THE **SITUATION** WITH **STEEL DECKS**

Steel roof deck design can affect roof system selection and design

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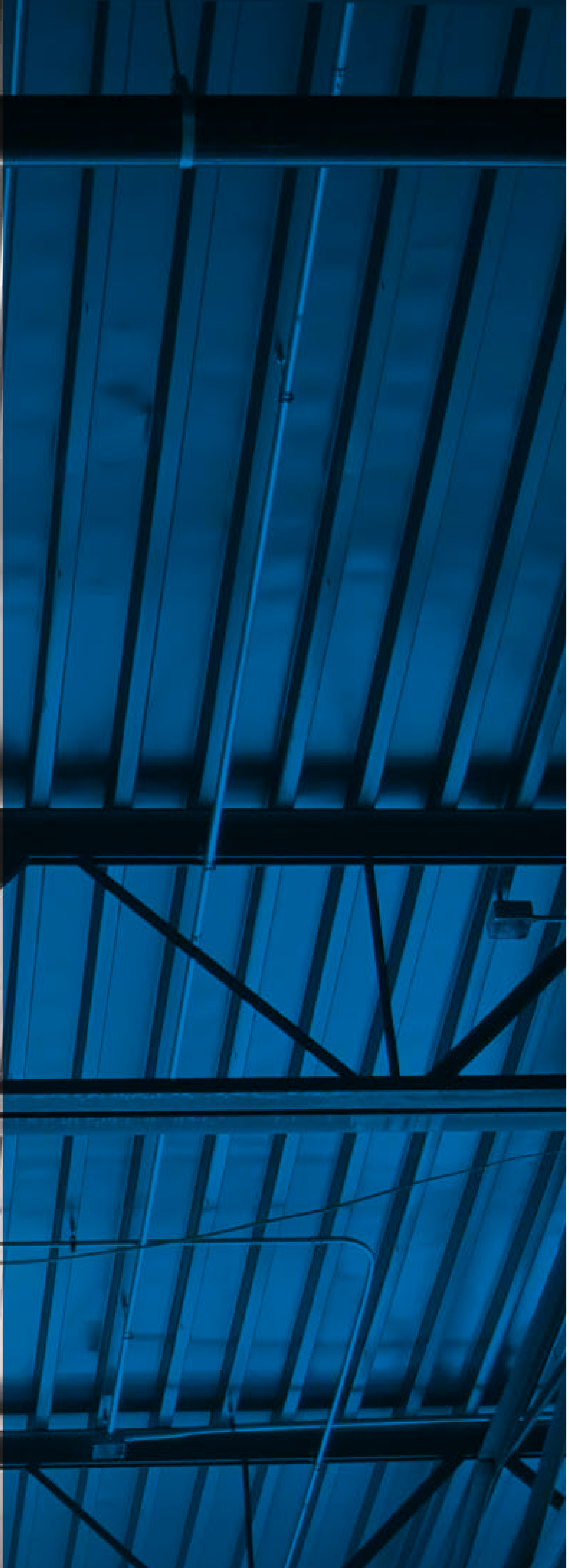

Steel roof decks commonly are encountered in low-slope roofing projects. According to NRCA's 2015-16 Annual Market Survey, steel roof decks are used in a majority of new construction building projects. Also, NRCA's market survey shows steel roof decks are in place on about half of all existing building reroofing projects.

Although steel roof decks have enjoyed widespread use and acceptance in the U.S. construction industry for years, the methods used to design steel roof decks to resist wind uplift have evolved and recently changed. Some changes may affect and limit specific roof system designs.

Typically, a building's steel roof deck designer—most commonly the building's structural engineer—will have little to no knowledge of the specific roof system type that will be used on the building. For new construction projects, the specific roof system type typically is selected and specified by an architect or roof consultant and not the roof deck designer.

For reroofing projects, the original designers of steel roof decks most often are not involved nor are structural engineers. During reroofing projects, roof system designers commonly assume steel roof decks were designed properly, are capable of resisting design wind-uplift loads and can transfer the loads to a building's underlying structural system.

Because of these assumptions, there often is a fundamental knowledge disconnect between the designers of steel roof decks and roof system designers.

Following is some basic information regarding designing steel roof decks for wind uplift with the intention of helping bridge this knowledge gap.

ESTABLISHED PRACTICES

Steel roof decks commonly have been designed using guidelines developed by the Steel Deck Institute (SDI). Since 1939, SDI has provided uniform industry standards for the engineering, design, manufacture and field usage of steel floor and roof decks.

SDI's members are manufacturers of steel roof decks. SDI also has associate members, which include engineers and manufacturers of fasteners, other anchoring products and coatings.

SDI publishes *Design Manual for Composite Decks, Form Decks and Roof Decks*, which provides a common basis for designing and specifying steel roof decks. The most current edition of SDI's design manual was published in 2007 and is identified as Publication No. 31. The previous edition, Publication No. 30, was published in 2000.

SDI's design manual includes load tables for various roof deck profiles (types) and gauges. The load tables provide allowable uniformly applied loads for roof decks

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installed in various simple- (one-), two- and three- or more span conditions. These load tables are derived using the American Iron and Steel Institute's (AISI's) Standard S100, "Specifications for the Design of Cold-Formed Steel Structural Members" (AISI S100). AISI S100 is referenced in model building codes as a recognized design method for cold-formed steel structural members.

SDI's design manual also provides guidelines for steel deck attachment to structural supports such as steel joists or purlins. It indicates anchorage of steel roof decks must resist a minimum of 30 pounds per square foot (psf) uplift and 45-psf uplift for roof eave overhangs. SDI permits the dead load (weight) of a roof deck construction to be subtracted from the uplift values.

It is important to realize SDI's minimum 30-psf uplift for steel roof decks is equivalent to only an FM Approvals 1-60 roof system classification in a roof area's field. In situations where design wind-uplift loads are greater than 30 psf, additional steel roof deck design considerations and attachment may be necessary.

In 2007, SDI published ANSI/SDI RD1.0-2006, "Standard for Steel Roof Deck," which provides design procedures similar to those included in SDI's design manual. ANSI/SDI RD1.0-2006 is referenced in the *International Building Code,® 2009 Edition* (IBC) as a permitted design method for steel roof decks.

In 2010, ANSI/SDI RD1.0-2006 was updated, revised and expanded and published as ANSI/SDI RD-2010, "Standard for Steel Roof Deck." One notable change relates to steel deck attachment to supports. ANSI/SDI RD-2010 indicates connections shall be designed according to AISI S100 or strengths shall be determined by tests according to AISI S905, "Test Methods for Mechanically Fastened Cold-Formed Steel Connections." The minimum 30-psf uplift and 45-psf uplift at roof overhangs requirements from SDI's design manual and ANSI/SDI RD1.0-2006 remain.

ANSI/SDI RD-2010 is referenced in IBC's 2012 and 2015 editions as a permitted design method for steel roof decks.

In November 2012, SDI published *Roof Deck Design Manual, First Edition*, which provides introductory information, deck design considerations, fastener installation, extensive load tables and design examples applicable to steel roof deck design. The load tables provide allowable downward and upward (wind uplift) uniform load values. Also, attachment (weld and fastener) tables, including fastener pull-out and pull-over values and fastener patterns, are provided.

SDI BULLETIN

In 2009, SDI published a position paper, "Attachment of Roofing Membranes to Steel Deck," which addresses the nonuniform, linear concentrated wind-uplift loading pattern of steel roof decks such as that caused by seam-fastened, mechanically attached single-ply membrane roof systems.

In the position paper, SDI acknowledges the existing design methods for steel roof deck under wind uplift are based on uniform uplift loading of roof decks. Uniform uplift loading occurs with conventional, adhered roof membrane types, including built-up, polymer-modified bitumen and adhered single-ply membrane roof systems.

Under wind-uplift loading, nonuniform, linear concentrated uplift loading pattern attachment of unadhered roof membranes with wide attachment spacing rows can produce localized loads on a roof deck that exceed the deck's capacity. Those same loads applied uniformly across the deck's surface would be acceptable. An example of a roof system type using nonuniform, linear concentrated uplift loading pattern attachment with wide attachment spacing rows is a seam-fastened, mechanically attached, single-ply membrane roof system.

The SDI position paper goes on to indicate the orientation of a roof membrane's fastener rows relative to the steel roof deck's flutes also can affect steel deck loading. If a roof membrane's fastener rows are perpendicular to the deck's flutes and the fastener rows occur midspan of the deck, the resulting bending moment on the deck can be 3.8 times greater than the moment produced by an equivalent uniform uplift load. If fastener rows occur at structural supports (joists), uplift loads on the individual joists can be two or more times greater than an equivalent uniformly distributed uplift load.

If fastener rows are parallel to the roof deck's flutes, bending and shear can be up to 12 times of what would occur in a roof deck under uniform loading.

These values are so much higher than for uniform uplift loading because the load is not resisted by the entire width of the roof deck but rather only by those deck flutes adjacent to the applied loads from linear, nonuniform uplift loading attachment.

SDI's position paper concludes seam fastener rows in seam-fastened, mechanically attached single-ply membrane roof systems only should be designed and installed perpendicular to deck flutes. Furthermore, SDI recommends a structural engineer review the adequacy of the steel deck and structural supports to resist the nonuniform, linear concentrated uplift pattern loading.

SDI does not provide specific design guidance or examples in the SDI Design Manual, ANSI/SDI RD1.0-2006, ANSI/SDI RD-2010 or *Roof Deck Design Manual, First Edition* for performing this analysis.

FM'S APPROACH

FM Global and its testing and approvals subsidiary, FM Approvals, have their own test methods and guidelines for designing and evaluating steel roof decks and membrane roof systems applied over steel roof decks.

FM 4451, "Approval Standard for Steel Deck Nominal 1½ in. (38.1 mm deep) as Component of Class 1 Insulated Steel Roof Deck Construction," dated October 1978, provided a basis for designing steel roof decks where FM Approvals' approved roof systems were used. This version of FM 4451 did not reference AISI S100 or other SDI guidelines. Instead, it contained an FM Approvals' uplift pressure-resistance test method used for classifying (approving) steel roof decks. Many users believed the 1978 FM 4451 was more stringent than AISI S100 and SDI's guidelines. As a result, relatively few steel roof decks were designed and installed according to the 1978 FM 4451.

In June 2012, FM Approvals updated FM 4451 to bring it more in line with SDI's current guidelines for steel roof deck design. This current version of FM 4451, "Approval Standard for Profiled Steel Panels for Use as Decking in Class 1 Insulated Roof Construction," is based on AISI S100-2007 and includes some additional specific test methods and design procedures. For example, FM Approvals' "Test Method for Determining the Pull Out/Pull Over Resistance of Fasteners for Use with Steel Roof Decking" is used to evaluate the pull-out and pull-over resistance of fasteners used to attach a steel roof deck to a building structure. This analysis directly affects steel roof decks' uplift resistances in nonuniform, linear concentrated uplift loading pattern situations.

FM 4451 requires steel roof decks complying with its requirements to bear product marking or package labeling identifying the manufacturer, date of manufacturing, and product trade name or model. FM 4451-compliant steel roof decks also are identified in FM Approvals' online RoofNav application (www.roofnav.com).

In June 2012, FM Approvals revised FM 4470, "Approval Standard for Single-Ply, Polymer-Modified Bitumen Sheet, Built-Up Roof (BUR) and Liquid Applied Roof Assemblies for Use in Class 1 and Noncombustible Roof Deck Construction," to incorporate the requirements of the 2012 FM 4451. This change resulted in FM Approvals reclassifying (in many cases reducing) the wind-uplift resistances of many previously approved roof systems. (For additional information about the FM 4470 revision, see "Changes reduce some FM classifications," January 2013, page 12.)

FM Global's Loss Prevention Data Sheet 1-29, "Roof Deck Securement and Above-Deck Roof Components," also provides information regarding the proper span and securement of steel roof decks to supporting members for wind resistance for FM Global-insured's buildings.

New in FM 1-29's April 2016 version (the previous version was published in September 2010) are design considerations for steel roof decks for roof systems that apply loads in nonuniform, linear concentrated uplift loading patterns, such as when using seam-fastened, mechanically attached, single-ply membrane roof systems.

FM Global indicates when the distance between rows of membrane sheet fasteners is greater than half a steel roof deck's span, the deck's design for wind uplift should be based on concentrated loads instead of uniform loads.

New tables provide maximum deck spans for 18-, 20- and 22-gauge steel roof decks used with mechanically attached roof systems resulting in concentrated loads. Table 1A applies to steel roof decks with 33-kip-per-square-inch (ksi) yield strengths, and Table 1B applies to steel roof decks with 60-ksi or greater yield strengths. For calculation purposes, FM allows only a maximum 60 ksi be used for higher yield (80-ksi) grade steels because these steels are more brittle in nature.

As an alternative to using Tables 1A or 1B, FM allows a performance-based design approach if calculations are conducted by a licensed professional engineer or structural engineer. The calculations should be based on assuming a three-span deck condition; the first row of roof fasteners should occur at the first deck span's midpoint, and maximum allowable stresses should be determined using the allowable strength design method from AISI S100-12, "North American Specification for the Design of Cold-Formed Steel Structural Members."

FM Global indicates its FM 1-29 information is intended for the building or project's structural engineer of record. (For additional information about the January and April 2016 revisions of FM 1-29, see "Updated guidelines," July 2016 issue, page 12.)

AN EXAMPLE

How the current SDI, FM Global and FM Approvals design guidelines for wind uplift affect roof systems applied on steel roof decks is best illustrated by example.

For example, a 22-gauge, 33-ksi steel roof deck spanning 6 feet (6-foot joist spacing) can resist a maximum ultimate uplift load of 165 psf if the roof system uniformly applies the uplift load to the roof deck. This would be the case with built-up, polymer-modified bitumen and adhered single-ply membrane roof systems.

Because of the resulting nonuniform, linear concentrated uplift loading pattern of steel roof decks, that same roof deck and span only can support a seam-fastened, mechanically attached, single-ply membrane roof system with 6-foot fastener row spacing to a maximum ultimate uplift load of 90 psf.

If the steel roof deck is changed from 33 ksi to 80 ksi, a seam-fastened, mechanically attached, single-ply membrane roof system with fastener row spacing of 9½ feet would have the same 90-psf maximum ultimate uplift load.

Also, using an 80-ksi steel roof deck, a seam-fastened, mechanically attached, single-ply membrane roof system with 6-foot fastener row spacing would have the same 165-psf maximum ultimate uplift load as the uniformly loaded roof system example.

CLOSING THOUGHTS

Although steel roof decks enjoy widespread acceptance and use in the U.S. and are a common substrate to which low-slope roof systems are applied, changes in the methods used to design steel roof decks for wind uplift have resulted in a need for steel roof decks to be more closely scrutinized by building and roof system designers. Further complicating this situation is the increased use and widespread acceptance of seam-fastened, mechanically attached single-ply membrane roof systems, which result in nonuniform, linear concentrated uplift pattern application of wind-uplift loads to steel roof decks.

In new construction projects, the structural engineer of record needs to be more aware of the specific roof system types that will be included in buildings' overall designs. If a seam-fastened, mechanically attached, single-ply membrane roof system on a steel roof deck is being considered for a building, the structural engineer or designer of the roof joists and steel roof deck needs to consider and account for the resulting nonuniform, linear concentrated pattern application of wind-uplift loads to the steel roof deck.

Notation of the uplift load consideration (uniform loading or nonuniform, linear concentrated loading) on structural drawings and similar notations on the joist and steel roof deck shop drawings would help communicate and clarify the design intent. The intended steel roof deck's yield strength (minimum 33 ksi or 80 ksi) also should be noted on buildings' structural drawings or project specifications and on steel roof deck shop drawings.

Also, for new construction projects, the roof system designer, whether that be the project architect or roof consultant, should verify steel roof decks have been designed for nonuniform, linear concentrated uplift loading patterns if a seam-fastened, mechanically attached, single-ply membrane roof system is being considered.

If the steel roof deck design cannot be verified, it would be prudent for the roof system designer to specify a seam-fastened, mechanically attached, single-ply membrane roof system with relatively narrow fastener row spacing (equal to or less than the joist spacing) or select a roof system that results in uniform uplift loading of the

STEEL ROOF DECK FINISHES

Steel roof decks typically are manufactured (rolled) using uncoated black steel or galvanized (zinc-coated) steel. Uncoated steel roof decks typically are delivered to a job site mill-primed on one or both sides with the intent of providing some degree of corrosion protection until job-site placement (erection). In some situations, steel roof decks are shop-painted before erection.

The Steel Deck Institute (SDI) indicates the finish of a steel roof deck should be suitable for the environment of the structure in which it is placed.

Furthermore, SDI indicates the primer coat on a steel roof deck is intended to protect the steel for only a short period of exposure in ordinary atmospheric conditions and shall be considered an impermanent and provisional coating. SDI recommends field painting of prime-painted steel, especially where the deck is exposed (exposed interior).

In corrosive or high-moisture atmospheres, SDI indicates a galvanized finish is desirable. In highly corrosive or chemical atmospheres or where reactive materials could contact the steel roof deck, special care when specifying the finish should be used.

In May 1991, based on the findings of a field research project, NRCA issued Technical Bulletin 15-91, "Corrosion Protection for New Steel Roof Decks," and recommended building designers specify steel roof decks be factory-galvanized or factory-coated with an aluminum-zinc alloy for corrosion protection. In highly corrosive or chemical environments, special care specifying protective finishes should be taken, and individual deck manufacturers should be consulted.

The technical bulletin was supported by The American Institute of Architects, Asphalt Roofing Manufacturers Association, Institute of Roofing and Waterproofing Consultants, and RCI Inc.

NRCA currently maintains its position: NRCA recommends steel roof decks have a minimum G-90 galvanized coating complying with ASTM A653, "Standard Specification of Sheet Steel, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process."

Additional information regarding steel roof decks is contained in *The NRCA Roofing Manual: Membrane Roof Systems—2015.*

roof deck, such as conventional, adhered membrane roof systems.

For reroofing projects, you should realize steel roof decks likely were not designed to the current SDI, FM Global or FM Approvals procedures if the building being reroofed was designed and built before about 2007.

If it cannot be verified an existing steel roof deck was designed for nonuniform, linear concentrated uplift loading patterns, it would be prudent for the roof system designer to specify a seam-fastened, mechanically attached, single-ply membrane roof system with relatively narrow fastener row spacing (equal to or less than the joist spacing) or select a roof system that results in uniform uplift loading of the roof deck.

Alternatively, a licensed design professional experienced in steel roof deck design can be retained to perform an in situ evaluation of the steel roof deck and supports to determine its suitability to accommodate a new seam-fastened, mechanically attached, single-ply membrane roof system.

NRCA does not consider solely performing fastener pull-out tests on a steel roof deck to be an accurate indicator of the steel roof deck's yield strength or ability to accommodate nonuniform, linear concentrated uplift loading patterns. There is little correlation between a steel roof deck's fastener pull-out resistance and yield strength and uplift (bending) strength. Further evaluation by an experienced, licensed design professional typically is necessary.

Although roofing contractors sometimes are given the responsibility of inspecting and accepting existing steel roof decks to receive a new roof system, determining a steel roof deck's design adequacy to resist wind uplift is beyond their expertise. This determination is best made during a project's design phase.

In late 2016, NRCA met with representatives of AISI, SDI and the Steel Joist Institute to review how different roof system types interface with steel roof decks and how AISI, SDI and FM 1-29's guidelines address nonuniform, linear concentrated uplift loading patterns. NRCA looks forward to continuing to constructively work with these organizations to address these issues.

Also, NRCA is participating in a university-based research project evaluating various nonuniform uplift loading patterns on steel roof decks. Results from this research are expected later this year.

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