When safety is addressed during design,
it can become easier to implement during construction.

Safety Hazard Prevention, BY DESIGN

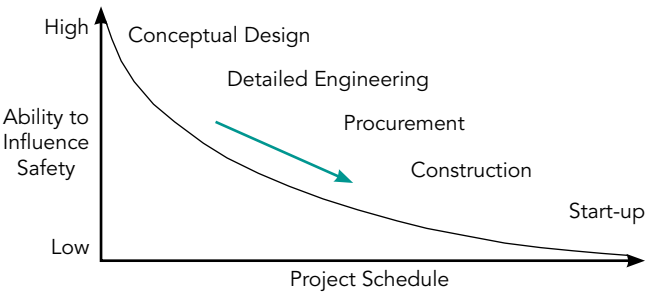
BY JIE ZUO

THE CONTROLLING CONTRACTOR is typically responsible for the means, method and overall safety of construction on the job site.

They must direct, coordinate and monitor the work of the subcontractors in a safe and efficient manner, knowing that the success of the project is often made by intricate planning and critical decision-making while on-site. However, the controlling contractor is actually just one of many influences on construction safety.

Personal protective equipment is often the most visible evidence of the safety efforts undertaken on a job site. In fact, this equipment more truly represents the last line of defense against working hazards. Other mechanisms that can prevent hazards from developing should be implemented to create hazard protection much earlier.

Over the course of a project schedule, the ability to influence construction safety decreases as the schedule progresses (see Figure 1). This creates a conundrum. While safety is the responsibility of the construction team and not the design team, the decisions made in the design phase can improve and reduce safety hazards. Safety hazards anticipated in the design phase often can be eliminated if they are recognized; if they are not addressed by the time the construction phase begins, safety hazards must instead be planned around and prepared for. Thus, as the designer chooses the plan and layout of the structure, safety can be improved through careful consideration of the procedures, equipment and techniques required to build it.



▲ Figure 1. The influence of safety over a project schedule.

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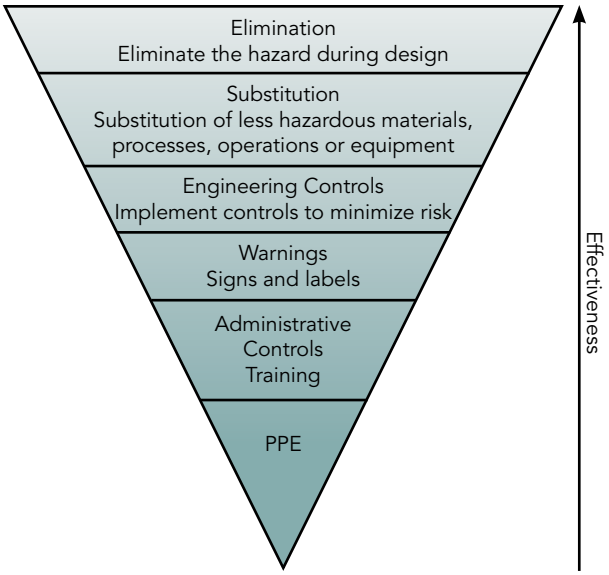
Figure 2 shows a hierarchy of safety controls in the order of their effectiveness, emphasizing that the most effective way to address a working hazard is by eliminating it at its source, when possible, in the design phase. If this cannot be done, each solution below that in the hierarchy is slightly less effective but still necessary.

In 2007, the National Institute of Safety Hazards (NIOSH) partnered with a number of industry organizations and state governments to launch a national initiative aimed at reducing occupational hazards and controlling risks at the source where they are created—or as early as possible in the schedule of a construction project. Recognizing the aforementioned conundrum, the program calls for a new construction model based upon extensive collaboration between the designer and controlling



▲ Figure 2. The hierarchy of safety controls.

contractor and has resulted in technical reports, presentations and workshops around the country. (For more information, visit www.cdc.gov/niosh/programs/ptdesign.)

Further guidance is available from the American Society of Safety Engineers, which developed a guide to help designers understand how to prevent hazards with design concepts. ANSI/ASSE Z590.3-2011 *Prevention Through Design: Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Process* became effective in January 2012 and can be used by engineers and controlling contractors alike to learn how to make it a successful process.

In addition, there are several more recommendations on how engineers can help control hazards and mitigate dangers before a construction worker even steps foot onto a job site. One must keep in mind that in order for this type of construction model to be successful, the engineer must understand what consequences their designs have on safety and that may require collaboration with the controlling contractor.

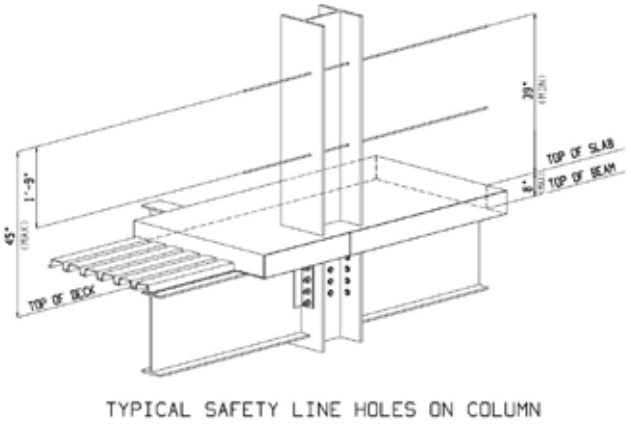
Maximize Off-Site Fabrication

The job site is a much less predictable environment than, say, a fabrication shop. Both have "moving parts" but those on the site are less regimented—plus there are uncontrollable aspects, such as weather conditions. The fabrication shop, on the other hand, is a more controlled atmosphere with fewer hazards and also provides access to equipment that may not be available in the field. By specifying work to be performed off-site, the engineer can reduce potential hazards and may even increase productivity or quality of work. For example, a worker making a difficult overhead weld in the shop is subject to less risk than a worker making the same weld in poor weather conditions while being several stories up in the air.

Design for Fall Protection

Structural framing decisions can make fall protection easier and more effective in the field. Here are some safety considerations for fall protection:

- In the design of beams, an engineer can specify a member size with a flange width of at least 6 in., which allows for an adequate walking surface.
- In the design of columns, an engineer can specify holes for safety cables at 24 in. and 45 in. above the metal deck for guardrail installation, as shown in Figure 3. This satisfies OSHA requirements and provides workable protection for both the steel erector personnel on the bare metal deck and workers from other trades after the concrete slab has been placed.



▲ Figure 3. Placement of safety cable holes on a column.

- Recognize that openings in the plan may require anchorage points for safety lanyards. Talk with a steel contractor about which beam sizes will work for the number of anchorage points that will be required for a given beam or opening.
- Where there are floor openings, one can place beams adjacent to the opening to support anchorage points for safety lanyards.
- It is prohibited to shop connect headed steel stud anchors and deformed anchors where they will obstruct the walking surfaces of beams or joists.
- When possible, one should design the steel framing with a consistent floor layout. This makes it easier for the construction worker to learn the hazards of each individual floor early and not have new hazards to face as floor layouts change.

Design Safe Connections

Connection design decisions also can make fall protection easier and more effective in the field. Here are some connection safety considerations:

- It is an OSHA requirement that column splices must be located at least 4 ft above the finished working floor such that it is away from the beam-column connection and allows for perimeter safety cables to be installed. However, the 4-ft column extension limit is sometimes not enough and can still cause interference between the splice plate and the holes for safety cables shown in Figure 4a. For constructability reasons, it is recommended that the column splice be conservatively located 5 ft above the top of the beam shown in Figure 4b.

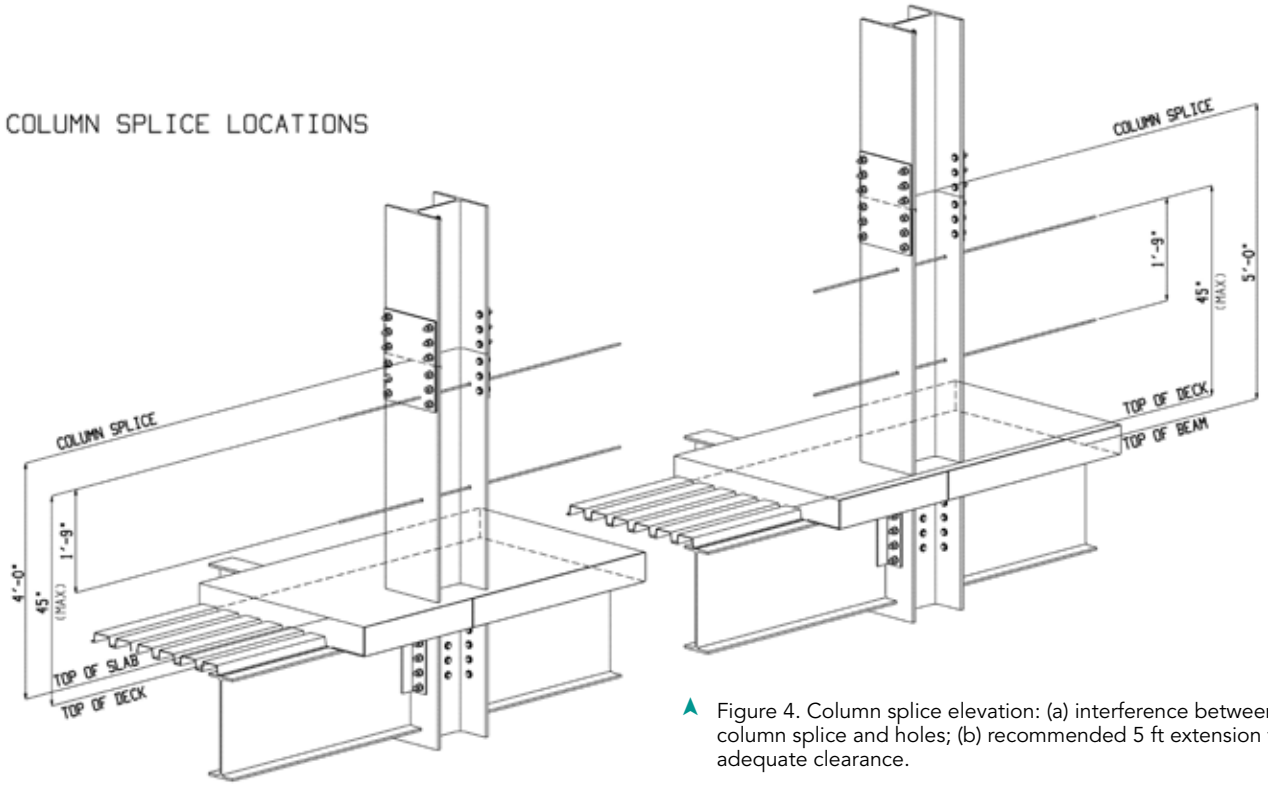
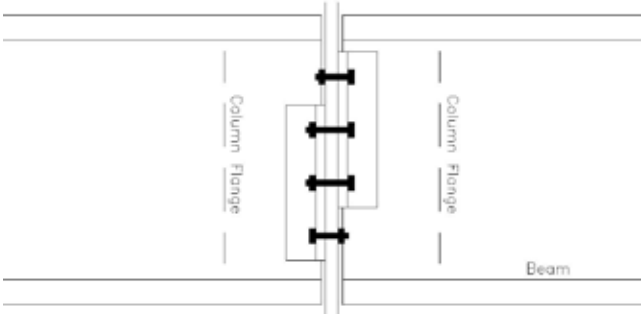


Figure 4. Column splice elevation: (a) interference between column splice and holes; (b) recommended 5 ft extension for adequate clearance.

Figure. 5 Angles are staggered and an extra row of holes is provided in the column web to allow for safer erection.

- OSHA requires a minimum of four anchor rods in every base plate for temporary column stability before the beams are erected.
- There are additional hazards involved in the design of connections where the beam is supported by hanging off of a connecting element. This requires the use of a crane to hold up the beam during installation. To avoid this hazard, one can design a seat angle connection such that the beam rests on top of the angle, making the connection installation safer and more stable.
- When detailing all-welded connections, one should recognize that erection aids and bolts may be necessary to provide immediate stability prior to welding.
- Design of welded connections requiring difficult welding positions should be avoided when possible. Welding in the flat position is the least problematic. Vertical and overhead positions are more difficult because there is no underlying support surface. Overhead is the most challenging position because gravity tends to make it difficult to make a proper weld.
- Consider cases where OSHA prohibits a double connection, such as when two double-angle connections frame into opposite sides of a column web and share common bolts. One solution is to stagger the double angles (Figure 5) such that the second row of bolts on the first beam connection coincides with the first row of bolts on the second beam connection. This allows the first beam to connect to the column securely before beginning to make the connection on the other side.
- It is generally recommended to use as few bolt sizes as necessary. Multiple bolt sizes, particularly sizes that appear identical to the naked eye, can lead to the wrong size being used in the field.



- It is important to understand what tools are required to install a connection and provide adequate space in connection design to facilitate the use of those tools in assembling a connection.

Control Roof and Floor Openings

Design engineers and controlling contractors need to be aware that small openings in floors and roofs must not be cut until the trade contractor filling those openings is ready to place the object. This applies to holes for such items as duct work, piping and exhaust fans. Metal deck should span over small openings until ready to be cut and filled. Large openings that cannot be safely spanned by decking due to constructability, such as elevator openings and stair openings, must be cut and guarded by the steel erector.

Prevention of hazards through design requires collaboration. It also leans upon the engineer to understand more about the techniques and tools used on a construction site. Fortunately, the steel fabricator can help!

The engineer and controlling contractor need to be able to communicate effectively in order for them to understand

OSHA Standard	Notes
1926.502(b)(1)	Top edge height of top rails, or equivalent guardrail system members, shall be 42 in. (1.1 m) plus or minus 3 in. (8 cm) above the walking/working level. When conditions warrant, the height of the top edge may exceed the 45-in. height, provided the guardrail system meets all other criteria of this paragraph. Note: When employees are using stilts, the top edge height of the top rail, or equivalent member, shall be increased an amount equal to the height of the stilts.
1926.754(c)(1)	Shear connectors (such as headed steel studs, steel bars or steel lugs), reinforcing bars, deformed anchors or threaded studs shall not be attached to the top flanges of beams, joists or beam attachments so that they project vertically from or horizontally across the top flange of the member until after the metal decking, or other walking/working surface, has been installed.
1926.756(e)(1)	The perimeter columns extend a minimum of 48 in. (1.2 m) above the finished floor to permit installation of perimeter safety cables prior to erection of the next tier, except where constructability does not allow.
1926.755(a)(1)	All columns shall be anchored by a minimum of 4 anchor rods (anchor bolts).
1926.754(e)(2)(iii)	Metal decking holes and openings shall not be cut until immediately prior to being permanently filled with the equipment or structure needed or intended to fulfill its specific use and which meets the strength requirements of paragraph (e)(3) of this section, or shall be immediately covered.

▲ This table provides additional information on the OSHA standards discussed in this article.

each other's work. The benefits are increased productivity and fewer lost-time accidents. Several major U.S. contractors have successfully implemented this construction model in design-build projects, and choosing to discuss safety in the design phase can help your projects too. ■