Steel TIPS
STRUCTURAL STEEL EDUCATIONAL COUNCIL
TECHNICAL INFORMATION & PRODUCT SERVICE

April 2008

COST-EFFECTIVE STEEL BRIDGE FABRICATION AND ERECTION

By

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President
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It is anticipated that a significant number of existing highway overcrossings will be replaced under the Safe, Accountable, Flexible, and Efficient Transportation Equity Act (SAFETEA). In many instances steel plate girder bridges may prove to be the most cost effective. However it is reasonable to assume that many design agencies do not have experience with modern fabrication methods and should acquaint themselves with current shop fabrication facilities and detailing processes. The Federal Highway Administration (FHWA) is developing a new “Bridge of the Future” steel bridge system that can provide rapid bridge construction alternatives for upgrading the interstate highway system. Their working group includes the National Steel Bridge Alliance (NSBA), American Iron and Steel Institute (AISI), American Association of State Highway and Transportation Officials (AASHTO), industry, and academia. As stated in the American Institute of Steel Construction (AISC) Manual the maximum opportunity to influence project quality and cost occurs during the design period. FHWA has visited states that are leaders in Accelerated Bridge Construction and plans on publishing an ABC Design and Construction Manual in 2008.

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First Printing, April 2008.

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ACKNOWLEDGMENTS

The publication of this report was made possible in part by the support of the Structural Steel Educational Council (SSEC). Funding was provided by the California Field Iron Workers Administrative Trust (CFIWAT), a union trust fund.

In addition the author wishes to thank the National Steel Bridge Alliance for permitting him access to the proceedings of its 2007 World Steel Bridge Symposium.

Also thanks are due to Trans Bay Steel Corporation (TBS), 2400 Cordelia Road, Fairfield CA 94534, not only for providing pictures of its fabricating facilities, but also for scanning some historic 1950's photos of the Murphy Pacific Corporation (MPC) Emeryville facility (below).

Figure 1 TBS Fabrication Shop

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1. Introduction

The technical aspects of bridge design utilizing steel plate girders has not significantly changed over the years. There have been however many changes in the physical characteristics of plain material as well as the erector's transportation and erection capabilities. Papers presented at recent conferences such as the World Steel Bridge Symposium (WBES) indicate that communication between designers, shop drawing detailers, fabricators and erectors' reflecting these advances has been poor to non-existent.

An economical design should utilize readily understood details and standard connections. The specified grade and size of steel plates should be readily available. The fabrication processes should be proven.

It would benefit the design team if they were to contact local industry to learn the capabilities of fabricating shops in their area. The National Steel Bridge Alliance (NSBA) and the American Institute of Steel Construction (AISC) can provide a listing of these certified structural steel fabricators and erectors. This Steel TIPS does not attempt to cover all the issues that can arise, but does cite some examples pointing out the benefits of such contacts.

The most important aspect of designing an economical steel bridge is to select the optimum span lengths. For major structures such as river crossings requiring navigation channel clearance spans over 500 feet long, in most of the country designers generally select a cable-stayed bridge. On the West Coast however designers of the Alfred Zampa Memorial Suspension Bridge (Steel TIPS August 06) and the new Tacoma Narrows Suspension Bridge elected to utilize orthotropic steel plate decks. Extensive information on this type of bridge can be found on the 2008 International Orthotropic Bridge Conference website (www.asce-sacto.org). This conference is sponsored by American Society of Civil Engineers (ASCE) Sacramento Section, and will be held there on August 25-28, 2008. Its goal is to bring owners, designers, fabricators, material suppliers, contractors, researchers, professors and students together to focus upon the sole subject of orthotropic steel deck bridges including design, fabrication, inspection and maintenance. The Federal Highway Administration (FHWA) will be providing a chapter-by-chapter review of its new *FHWA Orthotropic Manual* and soliciting participant comments. For shorter span steel structures in the 120-foot to 400-foot range, steel plate girders are more cost effective and will be the subject of this Steel TIPS.

2. Shop Fabrication of Girders

Sizing of plate girders has significant impact on the time required for fabrication. The designer should be aware of availability and lead time required for stock material delivery from the producing mill of the selected grades, thickness and lengths of plates. Plate thickness and shape variances should be kept to a minimum. When considering the overall cost one could reasonably assume that preparation of shop details and shop labor amounts to 55% of the total fabrication costs. The remaining balance is the sum of material, painting and transportation costs.

In order to properly appreciate this cost analysis the designer should tour fabrication facilities and physically observe their layout of areas such as the receiving bay, overhead cranes servicing the fabrication equipment, and the capabilities and size of such equipment. These will dictate the maximum weight and size of the girder for that fabricator.

Figure 1 shows the TBS fabrication shop, and Figures 2 and 3 show MPC storage and fabrication bays. Figure 4 shows pipe pile fabrication at TBS.

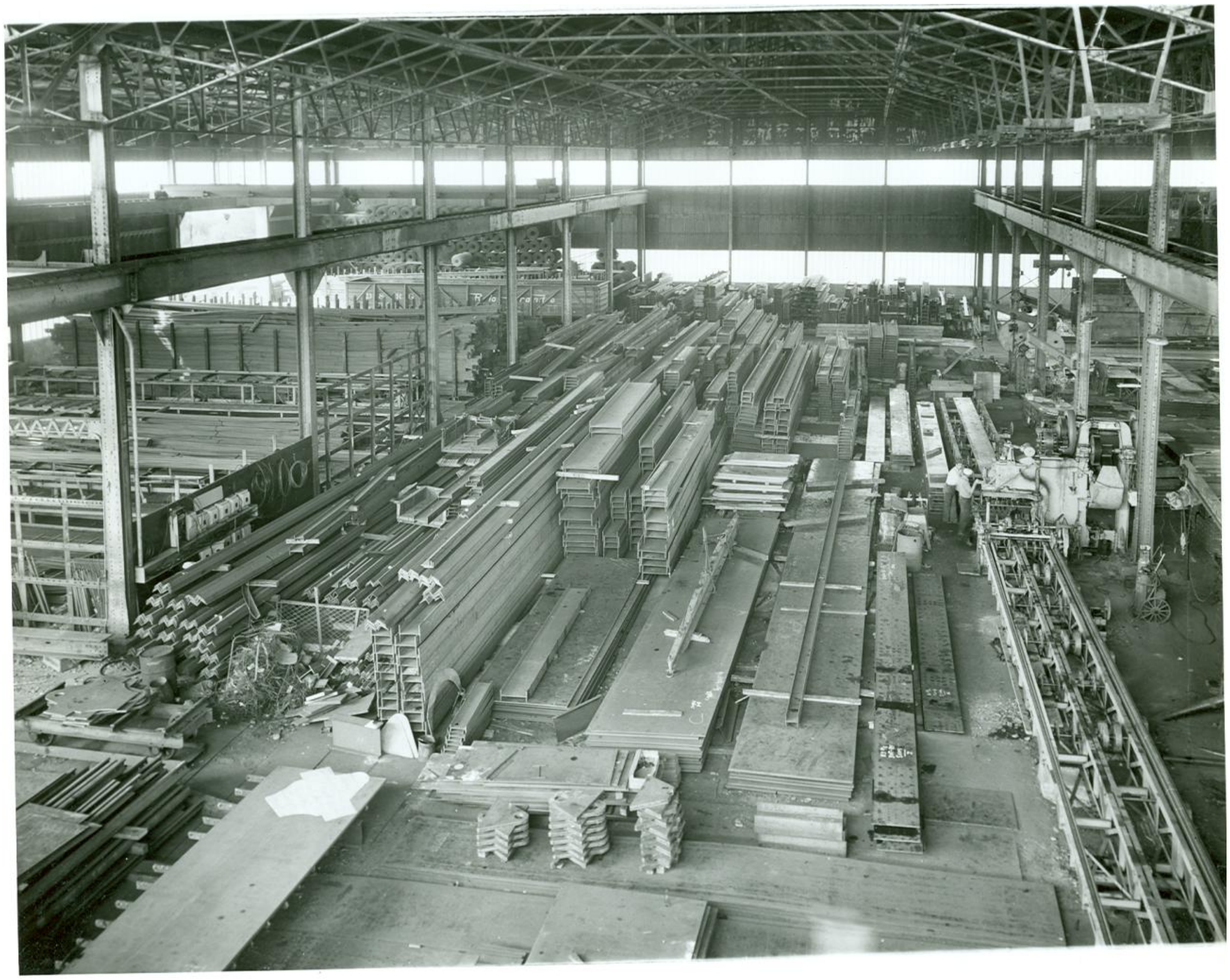

Figure 2 MPC Receiving and Plain Material Storage Bay

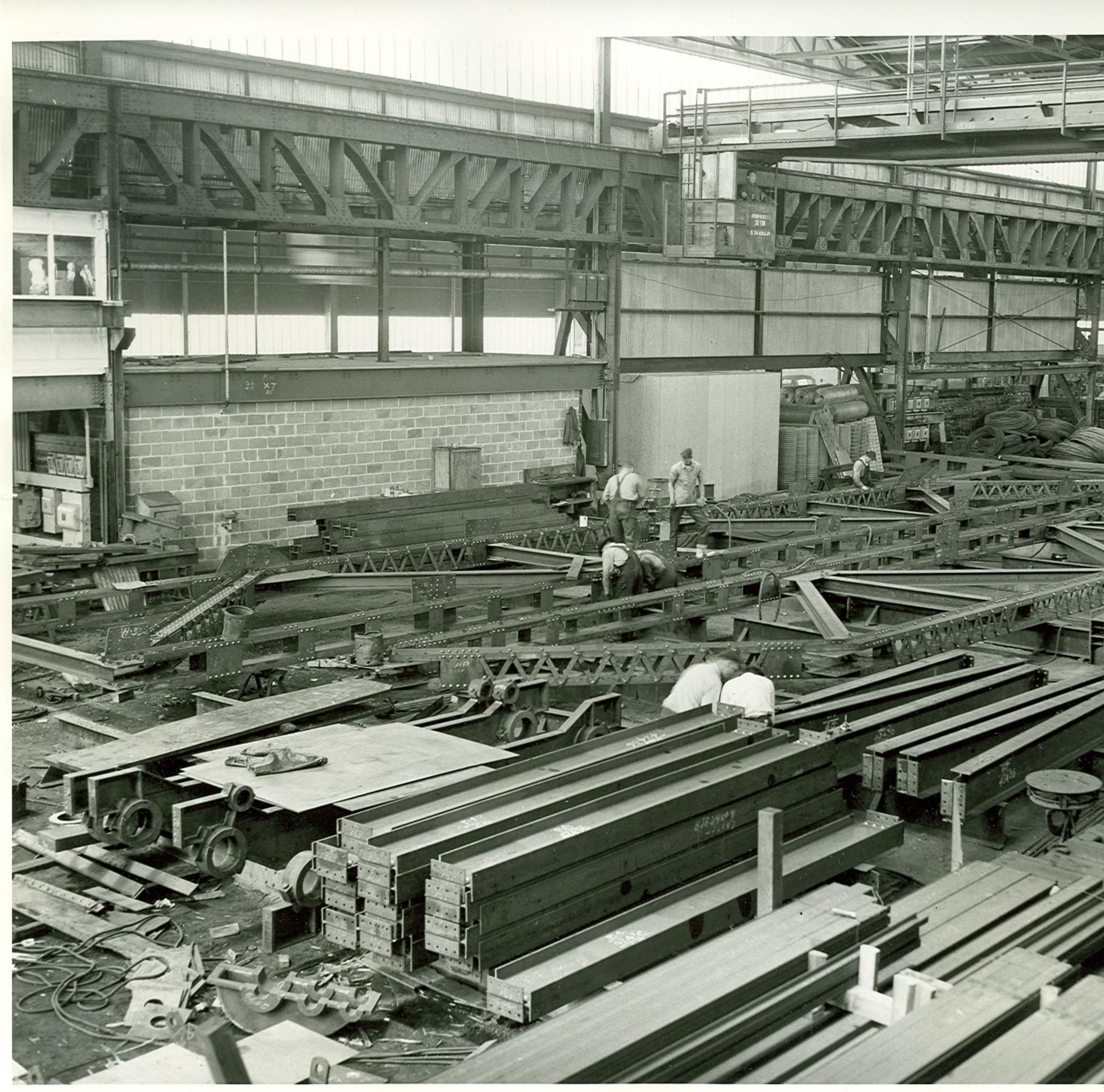

Figure 3 MPC Fabrication Bay

Also emphasized during these visits will be the importance of design drawings that permit expedient preparation and approval of the shop drawings needed for the labor force to accomplish its work.

Figure 4 TBS Pipe Pile Fabrication

These visits will assist the designer in consideration of girder proportions. Conventional wisdom has held that the lowest weight girder is the most economical girder. Given the change in the relative costs between labor and materials, this is not always true. The emphasis for economical design has shifted to developing simple, easily fabricated details. Simple details minimize the labor component of the fabrication, and they tend to perform well under repetitive loading, improving the serviceability of the structure.

Girder web design illustrates this approach. Years ago it was desirable to design girders with fully stiffened webs (webs designed as thin as possible while providing the transverse stiffeners necessary to develop the required shear capacity). Partially stiffened or unstiffened girder webs now tend to be more economical because the fabrication cost associated with additional transverse stiffeners exceeds the material cost for the thicker webs. Having fewer stiffeners also reduces the number of fatigue-prone details, minimizing future inspection and maintenance efforts for the girders.

The use of longitudinal web stiffeners becomes a design consideration for long-span girders. Longitudinally stiffened girders do not become economical until the web depth exceeds 10 feet. Longitudinal stiffeners increase fabrication costs because of the details required at the stiffener termination points and at the intersection with the cross frame connection plates. Longitudinal stiffeners are typically attached to the opposite side of the web from the transverse stiffeners requiring the girders to be turned over during fabrication, increasing the fabrication costs.

Another area to be considered is the sizing of the girders flanges. NSBA speaks to this issue by recommending that the minimum flange width in any field section be L/85 to permit reasonable shipping and handling of the piece. Minimum flange thickness is also important to the overall stability of the girder. As a general rule NSBA states that flanges less than ¾ inch thick by 12 inches wide should not be used. This not only provides stiffness for shipping and handling but also lessens the heat straightening required to meet required tolerances for straightness. The extra top flange material also reduces bending stresses which helps avoid web bend-buckling during deck placement prior to hardening of the concrete.

Material selection is another critical aspect of economical girder design. The most commonly used bridge steel is ASTM A709, Grade 50 or 50W material. It is desirable to use unpainted weathering steel whenever possible. The NSBA publication "Uncoated Weathering Steel Bridges" (Volume 1, Chapter 9 of the *Highway Structures Design Handbook*) summarizes the appropriate use of unpainted weathering steel in bridges. It should be pointed out that detailing is the key to successful use of this product. High Performance Steel (ASTM A709, Grade HPS70W) was developed in the 1990s and offers increased strength and ductility. (Steel TIPS – Dec' 03; Steel Construction in the New Millennium by Pat Hassett)

The width to thickness ratio of the individual plate elements that make up the cross sections of girders can have a significant impact on the strength of the girder. The process of proportioning the plate elements is often based upon geometrical limits on the width to thickness ratio that are referred to as plate slenderness limits. The plate slenderness is primarily important in elements of the cross section that are subject to compression since the buckling performance of these plates is relatively sensitive to the geometrical properties. While slenderness is a common consideration when evaluating the plate bucking performance, the initial imperfection in the plates can also have a significant impact on the behavior. Controlling imperfections in as-fabricated girders can be complicated due to inconsistencies in the plate tolerances, as well as difficulties in defining the out-of-flatness of the plates. Fabricators are typically governed by the American Welding Society (AWS) D1.5 Bridge welding code (2008), which provides some guidance for limits on plate imperfections in fabricated girders. However, difficulties can sometimes arise with plate stock that may satisfy the out-of-flatness requirements of the American Society of Testing and Materials (ASTM) A6 specification, but fails to meet the AWS D1.5 requirements.

3. Transport and Erection

Detailing criteria are also important for both economical fabrication and ease of shipping and erection (see Figures 5-8). Careful consideration of field section lengths and widths is important to economical shipping and erection as much as it is to keeping the field splice sizes to a minimum Again, by using industry input the designer should develop an understanding of common construction methods for bridges. By definition steel erection begins with the loading of members for shipment at the fabrication plant; and is complete when all field connections (bolts and/or welds) are installed to meet the required final design condition, and any falsework is or can be removed. Erection procedure drawings should be prepared by a qualified professional engineer with experience in steel erection and submitted to the owner. These will include site plan, utilities, crane locations and erection sequence. Calculations for the temporary supports, girder stability, rigging and coordination for follow on operations (for example, deck pour) will also be submitted along with a shipping plan showing support, lateral bracing and tie down points (see the figures below).



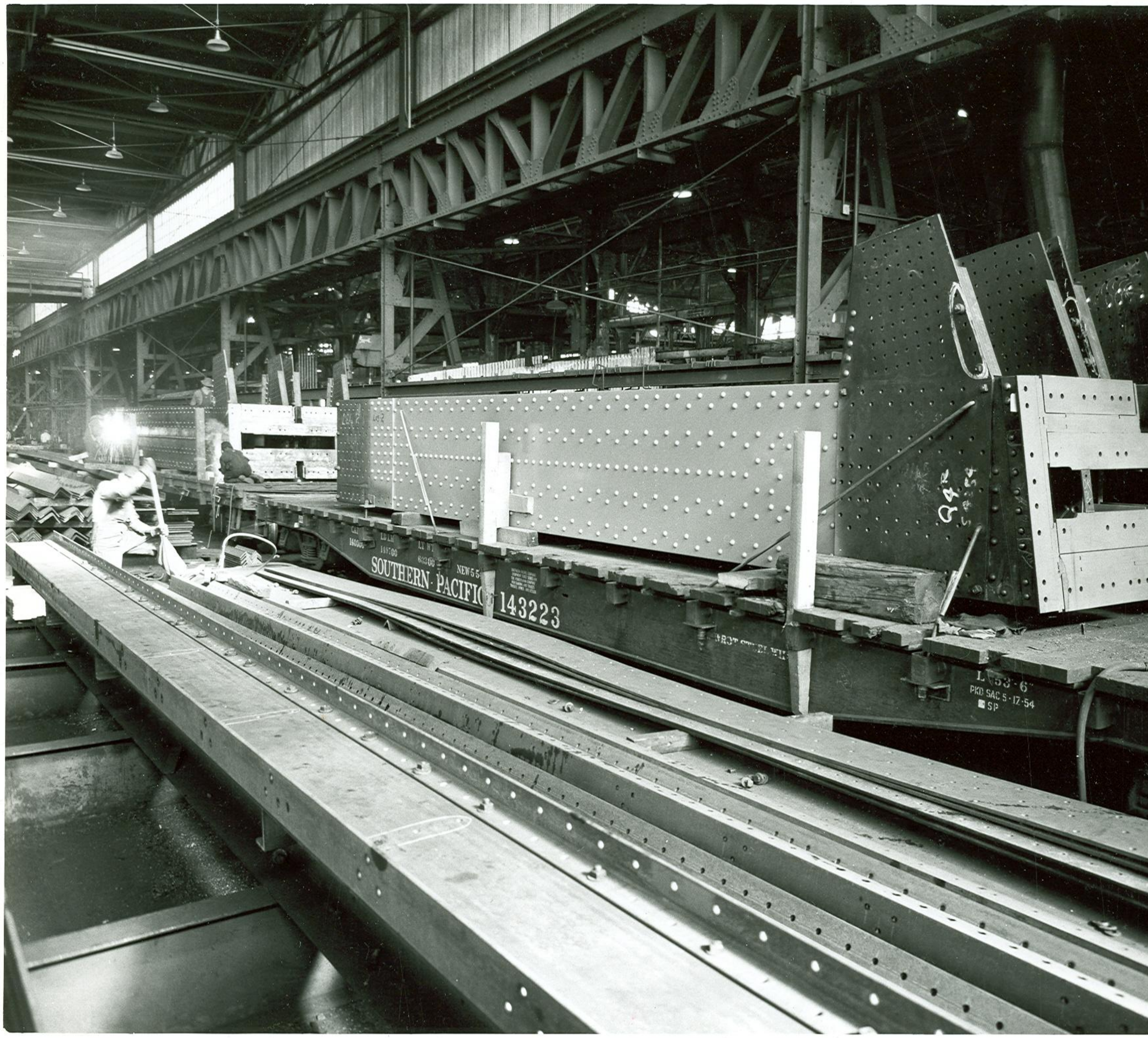

Figure 5 Load Out Richmond-San Rafael Bridge Member

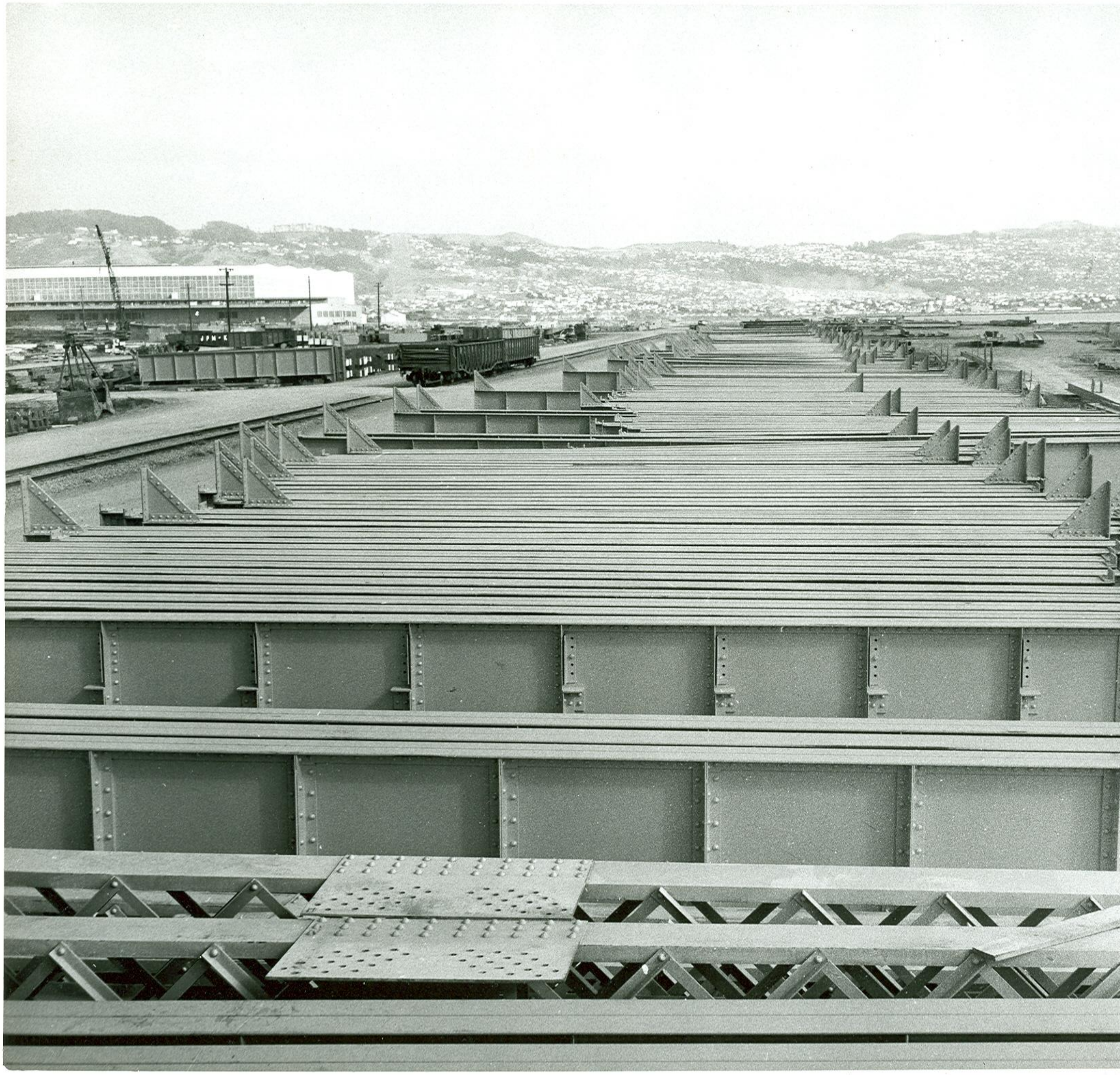

Figure 6 Richmond-San Rafael Plate Girder Floor Beams Awaiting Barge Shipment to Jobsite.

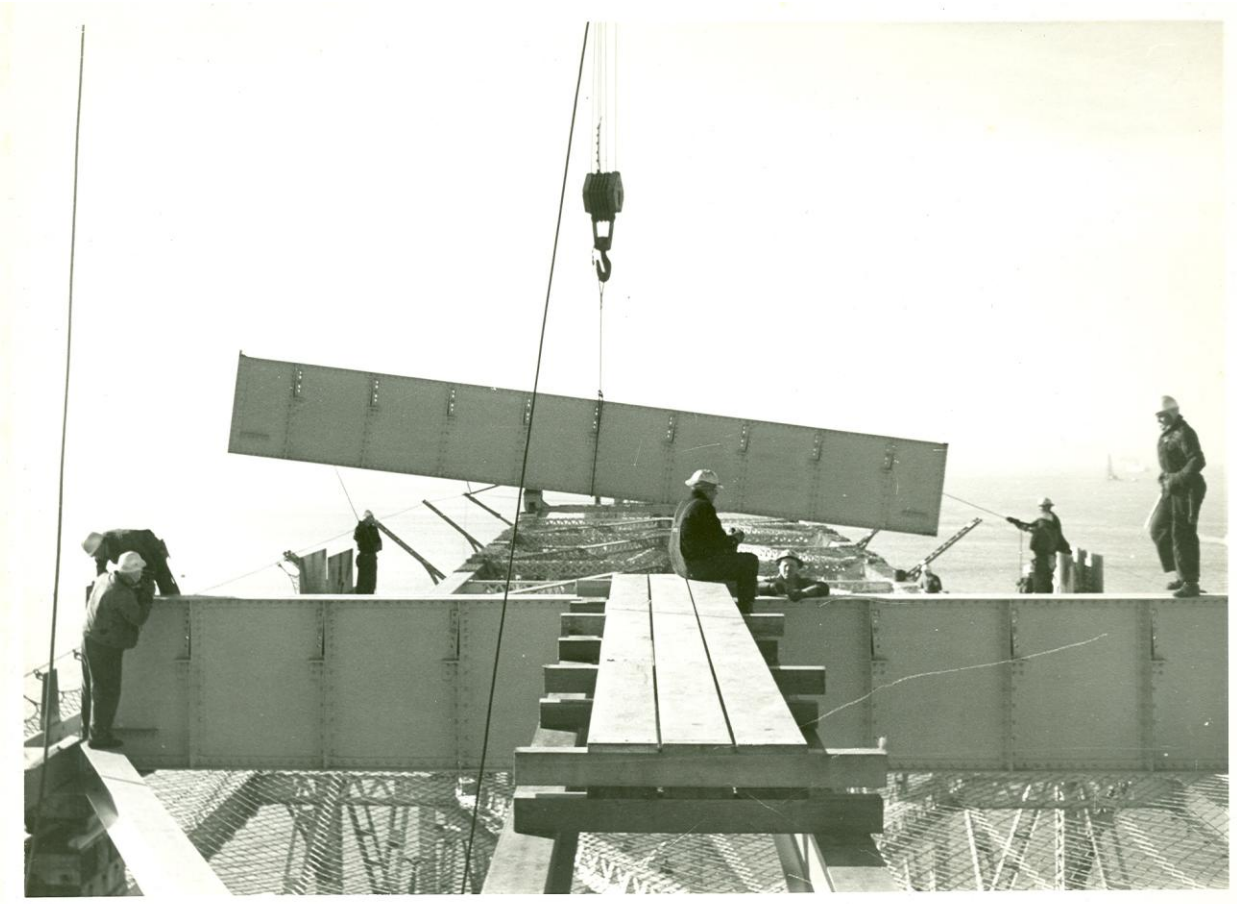

Figure 7 Erecting Floor Beam

Figure 7 shows erection by traveler cranes of a floor beam for an approach truss span of the Richmond-San Rafael Bridge. It is supported on a temporary aluminum deck type truss. Please note the safety net below the not tied-off field ironworkers.

Generally plate girder bridges will be erected by mobile cranes and industry generally has such equipment available with sufficient lifting capacity. Care should be taken however that there is sufficient radius of clear area to allow the crane to boom out. The pieces themselves would normally be shipped by truck in lengths and weights meeting highway restrictions. If necessary the erection pieces could be assembled at the site.

For very long girder spans, stability of the total girder span may be questionable prior to completion of the framing. In such a case a temporary top flange stiffening truss can be attached to stabilize the girder until a second girder line is erected and attached with cross frames to form a stable system. Also as span lengths increase temporary falsework bents may be necessary.

Figure 8 Girder Erection by a Crawler Crane and Also by Incremental Launching with Cable Tie-Backs.

Site access is a significant consideration when assessing girder details. If the terrain is rugged making crane access difficult, or if there are significant environmental constraints, incremental launching of the girders may be a solution. This is a technique that has been developed in Europe mainly on long span bridge construction and has now been used for several bridges in North America.

4. Maintenance

Painting of steel bridges is a major cost concern in West Coast states and weather conditions can vary substantially throughout an individual state such as California. There is also the possibility of using weathering steel. The author brought up this issue with numerous product suppliers exhibiting at the 2007 Western Bridge Engineers Seminar (WBES) and strongly suggests that the designer contact these companies directly. They all stated a willingness to provide technical data and cost analyses along with case histories. Again NSBA can provide a list of these contacts. Preparing surfaces and applying coatings to steel bridge members in a fabricating shop environment improves safety and access to the work, avoids interference from ambient weather conditions, and reduces contamination control problems.

5. Quality Assurance/Quality Control

During all of the aforementioned design and construction processes it is the joint responsibility of the owner and the steel fabricator erector to ensure that proper standards are specified and met. It has become increasingly common that owners are contracting out their portion of this task thereby introducing a third party to the contract. It is imperative that all of these entities have a full understanding of the contract documents prior to a call for proposals. Again the owner should by physically observing and discussing the fabricators in-house procedures to assure that they in fact meet the desired standards.

6. Summary and Example

It is possible for all bridge engineers to design economical steel girder bridges. The key to success is that designers must stay abreast of developments in the steel industry. This will happen by tracking what other designers are doing in the field of steel girder design. More importantly, it is critical that steel designers stay in regular contact with key fabricators in their geographical area in order to learn from those shops what types of details can be fabricated economically. All bridge engineers have access to the tools necessary to design economical steel girder bridges. This can be accomplished by maintaining regular contact with fabricators and erectors in their region.

There has been considerable publicity about the rapid replacement of the fire-damaged steel plate girders in the MacArthur Maze approaching the San Francisco-Oakland Bay Bridge. A presentation at the recent WSBS emphasized how interaction of the fabricator and owner accomplished this. Caltrans on the day of the accident mobilized a worldwide search to assess steel availability and fabrication facilities. This information was gathered within two days and became the critical guide for design engineers to select the reconstruction alternatives. The designers anticipated that the contractor would need a straightforward and simple design to complete the project in the required time frame. With the assistance of fabrication experts they made several engineering judgments allowing delivery of a fast and safe design. The team investigated prefabricated rolled shapes versus built-up sections; however the required rolled-shape sizes were not known to be readily available and would have required several weeks for fabrication; hence the team decided to proceed with built-up sections. In addition, to reduce the number of web stiffeners required and thereby reduce the amount of welding required on the built-up girders, the web thickness was increased. The flange plates were kept to one size only. Web depth was adjusted to ensure that the overall depth would not require adjustment of the existing bearings that were to be reused.

The construction contract that Caltrans then awarded to contractor C.C. Myers of Rancho Cordova, California, specified that their engineers would have only 24 hours to respond to all submittals and requests from the contractor. Providing a comprehensive yet expedited review required significantly increasing the staffing of the review teams. Upon being notified that Myers had selected Stinger Welding in Coolidge, Arizona to be the steel plate girder fabricator Caltrans immediately initiated contact to begin discussing the fabricator's first critical path item before fabrication could start; that being approval of welding procedures and shop details. Caltrans placed a senior reviewer full-time at Stinger Welding to provide immediate guidance; and to meet the accelerated review times directly solicited draft copies of all welding submittals. In this way Caltrans provided the fabricator with immediate feedback, often before the official copy was even submitted.

Three days after the contract was awarded all parties conducted a pre-welding meeting onsite at Stinger Welding. During this meeting, Caltrans provide Stinger Welding with review comments on their Welding Quality Control Plan, to which the fabricator was able to respond immediately. By the end of this meeting Caltrans officials were satisfied with the fabricator's plan and that same evening Stinger Welding began fabrication.

Constant communication played a large role in the success of this project. Daily status meetings with project managers and key Caltrans management cleared hurdles that would have caused costly delays. On the shop floor, Caltrans maintained a constant presence of quality assurance inspectors which proved to be critical to the success of the steel girder fabrication. Designer availability allowed materials engineers to quickly work through any issues that came up. Onsite Caltrans inspectors quickly elevated and addressed any issues that could potentially delay fabrication. See Figures 9 and 10.

Figure 9 Girder Fabrication at Stinger Welding

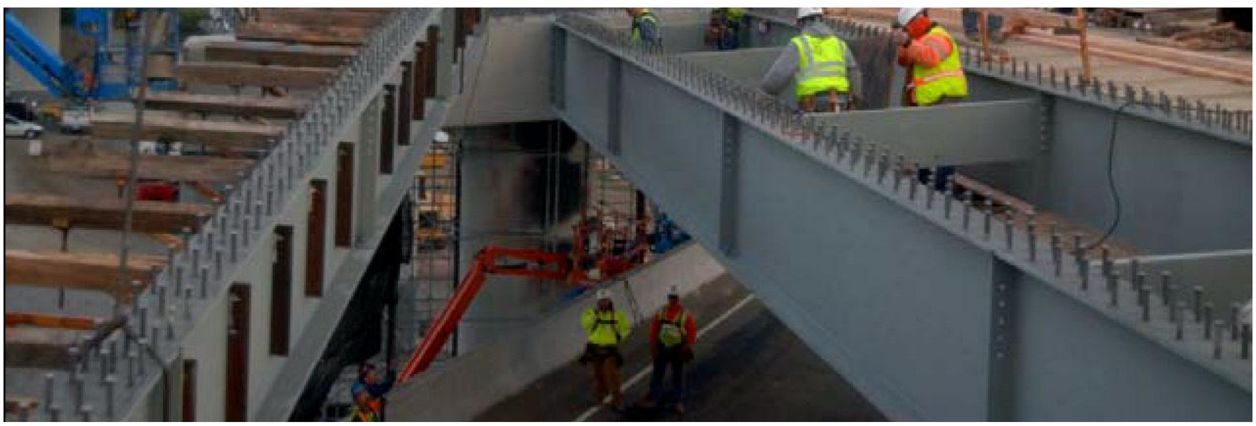

Figure 10 Erecting Final Replacement Girder at MacArthur Maze

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Produced by the National Steel Bridge Alliance; a division of AISC
www.steelbridges.org

About the Author:

Shown here on the right Jay Murphy is a Life Member of ASCE, a Life Industry Member of SEAONC and holds a personal California Class “A” Heavy Engineering Contractor’s License. He spent thirty years working in all departments of his family-owned company and was elected president in 1970. The company ceased fabrication and erection operations in 1983. He now serves as chairperson of Dispute Review Boards and also consults in the area of contract claims

Others shown left to right are Mike Foley, Chief Engineer of the Division of Bay Toll Crossings; Jim Moe, Caltrans Director; and Howard Schirmer, Regional Engineer for AISC.

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Funding provided by the California Field Iron Workers Administrative Trust
A Union Trust Fund

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