to leveling nuts?
   - Minimal since safety overrides such a minor cost difference in material. Also, grouting can be accomplished prior to placing the base plate eliminating the need to stuff grout under the base plate which may even reduce costs.
   - Leveling nuts cost almost nothing while leveling plates probably cost $50 or more.
   - Cheaper
   - Don't know.

3. Do field installed leveling plates provide any assistance in controlling erection tolerances?
   - Yes since the elevation of the plates can be confirmed prior to erection beginning and corrected if required.
   - I doubt it. All they would do is bring anchor rod problems to our attention sooner. Base plate elevations are seldom a problem. Leveling plates would control timing of grouting which might be of benefit.
   - No
   - No, we prefer shimming and wedging column bases.

4. How do you correct for out-of-plumb columns?
   - By using cables and pulling the building back into plumb.
   - First we try to determine why they are out of plumb
     a. Anchor rod locations – slot if possible
     b. Beam length – modify connections
     c. Evaluate p-Δ . If column is not architectural problem and it is adequately braced we recommend that it not be moved
   - Packing (Steel tapered shims)
   - For shop-attached base plates, we use steel wedges under the base plate to move into correct position. For loose base plates, we will attach plumb cables near the top of the column and pull into correct position.

5. Do you prefer loose base plates, or shop welded to the column?
   - Shop welded to the column.
   - Our erectors always insist on shop applied base plates. The exception is when the base plate and column gets over 10tons.
   - Shop welded.
   - We prefer shop welded column bases, as shop welding is less costly and the controlled environment of a shop minimizes the probability of lamellar tearing after welding. The only time we want to see a loose base plate is for extremely heavy columns (jumbo sections) where shop welding the plate to the column makes the assembly too heavy for our crane(s) to erect.

6. When laying out a column, do you use a theoretical centerline?
   - Yes.
   - Theoretically yes
   - Yes

- Yes, when practical. However, we often have to use an XXXXXX average line as allowed by AISC Code of Standard Practice.

7. Do the erection tolerances from the Code of Standard Practice reflect reality? Could they be tightened?
   - If anchor rod tolerances were tightened up the erection tolerances could be reduced substantially.
   - Most jobs are erected to about half of the COSP tolerances but when the specifications call for reduced tolerances the erectors either exclude this or substantially increase their price. I would not recommend changing erection tolerances until the actual shop fabrication tolerance for CNC equipment are evaluated.
   - Yes, they do reflect reality. We would argue against tightening them. If they are tightened, the erector is the one who will be responsible for almost all of the added costs, because the tolerances are cumulative. This means that if the mills use one half of the allowed tolerance, and the fabricator uses one half of the allowed tolerance, then there is no tolerance left for the erector. The existing AISC tolerances have worked well for almost a century and we see no reason to throw them out. While the mills and the fabricators may say that their product is much better (considering tolerances), our impression in the field is that steel received in the field now is no better (and maybe slightly worse) that that received 30 years ago. High-rise construction is an example – Fabricators now usually "saw-cut" their columns as opposed to the old practice of "milling" the columns. While this is allowed by AISC and is very cost-effective for the fabricators, it is our opinion that milling columns produced a splice that allowed us a better chance to erect the structure within tolerance with less plumbing effort.

8. Would there be any significant benefit from tightening the tolerances?
   - Finishes on the building such as precast panels would fit better.
   - It would only add to field backcharges from other trades and reduce the need for structural engineer and architect to properly plan for adjustable connections. You can not change tolerance until you fully understand how and when they are measured in the field along with knowing how the structure will deform under the effect of dead load and temperature.
   - No, this would be a cost item to the erectors.

MATERIAL TRACKING

1. Would you use a material tracking database to track your material from beginning to end including but not limited to material handling, shipping, field problems, inspection reports, and mill certs if you could?
   - Yes. We already have a database that does material handling, shipping and mill certs.
   - This would be big help is a comprehensive system could be developed.
   - Yes
   - No, not at this time.

2. What about for erection tracking on the site, including information such as when members are erected and where items are located on the site? Do you see any benefit to this?
   - This may help some but not significantly.
   - For certain projects this would be of benefit
   - No, not at this time.
   - No, not at this time.

PREFABRICATED METAL BUILDING

1. Would a simplified Code and Specification for single story manufacturing building be beneficial in helping you compete with prefabricated Butler type construction?
   - Yes
   - I doubt it. I good design manual showing short cuts for simple structures would benefit the industry. The manual could be based on using only compact rolled shapes and HSS.
   - No