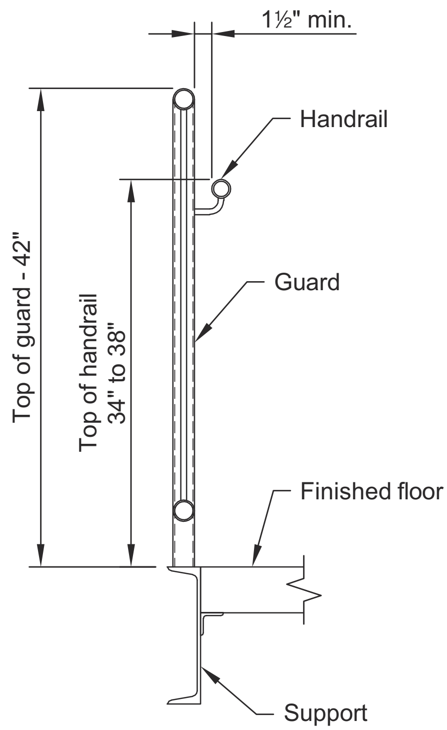

Fig. 7-2. IBC-style stairway guard, section view.

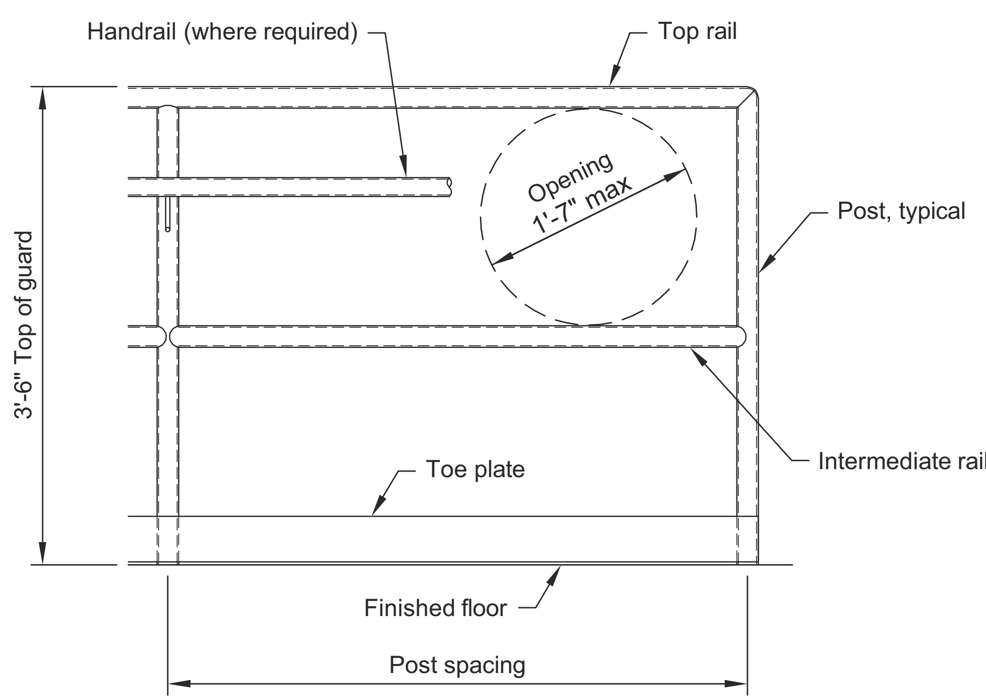

Fig. 7-3. OSHA-style guard, elevation view.

size is larger based on occupancy and use. For an OSHA-compliant stair, openings cannot exceed 19 in. in the smallest dimension.

Consideration should also be made to the layout of infill members to avoid creating a ladder effect. The ladder effect exists when infill members are oriented in a manner that allows an occupant (most likely young children) to climb the infill members. It is the responsibility of the architect to determine when the ladder effect could pose a concern based on the project type and occupancy.

7.2.5 Handrail

The handrail is provided for guidance and support of occupants traveling on the stairway. The handrail may be supported from the guard or wall mounted. Refer to the applicable project code to determine the height range at which to set the handrail above the walking surface and required clearances from obstructions. The applicable code will also provide graspability requirements that dictate the size and layout of the handrail. The handrail must have the strength and stiffness to span from support point-to-support point for vertical, lateral and axial forces.

7.2.6 Toe Plate

Toe plate or toeboard is provided to prevent debris or objects from falling off of the stairway or landing to the area below. Toe plate is typically required for OSHA-compliant stairways, landings and platforms. Toe plate should be provided in any situation where falling debris could pose a concern. Commercial stairs may not need toe plate in an occupancy where there is minimal risk of objects falling (i.e., office building). Designers should verify the need for toe plate with the architect. Alternatively, some stairway and guard designs will adjust the top of steel of the support member, shifting the top of steel above the finished floor, to act as the toe plate.

7.3 GUARD AND HANDRAIL CONNECTIONS

Connections for the guard and handrail system will vary based on the members being used. Most often steel guard and handrail assemblies are shop welded to the largest shippable size and then field welded or bolted to the stair stringer or other supporting structure.

7.3.1 Rail-to-Rail Joints

Steel members comprising the sloping or horizontal rails, vertical posts and infill pickets can be joined by welding. Fillet welds and butt welds are the most typical welds used to join these elements. Finishing of these welds is also important. Refer to the NAAMM *Pipe Railing Systems Manual Including Round Tube* for guidance on the levels of finish required at these joints.

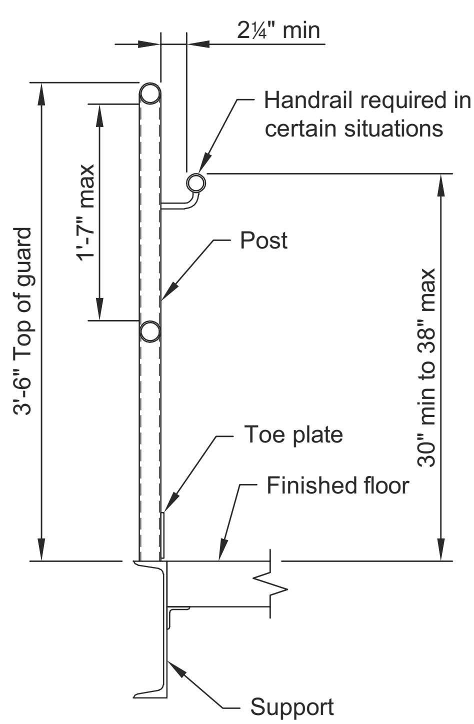

Fig. 7-4. OSHA-style stairway guard, section view.

7.3.2 Handrail Support Brackets

Support brackets for handrail can be fabricated from steel bar or rod and can also be purchased from a manufacturer. Designers should verify that the bracket and its fasteners are adequate to support the loads imposed on handrails, accounting for both vertical and lateral forces.

Support brackets purchased from manufacturers should come with testing documentation showing that the brackets meet the requirements of *Standard Test Methods for Performance of Permanent Metal Railing Systems and Rails for Buildings,* ASTM E935 (ASTM, 2013) and *Standard Specification for Permanent Metal Railing Systems and Rails for Buildings*, ASTM E985 (ASTM, 2006). Other appropriate testing to verify the brackets meet the load and deflection requirements of the code may also be acceptable. Note that at the time of writing, ASTM E985 has been withdrawn.

7.3.3 Post-to-Stringer

The guard post-to-stringer connection will most typically resist the largest design forces of all the elements and connections in the guard system. The post may be mounted to the face of a plate stringer or HSS member, as shown in Figure 7-5. Alternately, the post may be mounted to the top of a channel stringer or HSS member, as shown in Figure 7-6.

For posts mounted to the face of the stringer, welding or bolting to the stringer should be designed to provide the required strength to resist the vertical, lateral and torsional forces. Designers should ensure that the torsion in the stringer can be resisted by the member and end connections. One option to do so is to use the risers and treads to resist any force couples.

For posts mounted to the top of the stringer, welding is more common. Designers should carefully select a post size and weld that will fit on the top flange of the stringer and that also provides adequate strength for the combined forces.

Additional design requirements related to testing of railing systems is provided in *Standard Test Methods for Anchorage of Permanent Metal Railing Systems and Rails for Buildings*, ASTM E894 (ASTM, 2018). This ASTM standard provides the specifications for testing of a guard and handrail system to ensure it meets the governing building code.

When using pipe for the post, fillet welds are the easiest and most common option for connecting to the top flange of the stringer. When space is limited, a one-sided complete-joint-penetration (CJP) square groove weld in a butt joint configuration can also be used. However, this type of weld is not an AWS prequalified weld unless a backer bar is provided. If a backer bar is not used, the fabricator may be required to qualify the weld procedure and welders in accordance with AWS D1.1/D1.1M (AWS, 2015).

As noted previously, the applied moment at the top of the stringer should be considered by the designer. For channel stringers, additional checks should be made to determine if the top flange is adequate or if a stiffener plate should be provided at the location of the moment.

Based on past experience and finite element analysis, the author suggests using the following formula to establish the effective width of a channel flange when analyzing the stringer for the imposed moment from a guard post. The formula utilizes a 2.5:1 distribution to determine the effective width of the resisting element.

$$B_{eff} = N + 2(2.5)\left[\left(k - \frac{t_f}{2}\right) + b_f\right] \tag{7-1}$$

where

N = guard post diameter, in.

b_f = flange width, in.

k = beam fillet dimension, in.

t_f = flange thickness, in.

Utilizing Equation 7-1 for a single post mounted to the top flange of a channel without consideration of frame action or load sharing in the guard system, the author recommends

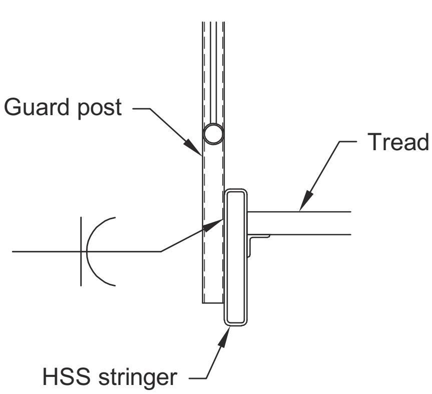

Fig. 7-5. Guard post mounted to side of HSS member.

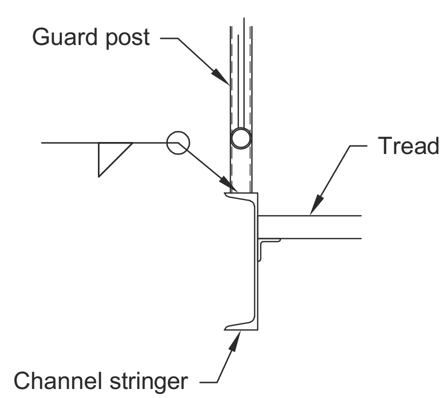

Fig. 7-6. Guard post mounted to top of channel.

that channel members with webs equal to or thinner than ¼-in. thickness should be fitted with a stiffener plate below the post to the channel to resist the applied moment. A more detailed analysis or alternative methods may show that the stiffener is not required. Engineering judgment should be used to determine the appropriate details at the post-to-channel flange junction.

7.3.4 Post or Handrail at Concrete or Masonry

Posts may be set into concrete slabs and floor systems in core-drilled holes filled with grout. This can be an effective detail for interior environments as long as adequate concrete depth is provided and the post location is away from concrete edges. This detail can also be used for exterior stairs, but material finish and concern for rust or failure at the steel-to-grout and concrete joint should be considered. This may be a maintenance issue that must be addressed over time and should be discussed with the end user or owner during design.

Wall brackets can effectively be used at concrete and masonry walls to support handrail. Refer to the previous section for general information regarding handrail support brackets. The use of approved, post-installed screw anchors is typical for attachment to concrete or masonry walls.

7.3.5 Handrail at Stud Wall

The use of handrail support brackets-to-stud walls is typical. Designers should ensure that additional blocking or support members are provided within wood or metal stud walls that can provide adequate resistance to the required loads. Attachment directly to gypsum board or wood sheathing is rarely adequate to support the code required loads. Fasteners must also be checked to ensure they are adequate to resist the imposed handrail forces. Refer to the previous section for general information regarding handrail support brackets.

Chapter 8
Additional Considerations

The wide use and variety of stairways presents a challenge for designers because there is not a single “typical” stair that can be provided for each project. Each stairway has its own set of challenges and project-specific requirements. Presented in this chapter are several additional items that require consideration in the design of steel-framed stairways.

8.1 CONSTRUCTION TOLERANCES

Construction tolerances of different materials can present a major challenge when designing, detailing, fabricating and erecting a steel stairway. Tolerances vary for steel, concrete, masonry and other materials. The designer should refer to material specific standards or guides for information on construction tolerances. Additionally, the *Handbook of Construction Tolerances* (Ballast, 1994) provides a valuable resource for the different tolerances for each material type and use.

It is important to recognize that stair layout and geometry must be maintained as required by the governing building code when tolerances for the support structure alter the layout as detailed. It is critical that dimensional uniformity is maintained and that maximum and minimum required dimensions for stair geometry are maintained. This may require that the support structure or the stairway be modified to ensure that the stair layout remains code compliant.

The recommendations presented herein are based on best practices and experience related to the design, fabrication and construction of steel stairways. In unique or unusual situations, designers must use their own judgment to determine appropriate design and construction criteria. Designers should consult with stair suppliers for additional input and recommendations.

8.1.1 Steel

Steel stairways connected to steel structures typically use a variety of framing arrangements, including stringers attached to main floor beams, intermediate landings with posts, hangers from main floor beams, and stairway perimeters enclosed by stud walls. Tolerances affecting steel members include mill variations, fabrication tolerances and erection tolerances. All of these items can affect both the supporting steel structures and the steel stairways.

Mill variations are based on tolerances provided in ASTM A6/A6M (ASTM, 2016a). Rolled shapes with acceptable mill tolerances may create fit-up issues unless connection details allow for adjustment. Additional information and tolerance limits can be found in AISC *Code of Standard Practice* Section 5.1 (AISC, 2016a). Conformance to this AISC standard should avoid most issues due to mill variations.

Fabrication tolerances are presented in AISC *Code of Standard Practice* Section 6.4. In most cases, providing connections with adjustability consisting of slotted holes or shim gaps should help to minimize issues related to fabrication. Conformance to the AISC *Code of Standard Practice* should avoid most issues due to fabrication tolerances.

Erection tolerances for the steel structure are presented in AISC *Code of Standard Practice* Section 7.13. In many cases, the position of structural members near stairways will be based on a maximum placement tolerance limit of 1/500 of the distance between working points. For most stairways, providing a gap from ¼ in. to ⅜ in. between the stairway member and the support structure (or stud walls) will provide sufficient clearance, but individual cases may vary. The *Handbook of Construction Tolerances* also recommends a tolerance of ±⅜ in. for horizontal and vertical positioning of secondary steel elements.

Additional tolerances related to architecturally exposed structural steel (AESS) are presented in the AISC *Code of Standard Practice*; fabrication and erection tolerances are covered in Sections 10.2 through 10.6.

The combination of these tolerances can create problems if allowances are not provided during design and detailing. Common allowances include providing a gap between stairway members and steel structures or stud walls, using connections with slotted holes or shim gaps, and welded connections with adjustment for fit-up. Addressing tolerance issues in advance will reduce the chance of problems arising during construction, but in some cases, field fixes will be unavoidable.

8.1.2 Cast-in-Place Concrete

Specification for Tolerances for Concrete Construction and Materials, ACI 117 (ACI, 2010), indicates that concrete construction allows for a ¼-in. variation over 10 ft of length from plumb in the placement of columns and walls. Distances between walls, columns, partitions and beams may vary by up to ¼ in. per 10 ft of distance but not more than ½ in. in any one bay. For many stairways, providing a gap of ¼ in. to ½ in. will provide sufficient clearance from the adjacent concrete structure, but individual cases may vary.

The design should also note that individual cast-in-place members can also have permissible variations. Column sections, beam sections and floor openings are examples.

According to the *Handbook of Construction Tolerances,* cross sections up to 12 in. can vary +⅜ in. to −¼ in., and floor openings can vary by +1 in. to −¼ in. and may be misplaced in plan by ±½ in. in each direction.

Due to these variations, it is recommended to field verify critical dimensions before fabrication commences. Using connection details with adjustability at locations framing to concrete can also avoid fit-up issues in the field.

8.1.3 Masonry

ASTM C90 (ASTM, 2016b) provides the tolerances for hollow load-bearing concrete masonry. Concrete masonry units are produced in nominal dimensions with the actual dimensions set to ⅜ in. less to accommodate a mortar joint. In the field, concrete masonry units can vary by ±⅛ in. in width, height and length.

Masonry construction allows for ±¼ in. variation in 10 ft, ±⅜ in. in 20 ft, and up to ±½ in. maximum for plumbness of walls and columns. Columns and walls continuing from one story to another may vary in alignment by ±¾ in. for nonloadbearing walls or columns and by ±½ in. for bearing walls or columns. For many stairways, providing a gap from ¼ in. to ½ in. will provide sufficient clearance from the adjacent masonry structure, but individual cases may vary.

Due to these variations, it is recommended to field verify critical dimensions before fabrication commences. Using connection details with adjustability at locations framing to masonry can also avoid fit-up issues in the field.

8.2 GALVANIZED STAIRWAYS

Galvanizing steel provides an exterior coating that gives members enhanced corrosion protection in certain environments. Galvanizing produces a different aesthetic finish and also requires additional considerations for design and construction. Some of these considerations when specifying galvanizing include:

- Field welding should be avoided. Welding galvanized members requires that the galvanized coating be removed to perform the weld, and members must be touched up after welding is complete. Field bolting is typically preferred.
- Bolt hole size considerations. The galvanizing process creates a coating on all member surfaces that may reduce the size of bolt holes. Coordinate with the fabricator and galvanizer to determine appropriate hole size. Providing oversized holes will typically provide adequate clearance for bolt installation but will also require the use of a slip-critical joint, which requires additional preparation.
- Hardware and weld metal matching. Use the appropriate galvanized bolts, hardware and weld materials to avoid issues with dissimilar metals in contact.
- Unsafe environments. Galvanized stairways should not be used in highly acidic environments, highly alkaline environments, or very high temperatures (over 400°F).
- Limitations on size of piece or assembly to be galvanized. Consult with the galvanizer for limits.
- Drain hole/air hole required in closed sections for galvanizing process.
- Distortion. Galvanizing may cause distortion of certain shapes or assemblies.

Galvanized stairways may be a desirable option for certain environments, but designers and fabricators must take care to ensure that proper details are used. Galvanizing will likely be more expensive for fabrication and installation but may be a good option for long-term maintenance and performance.

8.3 LONG-SPAN STAIRWAYS

Stairways with long simple spans will require additional structural analysis to ensure adequate stiffness. Long-span stairs typically incorporate plan bracing at the bottom flange of stringer members to stiffen the stairway to minimize lateral movements due to occupant loads. Cambering stringers for the dead load deflection may also help to meet serviceability requirements. Vibration can also be of greater concern with long-span stairways.

8.4 VIBRATION IN STAIRWAYS

Vibration analysis should be considered based on the size, use and configuration of a stairway. AISC Design Guide 11, *Vibrations of Steel-Framed Structural Systems Due to Human Activity* (Murray et al., 2016), provides additional guidance to evaluate steel-framed stairs for vibration.

8.5 ARCHITECTURALLY EXPOSED STRUCTURAL STEEL

Architecturally exposed structural steel (AESS) requires additional effort in design, detailing, fabrication and erection to ensure that the architectural design intent is met. Coordination among all parties involved is critical. Refer to AISC *Code of Standard Practice* Section 10 for recommendations and guidelines when using AESS for stairways, guards and handrails.

8.6 ERECTABILITY AND TEMPORARY SUPPORT

Similar to any steel-framed structure, erectability and temporary support must be considered when using steel-framed stairways. Stairways installed adjacent to a concrete or masonry core wall may limit access for bolted connections.

Similarly, phasing of construction activities for masonry construction may require that temporary support be provided for steel-framed stairways.

Stair designers should coordinate with the general contractor, architect, and structural engineer of record (SER) to determine project-specific limitations and concerns.

Chapter 9
Delegated Design

Delegated design provides an opportunity for the architect and the structural engineer of record (SER) to delegate the design of stairways to the fabricator. Depending on the project notes and specifications, delegated design may allow the fabricator to dictate all aspects of design for the stairway (architectural and structural) or the architect and/or SER will provide specific criteria for the fabricator to follow. For some projects, the fabricator will also be required to provide calculations and drawings sealed by a professional engineer for the structural design. Refer to the Purpose section of this Design Guide for common issues that should be considered as part of the delegated design process.

Delegated design can also be a point of confusion based on contractual obligations and design responsibility. Pryse et al. (1996) provided recommendations regarding delegated design in the *Modern Steel Construction* article "Metal Stairs and Railings: Will the Responsible Designer Please Step Forward?"

9.1 RECOMMENDED DELEGATED DESIGN INFORMATION

It is important for the architect and SER to provide clear and concise requirements for the fabricator when using delegated design for stairways, guards and handrail. The architect should provide design requirements for the egress provisions according to the governing building code. Accordingly, the architect should provide information regarding dimensional layout for stairways, guards, handrails, required clear dimensions, and other related information. The SER should provide information related to loading (or indicate code minimum loadings), preferred member type/size, restrictions for stairway supports or connection types, and other related information.

Included in Appendix A are checklists that will assist architects, structural engineers and component suppliers in providing the appropriate information to the fabricator for delegated design for stairways.

9.1.1 Design Documents

Design documents should provide adequate information to ensure that the stairway fabricator, detailer, and specialty structural engineer (SSE) have adequate information to meet the project architectural and structural design requirements. At a minimum, this information should consist of:

- Plans, sections and elevations at each stairway
- Stairway dimensional requirements
  - Clear distances at stairs
  - Clear distances at landings
  - Guard layout
  - Handrail position
- Preferred or required member types
- Layout of stair elements
- Slab openings
- Details where stairs attach to the building structure (fully detailed or conceptual)
- Any other special requirements

Many times, design documents may only show the general design intent for the stairways. The architect and SER should provide additional information as needed when special details or design elements are to be incorporated into the stairway. If the SER provides complete connection design for the stairs, then the drawings and details should include the information required in AISC *Code of Standard Practice* Section 3.1 (AISC, 2016a).

9.1.2 Project Specifications

Project specifications should provide additional information and guidance for the design of stairways in conjunction with the design documents. It is important that specifications are properly reviewed and accurately match the design documents to avoid questions and delays due to discrepancies.

It is particularly important that architectural requirements be provided by the architect and structural requirements be provided by the SER. Specifications for stairways and guard/handrail should reflect the specific project requirements.

9.2 CODE COMPLIANCE

Stairways, guards and handrail are critical components related to life safety. It is of the utmost importance that these elements are designed, detailed, fabricated and erected properly to meet the appropriate code requirements. The architect and SER are the design professionals most familiar with the requirements related to the building project.

Fabricators, detailers, erectors and the SSE do not generally have the knowledge and expertise that the architect has with respect to egress requirements and specific building requirements of the governing building code. The architect should provide adequate direction to ensure that the delegated design will be in general conformance with the design and code requirements.

The industry in general has recognized that only the owner's designated representative for design (typically the architect and SER) has all the information necessary to evaluate the total impact of deferred or delegated design details on the overall structural and architectural design of the project. This authority traditionally has been exercised during the approval process for the delegated design submittal (via structural calculations, shop drawings, etc.). Irrespective of delegated design submittals, the owner's designated representative for design retains responsibility for the adequacy and safety of the entire structure. This does not relieve the SSE of his or her design responsibility for the deferred submittal. It is intended to ensure that the deferred submittal is coordinated with the rest of the project, which only the owner's designated representative for design can verify and confirm.

9.3 SUBMITTAL REVIEW AND SHOP DRAWING REVIEW

The author recommends that engineers subcontracted to provide engineering analysis of structural performance and serviceability criteria for stairways (the SSEs) provide sealed calculations and stairway drawings to the fabricator. This package should be similar in content to a set of sealed design drawings that would be provided to the fabricator for a typical steel building project. The fabricator would use this package to create shop and erection drawings. It is also recommended that the SSE provide shop drawing review related to the stairway design during the approval process. This combined package of sealed calculations and stairway drawings, along with the fabricator's shop and erection drawings, should be adequate as a deferred submittal.

A requirement for the SSE to seal and sign each sheet of the shop and erection drawings produced by the fabricator is discouraged. Furthermore, sealing drawings produced by others is not permitted under laws in certain states. Requiring the SSE to seal shop drawings produced by the fabricator does not change the designer's professional responsibility and does not replace the shop drawing approval process. The owner's designated representative for design is still required to review the stairway shop and erection drawings during the approval process for conformance with the specified criteria and compatibility with the design of the primary structure.

9.4 QUALITY ASSURANCE

For delegated design of stairways, guards and handrail, the author recommends that all parties adhere to the requirements of the NAAMM *Metal Stairs Manual* (NAAMM, 1992) and *Railing Manual* (NAAMM, 2001).

Specifically related to steel members, the author recommends that all parties agree to follow the AISC *Code of Standard Practice* (AISC, 2016a) as a framework for delegated design of stairways, guards and handrail. These provisions are not intended for stairs but do provide reasonable criteria for trade practices related to steel stairways.

Using these recommendations will help to ensure that all involved parties have the same expectations for the architectural design, structural design, detailing, fabrication and erection of steel-framed stairways.