Designing for Construction Safety

Taking construction safety into account during the design phase of a project is become more and more common.

BY T. MICHAEL TOOLE, NICOLE HERVOL, AND MATTHEW HALLOWELL

STRUCTURAL ENGINEERS, STEEL DETAILERS, AND OTHER DESIGN PROFESSIONALS ARE STARTING TO EXPLICITLY CONSIDER THE SAFETY OF CONSTRUCTION WORKERS DURING THE DESIGN PHASE OF PROJECTS. There are practical and ethical reasons why designers should consider the "design for construction safety" concept, and there are practical and specific ways that structural engineers and steel detailers can put it into practice.

What is designing for construction safety?

Designing for construction safety is defined as the deliberate consideration of construction site safety in the design phase of a construction project, with the goal of reducing inherent risk to construction workers. It represents a change from custom and practice: the design professional becomes involved in facilitating construction site safety at the earliest stages of a project's life cycle.

Most people are familiar with the term constructability, which refers to the idea of incorporating construction expertise into the design process to ensure that the design is cost-effective and buildable. Designing for construction safety incorporates design decisions that are made based partially on how construction worker safety may be affected and places the project's safety aspects within the constructability review.

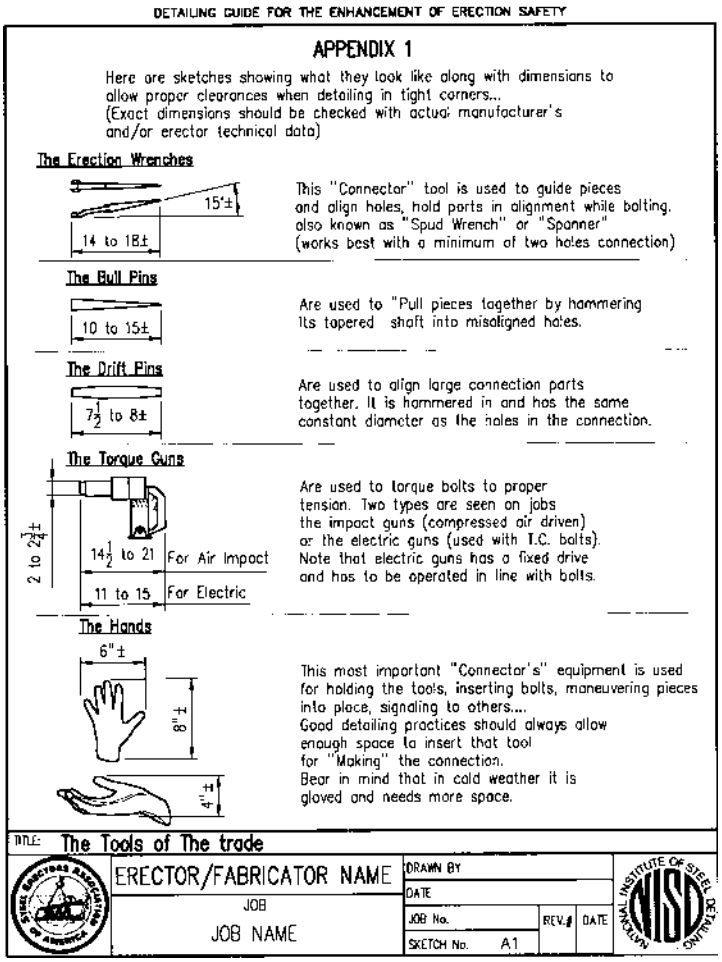
It is important to note that the design for safety concept applies only to the design of the permanent facility; that is, to the aspects of the completed building that make a project inherently safer to build. This initiative does not focus on how to make different methods of construction engineering safer. For example, it does not focus on how to use fall protection systems, but it does include design decisions that influence how often fall protection will be needed. Similarly, designing for safety does not address how to erect safe scaffolding, but it does relate to decisions that influence the location and type of scaffolding needed to accomplish the work.

Why should designers take responsibility?

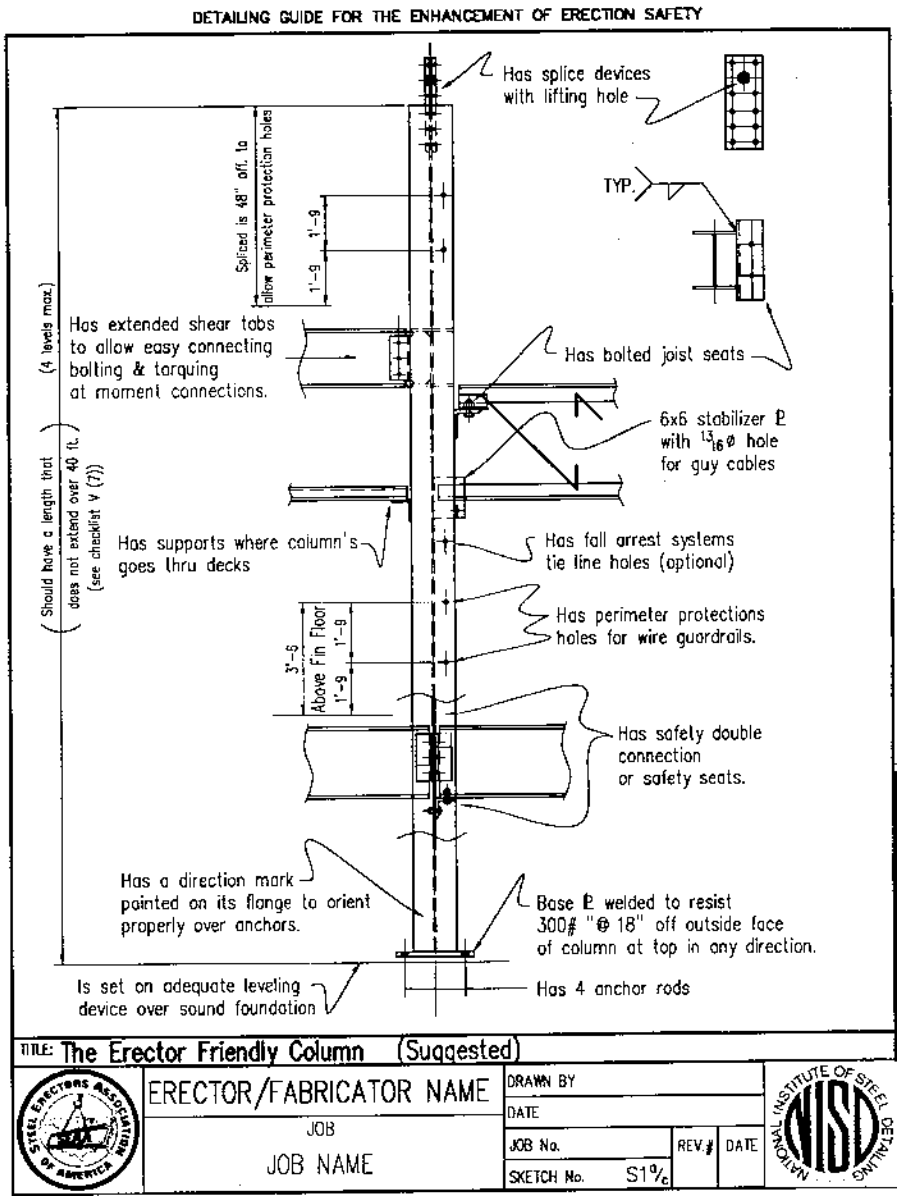
Structural engineers and steel detailers have not actively managed site safety issues in the past for several reasons. For one, model contracts, such as those promulgated by ASCE through the Engineers Joint Contracts Documents Committee, clearly state that designers have no responsibilities for means and methods affecting the safety of construction workers. OSHA standards also support this position by clearly ascribing primary safety responsibility for construction workers to their employers (Toole 2002).

However, researchers and practitioners in the United States and elsewhere have demonstrated that design decisions do affect construction safety (Gambatese 2000; Gambatese Behm and Hinze 2005).

- A 1996 paper showed that 50% of general contractors interviewed identified poor design features as affecting safety (Smallwood 1996).
- A European study published in 1991 found that 60% of accidents studied could have been eliminated or reduced with more thought during design (European Foundation 1991).
- Researchers in the United Kingdom found that design changes would have reduced the likelihood of 47% of the 100 construction accidents studied (Gibb et al 2004).
- An American researcher found that design was linked to accidents in approximately 22% of 226 injury incidents in Oregon,



Sketch A1 from the *Detailing Guide for the Enhancement of Erection Safety*. (See item 9, p. 57.)



Sketch S1a from the *Detailing Guide for the Enhancement of Erection Safety*. (See item 1, next page.)

Washington, and California and to 42% of 224 fatality incidents between 1990 and 2003 (Behm 2004).

Practical Benefits

There are practical and substantial benefits that result from designing for construction safety. Projects that have been designed for safety can often be completed faster because safety-related delays are reduced or eliminated. Designers who are part of design-build teams also can benefit financially from reduced accident rates during construction. And because these benefits are also attractive to owners and developers, progressive clients are increasingly seeking design professionals who are experienced in or willing to incorporate safety design into their projects.

Some designers and detailers may understandably fear that if they make an effort to consider the safety of construction workers, they could face a lawsuit by injured workers. The promoters of safety design are not suggesting that designers should be held partially responsible for construction accidents.

Applying Design for Construction Safety Principles

The two general areas of steel design and detailing that can be positively affected by the application of design for construction safety principles are site and building layout and connection layout, design, and detailing.

Site and Building Layout Issues

The sooner safety is considered, the greater the potential for influencing project safety. Reducing the hazards associated with working at heights is one area where design can make a big difference.

Prefabricated components: On a broad level, the use of prefabricated components reduces the number of activities that must be performed above the ground and therefore reduces the risk of fall-related injuries. For example, prefabricated steel stairs and panelized joist assemblies are common on building projects and prefabricated bridge segments are possible on infrastructure projects. Because prefabricated components are typically lifted into place by cranes, designers must consider horizontal and vertical space needs when making site layout decisions.

Safe crane operation: While crane safety is the responsibility of the operator, design professionals can facilitate safe operations by considering whether the site design provides necessary bearing capacities, sufficient proximity to the building to prevent excessively long load radii, and vertical space that is clear of power lines and other obstructions.

Roof and floor openings: Structural designers can also influence the safety of the project by considering the placement of openings in the roof or floor slabs. Adequate supports may be positioned under decking near openings (NISD/SEAA 2001). Openings for roof skylights may be located away from readily accessed areas on the construction site to prevent falls or to prevent drop hazards from elevated work spaces. Other specific suggestions for skylights include designing permanent guardrails to be installed around skylights or designing skylights to be installed on a raised curb (Gambatese Hinze and Haas 1997).

Another broad-level principle is maintaining a consistent floor layout throughout the building. This not only promotes efficient production but also gives workers the opportunity to have thorough knowledge of the hazards present on each floor. It is acknowledged, however, that architectural concerns, room layout needs, and mechanical systems often limit the extent to which this principle can be applied.

Many examples of construction safety

design do not affect the appearance or performance of the completed structure, but some decisions do result in a final design that is slightly different than what might have resulted otherwise. For example, upper story window sills designed at least 39" above the floor level allow them to function as guardrails during construction. However, only those changes that do not unduly compromise the aesthetics or performance of the completed structure should be pursued.

Connection Layout and Design

OSHA mandates consideration and remediation of many safety hazards throughout the planning and construction phases. Even though safety is ultimately the employer's responsibility, there are many aspects of connection design that structural engineers and detailers can influence to reduce the inherent risk of a project.

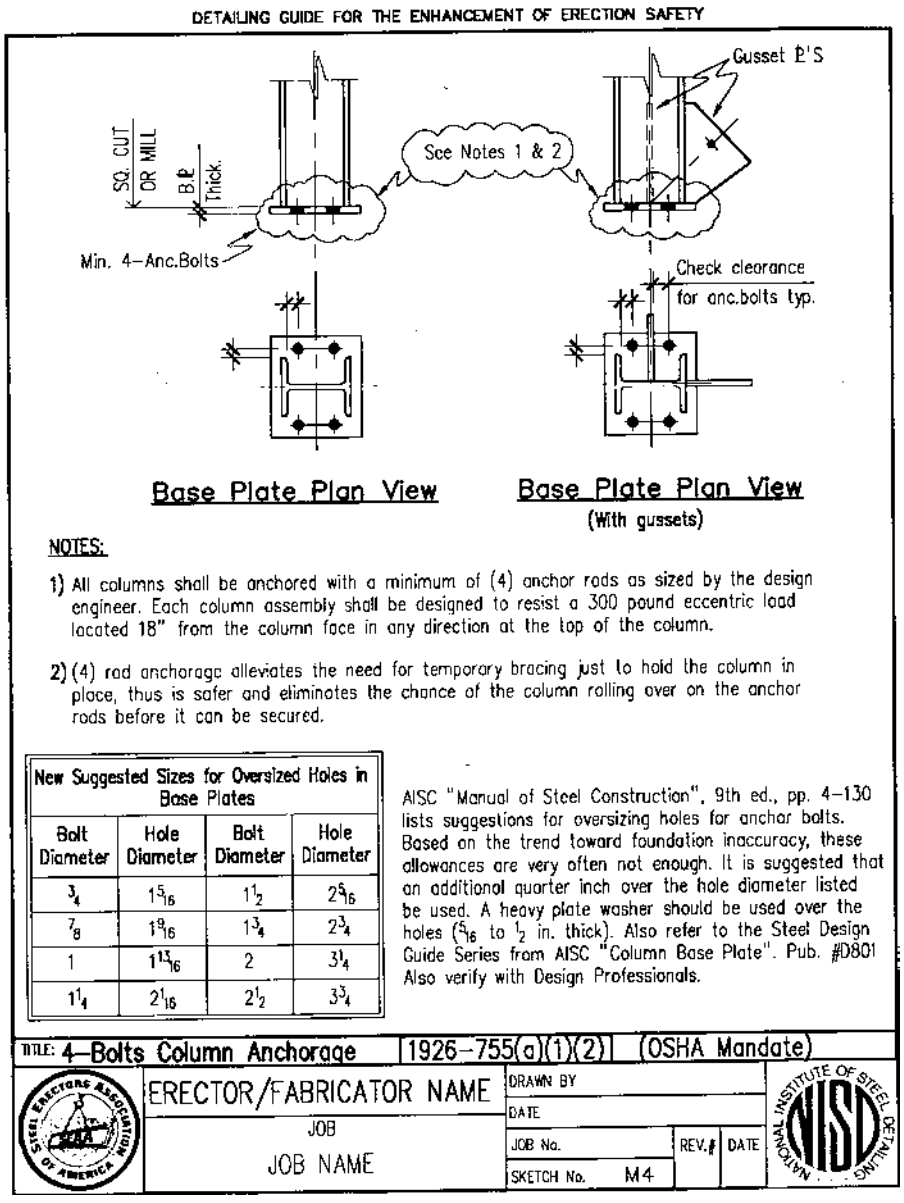
1. **"The erector friendly" column:** Safety and constructability can be improved by specifying holes for tie lines 21" and 42" above each floor slab, safety seats for beam connections, markings for orientation, and secure connections and anchoring systems (NISD/SEAA 2001, sketch S1a/c).

2. **Beam marking systems:** A clear and consistent beam marking system can be established to help workers orient themselves to hazards in certain sections of the structure and increase erection speed (AISC 2002).

3. **Shop welding:** Where possible, specify shop welded connections instead of bolts or field welds to avoid dangerous or awkward positions for the welder or connector (NISD/SEAA 2001, sketch S8).

4. **Dummy hole:** For bolted beam connections, provide an extra "dummy" hole in which a spud wrench or other object can be inserted to provide continual support for the beam during installation of the bolts (Construction Industry Institute 1997).

5. **Column connections:** A minimum of four (and in many cases much more than four) anchor rods must be used to secure columns in order to prevent movement and remove the need for temporary bracing during placement (NISD/SEAA 2001, sketch M4).



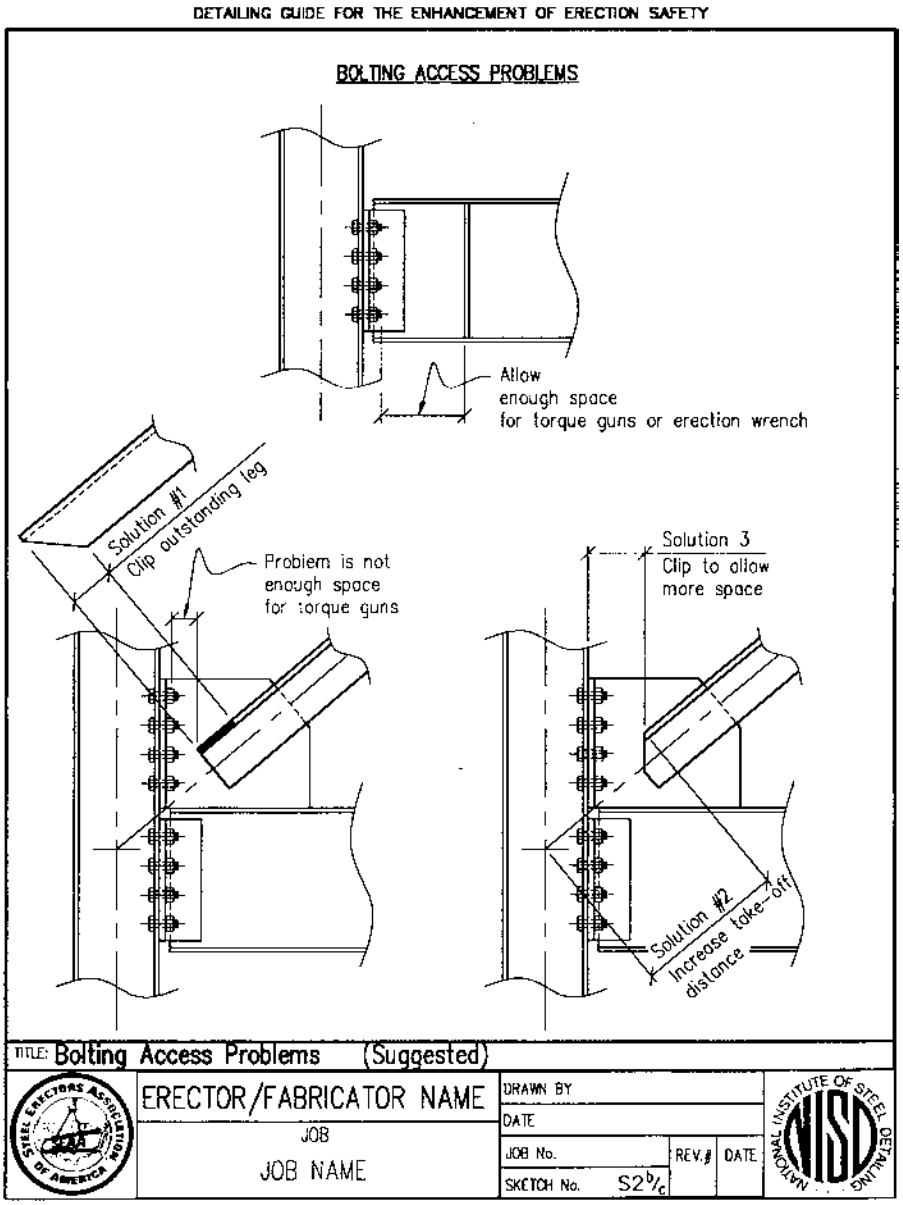
Sketch M4 from the *Detailing Guide for the Enhancement of Erection Safety*. (See item 5, this page.)

6. **Access for connections:** In small (short-webbed) columns, flanges can inhibit access to connections for construction purposes. Plates and bolts can be placed to provide more accessible designs (NISD/SEAA 2001, sketches S2a/c through S2c/c).

7. **Placement of members:** Hands or clothes can be caught in tight spaces when constructing connections, especially near walls. Another prevalent hazard is puncture wounds on sharp corners when not hidden by bracing connections (NISD/SEAA 2001, sketches S3 through S4b/b).

8. **Self-supporting connections:** Avoid hanging connections—design to bear on columns instead (NISD/SEAA 2001, sketches S5a/b through S5b/b).

9. **Know approximate dimensions of necessary tools to make connections:** Familiarity with realistic dimensions can help the detailer specify connections with improved constructability to prevent pinches or awkward assemblies (NISD/SEAA 2001, sketch A1).



Sketch S2b from the *Detailing Guide for the Enhancement of Erection Safety*. (See item 6, previous page.)

10. **Tripping hazards:** Avoid connections or protrusions above floor framing members (NISD/SEAA 2001, sketch M2).

Tools for Construction Safety Design

Tools have been developed by researchers and government bodies specifically to help designers incorporate site safety knowledge into design decisions.

Safety researchers sponsored by the Construction Industry Institute (CII) developed over 400 design suggestions that can be used by design professionals to minimize or eliminate safety hazards (Gambatese Hinze and Haas 1997). These design practices were incorporated into the computer design tool "Design for Construction Safety Toolbox," which can be purchased from CII (**www.construction-institute.org/scriptcontent/more/rr101_11_more.cfm**).

The Health and Safety Executive (HSE) in the United Kingdom (the equivalent of OSHA) has developed several documents that help designers comply with design for construction safety requirements. These documents are available free of charge at **http://www.hse.gov.uk/construction/designers/index.htm**.

Safety professionals in Australia have created a tool called Construction Hazard Assessment Implication Review (CHAIR). CHAIR specifies that all stakeholders review the design in a prescribed manner to ensure the safety and health of all stakeholders is considered. Information on the CHAIR process can be downloaded free from **www.workcover.nsw.gov.au/Publications/OHS/SafetyGuides/chairsafetyindesigntool.htm**.

A question sometimes raised is whether the product of a project that has been designed for construction safety looks different than that of a standard project. For now, the answer is no: drawings and technical specifications on these projects, at least at first, will likely look the same as typical construction documents. Eventually, as industry professionals gain experience and insight, it is hoped that construction documents that were prepared with construction safety in mind will include safety-enhancing details and notes that are not currently found on standard plans and specifications.

Designers' Influence on Safety after Design

There are other tasks that are not related to design decisions per se that designers can perform to contribute to increased safety on project sites:

Procure for safety: Lead design firms are often asked by clients to assist in procuring construction; that is, issuing requests for bids, reviewing bids, and recommending a winning contractor. Designers can suggest that clients consider the safety records and safety programs of bidders when selecting the contractor to receive the contract award. It is ideal to have the request for bid explicitly require bidders to provide specific safety program information, such as their workers compensation experience modification ratings (EMR), OSHA 300 logs for the past three years, and affirmation that they have a written safety plan and designated safety officer.

Review submittals for safety: Structural engineers are often required to approve shop drawings from detailers and subcontractors, which provides an opportunity to review these drawings for specific safety issues. The premise behind this review is not that the designer has responsibility for managing possible hazards; rather, the premise is that the more professional eyes review documents, the less chance there is that an unnecessary hazard will slip through the cracks and onto the construction site.

Inspect for safety: Structural engi-

neers are often required to observe structural systems under construction to monitor progress and compliance with technical specifications. While on site, designers could also monitor for compliance with the safety requirements indicated in the contract documents (plans, technical specifications, and general conditions), submittals, owner standards, or OSHA standards. Designers could use their expertise to spot hazards associated with the improper application of engineering principles, such as with retaining walls, falsework, and scaffolding systems. MSC

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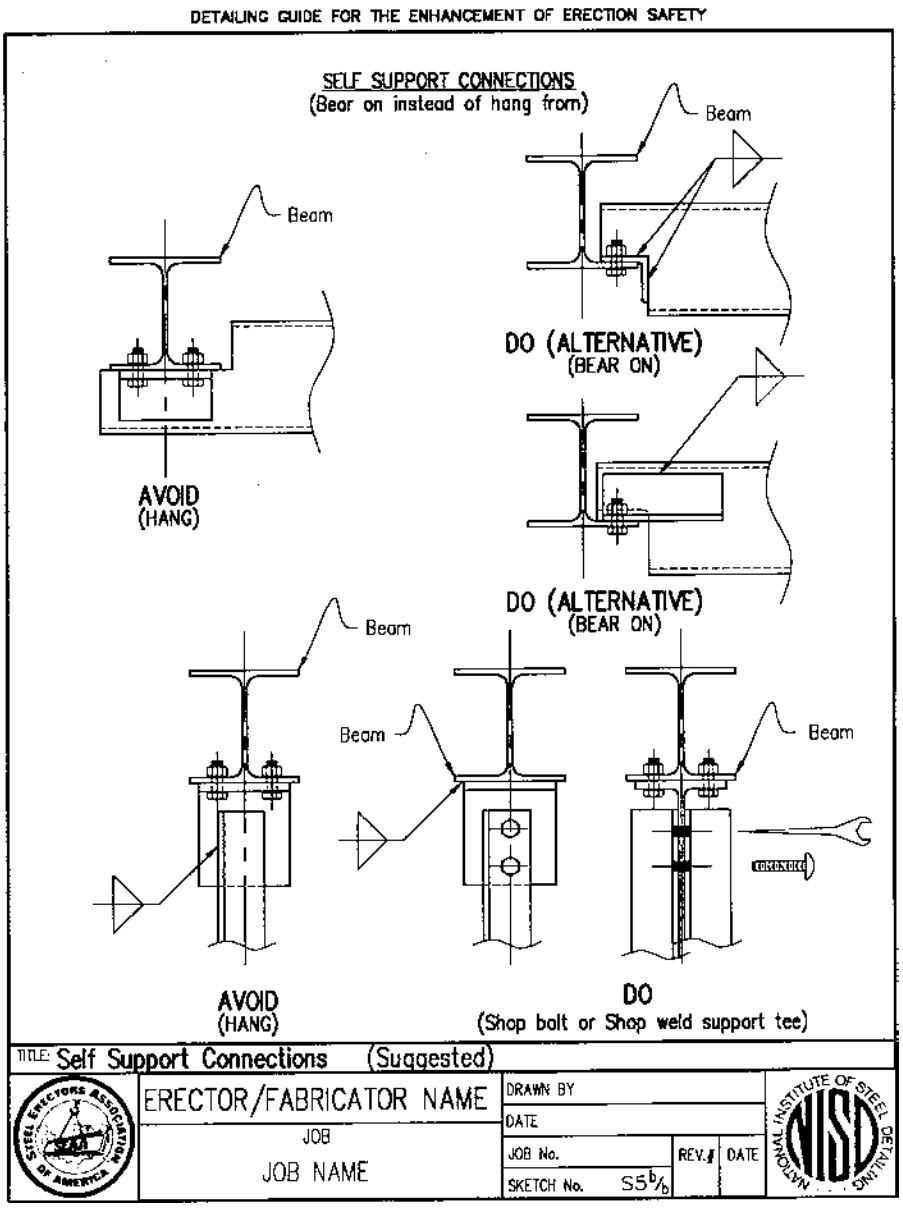

Sketch S5b from the *Detailing Guide for the Enhancement of Erection Safety*. (See item 8, p. 57.)

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