Early involvement of both the bender-roller and the fabricator on a recent airport project ensured that all the curves ended up going the right way.

Takeoffs That Helped Land an Aviation Marvel

BY GEORGE WENDT

IT PAYS TO INVOLVE a bender-roller early on as a member of a steel team when the project incorporates curved HSS—specifically hollow structural sections, whether round, square or rectangular—and/or other curved structural members. Bender-rollers are specialty subcontractors whose expertise can be invaluable to architects, engineers, fabricators and erectors. As specialists, they not only know the answers to the questions about curved steel; they also know the questions that should be asked (see sidebar).

The recently completed expansion of the Mineta San Jose International Airport Terminal B and Concourse provides a good example of the benefits of such an approach. The project called for the fabrication and erection of 420 tons of curved steel to provide the distinctive curvilinear shapes of the terminal and concourse structures.

The curved sections serve multiple purposes in the airport. They help create sun-filled walkways while alternately serving as sunscreens, and they pay tribute to the technical prowess of Silicon Valley by suggesting the shape of an electrical cable with its sheath pulled back to reveal the electricity within.

Early Involvement and Planning: A Great Take-Off

AISC members Chicago Metal Rolled Products and Woodland, Calif.-based Gayle Manufacturing Company were recruited early in the project, as the bender-roller and fabricator, respectively. The Gayle team developed a material takeoff spreadsheet for the rolled sections before the bid was turned in. Through the sharing of information, the spreadsheet became increasingly more detailed as the planning went on among the roller/bender, the fabricator, and the steel suppliers. To see an example, go to **http://bit.ly/lWBFMs**.

This communication helped in the highly complex nesting of parts to minimize the amount of waste generated. In addition to the typical information of section size, orientation, radius and arc length, the spreadsheet included amount of grip, the part width (for shipping considerations), and how the member would be seen when the airport was finished: exposed, partially exposed, enclosed, or fireproofed. Team members from Gayle really seemed to think of everything, grilling Chicago Metal on many questions before even asking for price, unlike some customers who ask only for price. Through

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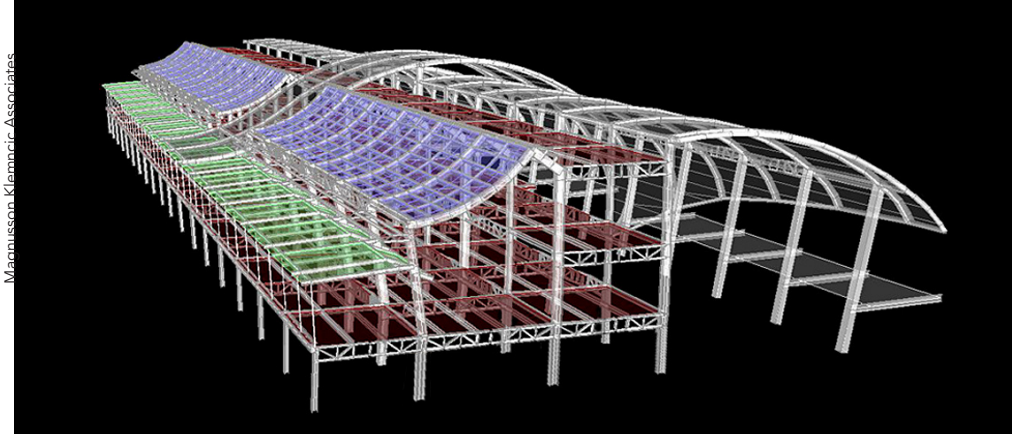

Magnusson Klemencic Associates

▲ Before their bid was turned in, Gayle Manufacturing Company and Chicago Metal Rolled Products developed an extraordinarily detailed material takeoff spreadsheet for the numerous rolled sections to facilitate efficient material nesting, to maintain various quality requirements, and to minimize shipping costs.

➤ Chicago Metal Rolled Products maintained rolling tolerances of ⅛ in. over 20 ft. to ensure the proper alignment for Gayle to weld the wide-flange roof sections together lengthwise.

▼ Chicago Metal Rolled Products curved 16-in. pipe helically as well as HSS 12×8×5/16 off-axis to help Gayle Manufacturing Company achieve the marvelous shapes designed by Steinberg Architects of San Jose, Calif., and Gensler of San Francisco with engineering by Magnusson Klemencic Associates, Seattle.

Gayle Manufacturing Company

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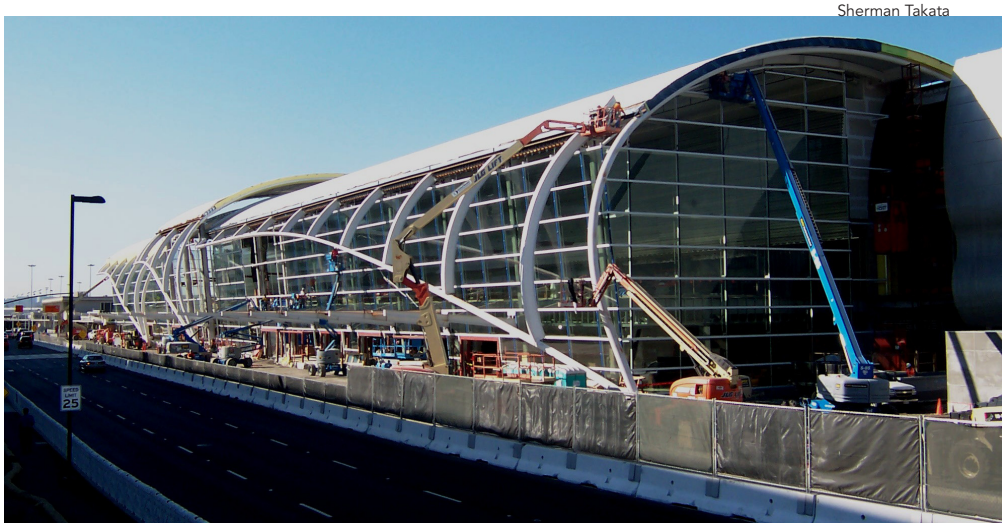

these discussions, Gayle and Chicago Metal personnel achieved a level of comfort and confidence in their joint ability to meet the challenges of the project.

"Involving Chicago Metal Rolled Products early in the project prior to detailing was critical to properly detail, order material, and roll the curved members without issue," said Gary Glenn of Gayle Manufacturing Company.

Some 200 pieces of steel were curved, with a number of them subsequently cut into shorter lengths. Each type of rolled

George Wendt is president of Chicago Metal Rolled Products, www.cmrp.com, which in 2008 celebrated 100 years of curving steel. He frequently lectures and writes on curving structural steel for architects, engineers and structural steel fabricators.

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➤ Some curved sections were exposed, some were partially exposed, some were enclosed and some were fireproofed. A mock-up wide-flange section that was to occur at one of the areas most visible to the public was rolled to the tightest radius. After being painted, it was inspected and approved by the architect. Such communication guaranteed that design expectations were met in every case.

member required a different type of presentation to allow for proper rolling and measuring. The project required W8×31, W10×12, and four W24 shapes, all rolled the "hard way," i.e. against the strong axis, to radii from 30 ft to 135 ft. HSS 12×8×½ were to be rolled in two planes and helically. HSS 12×8×⅝ were to be rolled the "easy way" to an 84-ft radius. (Actually, at times it is easier to roll a rectangular tube the "hard way" because the ID is less likely to become concave than that of a tube rolled the "easy way.") Lastly, 16-in. XS pipe was to be rolled helically.

There was also concern about the distortion that might occur during rolling, such as oil canning and other distortion. As it turned out there was minimal to no distortion of the rolled HSS and pipe members. "The use of Chicago Metal Rolled Products' processes from planning to actual bending definitely made the rolling possible and limited any distortion that did occur," Glenn said.

According to Dan Wendt, vice president of operations for Chicago Metal Rolled Products, the initial conversations with Gayle were about whether the special grade of W24×104 beams could be curved the hard way (x-x axis) to a 44-ft radius without distortion. Gayle had encountered some difficulty in finding a bender-roller to curve these sections without unacceptable distortion.

A mock-up wide-flange section that was to occur at one of the most visible areas to the public was rolled to the tightest radius. The texture of the finish paint (satin versus matte) was also a consideration. Very little distortion occurred, and a review of the mock-up with the architect ensured its acceptability. Such actions guaranteed that expectations would be met in the finished structure.

In general, the limits of bending come from a combination of the physical limits of the steel and the method of bending. Different bender-rollers have different equipment, methods, operator skill levels, and material sources. Consequently, any steel team might benefit from contacting more than one bender-roller to make sure they have explored all the various avenues to curving structural steel.

Agreements were made up front between the bender-roller, fabricator, and erector for the shop drawing presentation and for the tolerances to be maintained. Shop drawings were provided showing offsets for rolling in multiple planes. The actual checkpoints were specified on the drawing and then marked on the piece by the bender-roller so that the fabricator could verify the dimensions in his shop.

On more complicated spiral-rolled members, the degrees of tilt were shown on shop drawings in planes tangent to the section at various locations along the axis of the member. AutoCAD was used for detailing and production of shop drawings, rather than working more directly with the virtual model, because of the complex assemblies involved, including cruciform/kinked columns, trusses, etc.

Curving, Fabricating and Erecting: Following the Flight Plan

The roof beams of the terminal consist of rolled wide-flange sections welded together lengthwise. Chicago Metal maintained rolling tolerances of ⅛ in. over 20 ft to ensure the proper alignment for Gayle to shop-weld the sections together. (The AISC *Code of Standard Practice* calls for a radius tolerance of ⅛ in. over 10 ft for curved beams.)

Maintaining tight tolerances during rolling and fabrication was also necessary due to the complex geometry of the rolled roof members and sloping columns in the final structure. The presentation of the shop drawings allowed for not only proper rolling, but also for inspection of tolerances at Chicago Metal and again at Gayle Manufacturing Company's facility. Rolling, fabrication, and erection tolerances were maintained and checked again onsite to ensure conformance.

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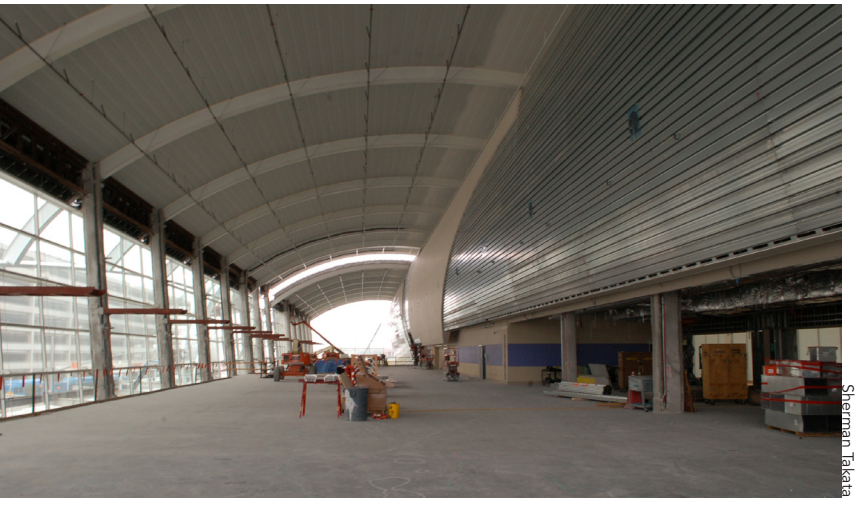
Gayle Manufacturing Company

▲ Costing studies by the steel team optimized spacing and minimized the number of curved pieces. The radius of a curve was repeated where possible to minimize set-up time and fabrication costs.

▼ AESS elliptically curved tubing supports the roof and extends out to help form the curvilinear shape of the structure.



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▲ The Mineta San Jose International Airport Terminal B and Concourse earned a National Award in the AISC 2011 Innovative Design in Engineering and Architecture with Structural Steel (IDEAS²) awards program.

"The Gayle detailers did a phenomenal job," Wendt said. "Not only did they detail everything well, they even communicated how to check these complex bends to ensure that no sections would have to be shipped back from California for repair."

Once all preliminary issues were resolved, Chicago Metal and Gayle worked closely to coordinate delivery of the steel directly from the mill to Chicago. All material was stored inside until it was rolled to meet the project's schedule.

There were also multiple challenges for the erector, California Erectors, Inc. The rolled roof beams and intermediate purlins were assembled on the ground, then hoisted as single picks to expedite erection. Connections were designed and/or modified to be bolted where possible to minimize field welding.

An engineered erection plan was developed with temporary bracing/struts so as to maintain stability of the kinked cruciform columns until the rolled roof beams could be erected. During this process, anticipated deflection of the rolled roof members and columns was calculated, then monitored in the field so as to control tolerance.

Erection aid geometry was reviewed and detailed to accommodate such deflection. Behavior of the structure, before and after release of temporary bracing and struts, had to be considered. Agreements were made between the fabricator, erector, and general contractor as to how tolerances would be surveyed and maintained.

The teamwork manifest from the earliest stages until the end of this project allowed for maximum agreement regarding the expectations of all members of the team, and ultimately a great landing for a visually inspiring project. The Mineta San Jose International Airport Terminal B and Concourse earned a National Award in the AISC 2011 Innovative Design in Engineering and Architecture with Structural Steel (IDEAS²) awards program. Read more about the project in the May 2011 issue of *MSC*, available at **www.modernsteel.com/backissues**. MSC

Questions About Curving Steel

On projects using curved steel, communication among the project team members can alleviate confusion and avoid problems in both fabrication and the field. The questions bender/rollers usually receive include:

1. Can you curve a given section with a particular orientation to a given radius and arc length or degree of arc? Are there better alternatives—different sections and/or orientations—from a bending perspective?
2. In addition to bending in a single plane to a constant radius, can you form a given section to a helical, off-axis, compound, reverse or multi-radius curve?
3. What tolerances can you hold for each curve?
4. Will there be any distortion, and if so, what kind? The ensuing dialogue may involve these questions: Will the parts be exposed? What level of distortion is acceptable? Will AESS quality be required?
5. What material, at what price and availability, can be purchased from service centers and/or mills?
6. Can you deliver the curved sections to meet the project's schedule?
7. Are there any special shipping concerns?
8. What is your price for these services, and does the price, quality, service, and delivery provide value?
9. Do you have any cost-saving and/or time-saving ideas?

Perhaps the most important issue regarding curving structural steel sections is what distortion, if any, is acceptable. If the section is going to be exposed to view close to the eyes of the people in the structure in an AESS application, it will need to be near perfect. If it is covered up, as some sections of the Mineta airport project are, then some distortion may be permissible, but nothing, of course, that would compromise the structural integrity of the section.

Owner
Mineta San Jose International Airport, San Jose, Calif.

Architect – Terminal B
Fentress Architects, San Jose, Calif.

Architect – Concourse
Steinberg Architects, San Jose, Calif. / Gensler, San Francisco

Structural Engineer
Magnusson Klemencic Associates, Seattle (AISC Member)

Steel Fabricator
Gayle Manufacturing Company, Woodland, Calif. (AISC Member)
Beck Steel Inc., Lubbock, Texas (AISC Member)

Bender-roller
Chicago Metal Rolled Products Company, Chicago (AISC Member)

Steel Erector
California Erectors, Benicia, Calif. (IMPACT Member)

General Contractor
Clark Construction Group, LLC, Oakland, Calif.