NRCA University Webinar
May 4, 2017

The situation with steel roof decks

presented by

Mark S. Graham
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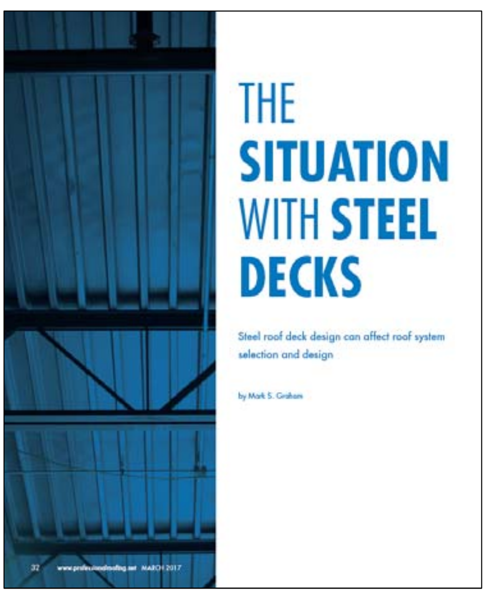
National Roofing Contractors Association



Professional Roofing
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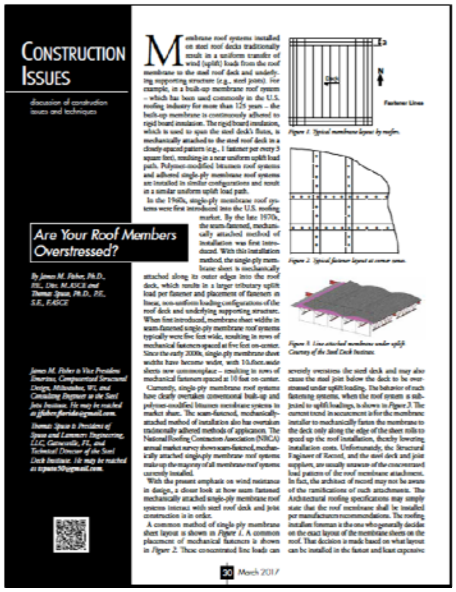

Construction Issues

discussion of construction issues and techniques

Are Your Roof Members Overstressed?

***Structure* magazine**

March 2017

www.structuremag.org

Steel roof deck design

- SDI Design Manual
- AISI S100, “Specifications for the Design of Cold-formed Steel structural Members”
- ANSI/SDI RD1.0-2006, “Standard for Steel Roof Deck”
- ANSI/SDI RD-2010, “Standard for Steel Roof Deck”
- SDI *Roof Deck Design Manual, First Edition* (Nov. 2012)

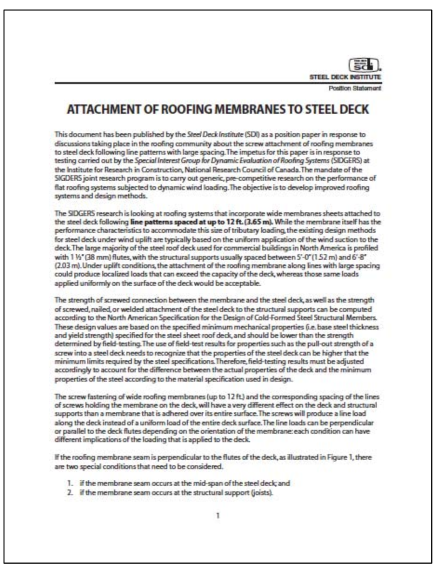
Steel roof deck design

Wind uplift resistance

- Minimum 30 psf uplift (uniform loading)
- Minimum 45 psf uplift (uniform loading) at roof overhangs

SDI bulletin

2009



STEEL DECK INSTITUTE

Position Statement

ATTACHMENT OF ROOFING MEMBRANES TO STEEL DECK

This document has been published by the *Steel Deck Institute* (SDI) as a position paper in response to discussions taking place in the roofing community about the screw attachment of roofing membranes to steel deck following line patterns with large spacing. The impetus for this paper is in response to testing carried out by the *Special Interest Group for Dynamic Evaluation of Roofing Systems* (SIDGERS) at the Institute for Research in Construction, National Research Council of Canada. The mandate of the SIGDERS joint research program is to carry out generic, pre-competitive research on the performance of flat roofing systems subjected to dynamic wind loading. The objective is to develop improved roofing systems and design methods.

The SIDGERS research is looking at roofing systems that incorporate wide membranes sheets attached to the steel deck following **line patterns spaced at up to 12 ft. (3.65 m).** While the membrane itself has the performance characteristics to accommodate this size of tributary loading, the existing design methods for steel deck under wind uplift are typically based on the uniform application of the wind suction to the deck. The large majority of the steel roof deck used for commercial buildings in North America is profiled with 1 ½" (38 mm) flutes, with the structural supports usually spaced between 5'-0" (1.52 m) and 6'-8" (2.03 m). Under uplift conditions, the attachment of the roofing membrane along lines with large spacing could produce localized loads that can exceed the capacity of the deck, whereas those same loads applied uniformly on the surface of the deck would be acceptable.

The strength of screwed connection between the membrane and the steel deck, as well as the strength of screwed, nailed, or welded attachment of the steel deck to the structural supports can be computed according to the North American Specification for the Design of Cold-Formed Steel Structural Members. These design values are based on the specified minimum mechanical properties (i.e. base steel thickness and yield strength) specified for the steel sheet roof deck, and should be lower than the strength determined by field-testing. The use of field-test results for properties such as the pull-out strength of a screw into a steel deck needs to recognize that the properties of the steel deck can be higher that the minimum limits required by the steel specifications. Therefore, field-testing results must be adjusted accordingly to account for the difference between the actual properties of the deck and the minimum properties of the steel according to the material specification used in design.

The screw fastening of wide roofing membranes (up to 12 ft.) and the corresponding spacing of the lines of screws holding the membrane on the deck, will have a very different effect on the deck and structural supports than a membrane that is adhered over its entire surface. The screws will produce a line load along the deck instead of a uniform load of the entire deck surface. The line loads can be perpendicular or parallel to the deck flutes depending on the orientation of the membrane: each condition can have different implications of the loading that is applied to the deck.

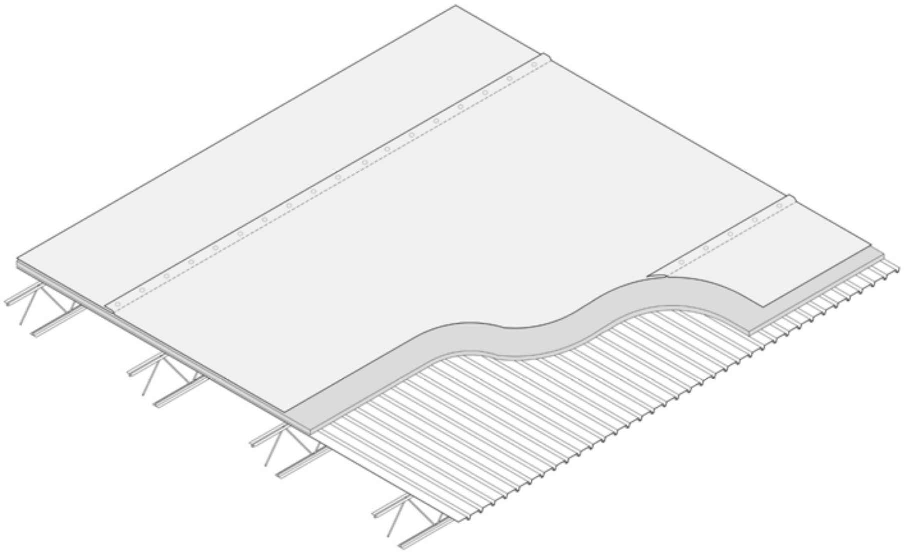
If the roofing membrane seam is perpendicular to the flutes of the deck, as illustrated in Figure 1, there are two special conditions that need to be considered.

1. if the membrane seam occurs at the mid-span of the steel deck; and
2. if the membrane seam occurs at the structural support (joists).

1

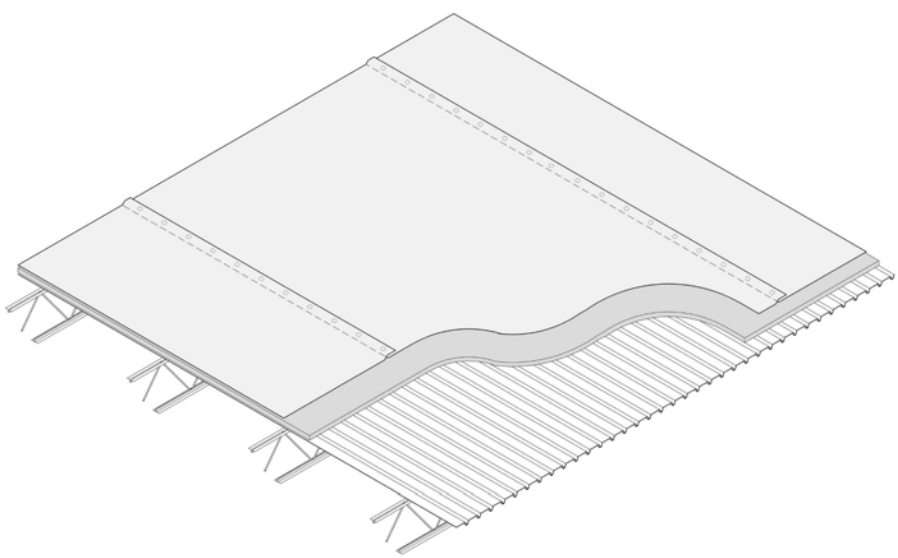
- Decks designed for joist spacing between 5' and 6' 8" o.c.
- Deck designed for uniform loading
- Seam-fastened single-ply membranes are a concern

Membrane seams across deck flutes



SDI: 3.8 X moment (deck); 2 X load (joists)

Membrane seams in deck flute direction



SDI: 12 X bending moment and shear (deck)

SDI bulletin -- Conclusion

"…SDI does not recommend the use of roofing membranes attached to the steel deck using line patterns with large spacing unless a structural engineer has reviewed the adequacy of the steel deck and the structural supports to resist to wind uplift loads transmitted along the lines of attachment. Those lines of attachment shall only be perpendicular to the flutes of the deck."

FM's guidelines

- FM 4451, 1978 edition (Steel roof deck)
- FM 4451, June 2012 edition (Steel roof deck)
  - Incorporates AISI S100-07
- FM 4470, June 2012 edition (Roof systems)


TECH TODAY

Changes reduce some FM classifications

FM 4470 has been revised, resulting in different uplift resistance criteria

by Mark S. Graham

FM 4470

All products tested after Dec. 31, 2012, are required to satisfy the new standard's requirements

What this means

Proceed cautiously

12 www.professionalroofing.net JANUARY 2013

Professional Roofing
January 2013
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<u>FM's guidelines</u>

- FM 4451, 1978 edition (Steel roof deck)
- FM 4451, June 2012 edition (Steel roof deck)
  - Incorporates AISI S100-07
- FM 4470, June 2012 edition (Roof systems)
- FM 1-29, January/April 2016 (Securement)

FM 1-29 updated

www.fmglobaldatasheets.com

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ROOF DECK SECUREMENT AND ABOVE-DECK ROOF COMPONENTS

Note to Insureds of Factory Mutual Insurance Company: Contact the local FM Global office before beginning any roofing work.

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New criteria for steel roof deck uplift:

- Uniformly-distributed loading
- Concentrated loading

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2.2.3.2 When designing the steel deck, give consideration to the needed wind rating, and how the load is applied (concentrated vs. uniformly distributed) from the above-deck components to the deck. Where the distance between rows of roof cover fasteners is greater than half the deck span, treat as a concentrated load.

As an alternative to using Tables 1A or 1B for concentrated loads, a performance-based approach may be used if calculations are conducted by a licensed S.E. or P.E. in structural engineering. This applies to situations where the distance between rows of roof cover fasteners is greater than one-half the deck span. Make the following assumptions:

A. Assume a 3-span structural condition.

B. Assume the first row of roof cover fasteners is located at mid-point of the first deck span.

C. Assume maximum allowable stresses are determined using allowable strength design (ASD) in accordance with AISI S100-2012, or comparable standard outside the United States

Due to the more brittle nature of higher grade steels, the maximum yield stress used in the analysis is 60,000 psi (414 MPa), even for 80,000 psi (552 MPa) yield stress steel. Use Tables 1A through 1E as follows to facilitate deck selection:

Table 1A. Use for roof covers or base plies that are mechanically fastened to the steel deck when the distance between rows of roof cover fasteners is more than half the deck span and the deck is 1-1/2 in. (38 mm) deep, wide rib (Type B) with a minimum yield stress of 33,000 psi (228 MPa).

Table 1B. Use for roof covers or base plies that are mechanically fastened to the steel deck when the distance between rows of roof cover fasteners is more than half the deck span and the deck is 1-1/2 in. (38 mm) deep, wide rib (Type B) with a minimum yield stress of 60,000 psi (414 MPa).

Note: Where the minimum specified yield stress is between 33,000 psi (228 MPa) and 60,000 psi (414 MPa), it is reasonably accurate to interpolate the maximum deck span linearly based on Tables 1A and 1B.

Table 1C. Use for roof covers or base plies that are adhered to insulation or cover board, or mechanically fastened to the steel deck when the distance between rows of roof cover fasteners is one-half the deck span or less and the deck is 1-1/2 in. (38 mm) deep, wide rib (Type B) with minimum yield stresses of 33,000 psi (228 MPa) and ultimate wind ratings of from 60 to 225 psf (2.9 to 10.8 kPa).

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Table 1C. Maximum Steel Deck Span (ft) for 1½ in. (38 mm) Deep, Wide Rib (Type B) Steel Deck with an Adhered Roof Cover, for Wind Ratings from 60 to 225 psf (2.9 to 10.8 kPa)
(NOTE: Use this table when the distance between rows of roof cover fasteners is one-half the deck span or less. Green font indicates that deflection governs over bending stress.)

Yield Stress psi	Deck Gauge	Ultimate Wind Rating per RoofNav (psf) Maximum Span (ft)											
		60	75	90	105	120	135	150	165	180	195	210	225
33,000	22	7.10	7.10	7.10	7.10	7.07	6.67	6.33	6.03	5.78	5.55	5.35	5.17
	20	7.78	7.78	7.78	7.78	7.78	7.43	7.05	6.72	6.44	6.18	5.96	5.76
	18	9.08	9.08	9.08	9.08	9.08	8.66	8.22	7.84	7.50	7.21	6.95	6.71
	16	10.36	10.36	10.36	10.36	10.36	9.89	9.38	8.94	8.56	8.23	7.93	7.66
40,000	22	7.10	7.10	7.10	7.10	7.10	7.10	6.96	6.64	6.35	6.10	5.88	5.68
	20	7.78	7.78	7.78	7.78	7.78	7.78	7.76	7.40	7.08	6.80	6.56	6.33
	18	9.08	9.08	9.08	9.08	9.08	9.08	9.04	8.62	8.25	7.93	7.64	7.38
	16	10.36	10.36	10.36	10.36	10.36	10.36	10.32	9.84	9.42	9.05	8.72	8.43
45,000	22	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.04	6.74	6.48	6.24	6.03
	20	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.51	7.22	6.95	6.72
	18	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	8.76	8.41	8.11	7.83
	16	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	9.99	9.60	9.25	8.94
50,000	22	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	6.93	6.66	6.42	6.20
	20	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.72	7.42	7.15	6.91
	18	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.00	8.65	8.33	8.05
	16	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.28	9.87	9.51	9.19
55,000	22	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	6.90	6.67
	20	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.69	7.43
	18	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	8.97	8.66
	16	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.24	9.89
60,000 +	22	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	6.97
	20	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.77
	18	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.06
	16	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.34

Green font indicates that deflection governs over bending stress.

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Table 1A. Maximum Steel Deck Span (ft) for 1½ in. (38 mm) Deep, 33,000 psi (228 MPa) Yield Stress with a Mechanically Fastened Roof Cover
(Note: Use this table when the distance between rows of roof cover fasteners is more than one-half the deck span.)

Max Deck Spans By Wind Rating/Fastener Spacing, Sheet Gauge for 33 ksi, 1½ in. Deep Wide Rib Deck

Roof Cover Fastener Row Spacing (ft)	Gauge	Wind Rating [psf]																		
		330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60
3.5	18	4.5	5.5	5.5	5.5	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	4	4	4.5	4.5	4.5	5	5.5	5.5	5.5	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	4	4	4.5	4.5	4.5	5.5	5.5	5.5	6	6	6	6	6	6
4	18	4.5	4.5	5	5	5	6	6	6	6	6	6	6	6	6	6	6		6	6
	20	-	-	-	-	4	4.5	4.5	5	5	5.5	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	4	4.5	5	5	6	6	6	6	6	6	6
4.5	18	-	4	4	4.5	5	5	5.5	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	4	4	5	5	5.5	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6
5	18	-	-	-	4	4	4.5	5	5	5.5	6	6	6	6	6	6	6	6	6	6
	20									4	4.5	5	5.5	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6	6	6
5.5	18	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5	6	6	6	6
6	18	-	-	-	-	-	-	-	-	4	5	5.5	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5.5	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5.5	6	6	6
6.5	18	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5.5	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5.5	6	6
7	18	-	-	-	-	-	-	-	-	-	-	-	4	5.5	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	6	6
7.5	18	-	-	-	-	-	-	-	-	-	-	-	-	4	5.5	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	6	6

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Table 1B. Maximum Steel Deck Span (ft) for 1½ in. (38 mm) Deep, Yield Stress ≥ 60,000 psi (414 MPa) with a mechanically fastened Roof Cover (continued)
(Note: Use this table when the distance between rows of roof cover fasteners is more than one-half the deck span.)

Max Deck Spans By Wind Rating/Fastener Spacing, Sheet Gauge for 80 ksi, 1½ in. Deep Wide Rib Deck

Roof Cover Fastener Row Spacing (ft)	Gauge	Wind Rating [psf]																		
		330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60
8.5	18	-	-	-	-	-	4	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	4	4	4.5	5.5	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6	6
9	18	-	-	-	-	-	-	4	4	4.5	5	5.5	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6
9.5	18	-	-	-	-	-	-	4	4	4	4.5	5	5.5	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	4	4	4.5	5	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6
10	18	-	-	-	-	-	-	-	4	4	4.5	4.5	5	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	4	4.5	4.5	5.5	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	4.5	5.5	6	6
10.5	18	-	-	-	-	-	-	-	4	4	4.5	4.5	5	5.5	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	4	4	4.5	5	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6
11	18	-	-	-	-	-	-	-	-	4	4	4.5	5	5	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6
11.5	18	-	-	-	-	-	-	-	-	-	4	4	4.5	5	5.5	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6
12	18	-	-	-	-	-	-	-	-	-	4	4	4.5	5	5.5	66		6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	5.5	6
Roof Cover Fastener Row Spacing	Gauge	330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60
		Wind Rating [psf]																		

Changing from 33 ksi to 80 ksi --> 6 ft. to 9.5 ft. seam spacing

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Table 1B. Maximum Steel Deck Span (ft) for 1 ½ in. (38 mm) Deep, Yield Stress ≥ 60,000 psi (414 MPa) with a mechanically fastened Roof Cover
(Note: Use this table when the distance between rows of roof cover fasteners is more than one-half the deck span.)

Max Deck Spans By Wind Rating/Fastener Spacing, Sheet Gauge for 80 ksi, 1½ in. Deep Wide Rib Deck

Roof Cover Fastener Row Spacing (ft)	Gauge	Wind Rating [psf]																		
		330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60
3.5	18	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	22	5.5	5.5	5.5	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6
4	18	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	22	4.5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
4.5	18	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	22	4	4	4.5	5	5	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6
5	18	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	4.5	5	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	22	-	-	4	4	4.5	4.5	5	5.5	6	6	6	6	6	6	6	6	6	6	6
5.5	18	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	4	4.5	4.5	5	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6	6
6	18	5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6	6	6	6
6.5	18	4.5	5	5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	4	5	5.5	6	6	6	6	6	6	6
7	18	-	4	4	4.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	4	4	5	5.5	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6	6	6	6
7.5	18	-	-	-	4	4.5	4.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	4	4.5	6	6	6	6	6	6
8	18	-	-	-	-	4	4	4.5	5	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	4	5	6	6	6	6	6

In summary

Hypothetical analysis using FM 1-29

- Adhered (uniform loading) roof system:
  - 6 ft. joist spacing → Class 165
- Seam-fastened (nonuniform, linear load) roof system:
  - 6 ft. seam spacing → Class 90 (33 ksi steel deck)
  - 9.5 ft. seam spacing → Class 90 (80 ksi steel deck)
  - 6 ft. seam spacing → Class 165 (80 ksi steel deck)

Seam spacing wider than joist spacing begins to get problematic

NRCA's recommendations

Uniformly-loaded vs. non-uniform, linear pattern loaded steel roof decks

New construction:

- Structural engineer awareness of roof system design
  - Note load pattern and steel's yield strength on structural drawings and shop drawings
- Roof system designer awareness of steel roof deck design

NRCA's recommendations – cont.

Uniformly-loaded vs. non-uniform, linear pattern loaded steel roof decks

Reroofing:

- Realize steel roof decks are not likely designed to current SDI, FM Global and FM Approvals' standards
- If steel deck design cannot be verified:
  - Use narrow fastener row/seam spacing (rows/seams ≤ joist spacing)
  - Use a uniform uplift loading roof system (BUR, MB, adhered single ply)

Fastener pull-out tests…

There is little correlation between fastener pull-out resistance and a steel roof deck's yield strength and uplift (bending) strength

Although roofing contractors sometimes are given the responsibility of inspecting and accepting steel roof decks to receive a new roof system, determining a roof deck's design adequacy is beyond the expertise of most roofing contractors.

This determination is best made during a project's design phase.

***Structure* magazine**

March 2017

Reasons for few reported deck/joist failures to date:

- A majority of roofs have not seen ASCE 7 design uplift loads (no major hurricanes in 10+ years)
- Design uplift of deck-to-joist does not exceed the fasteners' safety factor
- Decks likely have actual yield strengths higher than the 33 ksi design yield strength (60 ksi vs. 33 ksi can increase deck flexural strength by about 70%)

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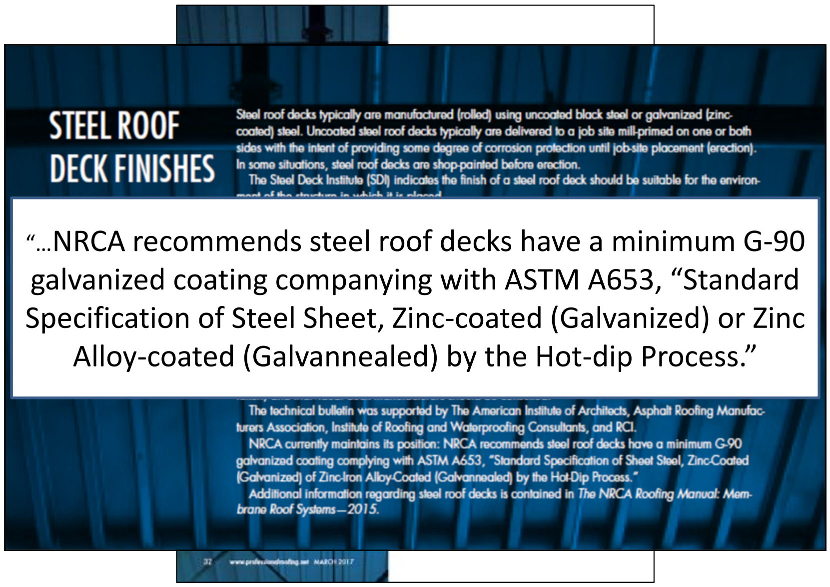

STEEL ROOF DECK FINISHES

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.

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

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) of 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.*

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THE SITUATION WITH STEEL DECKS

Steel roof deck design can affect roof system selection and design

by Mark S. Graham

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 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.

There often is a fundamental knowledge disconnect between the designers of steel roof decks and roof system designers

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.

MARK S. GRAHAM is NRCA's vice president of technical services.

Construction Issues

discussion of construction issues and techniques

Are Your Roof Members Overstressed?

By James M. Fisher, Ph.D., P.E., Dist. M.ASCE and Thomas Sputo, Ph.D., P.E., S.E., F.ASCE

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Membrane roof systems installed on steel roof decks traditionally result in a uniform transfer of wind (uplift) loads from the roof membrane to the steel roof deck and underlying supporting structure (e.g., steel joists). For example, in a built-up membrane roof system – which has been used commonly in the U.S. roofing industry for more than 125 years – the built-up membrane is continuously adhered to rigid board insulation. The rigid board insulation, which is used to span the steel deck's flutes, is mechanically attached to the steel roof deck in a closely-spaced pattern (e.g., 1 fastener per every 3 square feet), resulting in a near uniform uplift load path. Polymer-modified bitumen roof systems and adhered single-ply membrane roof systems are installed in similar configurations and result in a similar uniform uplift load path.

In the 1960s, single-ply membrane roof systems were first introduced into the U.S. roofing market. By the late 1970s, the seam-fastened, mechanically attached method of installation was first introduced. With this installation method, the single-ply membrane sheet is mechanically attached along its outer edges into the roof deck, which results in a larger tributary uplift load per fastener and placement of fasteners in linear, non-uniform loading configurations of the roof deck and underlying supporting structure. When first introduced, membrane sheet widths in seam-fastened single-ply membrane roof systems typically were five feet wide, resulting in rows of mechanical fasteners spaced at five feet on-center. Since the early 2000s, single-ply membrane sheet widths have become wider, with 10-foot-wide sheets now commonplace – resulting in rows of mechanical fasteners spaced at 10 feet on-center.

Currently, single-ply membrane roof systems have clearly overtaken conventional built-up and polymer-modified bitumen membrane systems in market share. The seam-fastened, mechanically-attached method of installation also has overtaken traditionally adhered methods of application. The National Roofing Contractors Association (NRCA) annual market survey shows seam-fastened, mechanically attached single-ply membrane roof systems make up the majority of all membrane roof systems currently installed.

With the present emphasis on wind resistance in design, a closer look at how seam-fastened mechanically attached single-ply membrane roof systems interact with steel roof deck and joist construction is in order.

A common method of single-ply membrane sheet layout is shown in *Figure 1*. A common placement of mechanical fasteners is shown in *Figure 2*. These concentrated line loads can severely overstress the steel deck and may also cause the steel joist below the deck to be overstressed under uplift loading. The behavior of such fastening systems, when the roof system is subjected to uplift loadings, is shown in *Figure 3*. The current trend in securement is for the membrane installer to mechanically fasten the membrane to the deck only along the edge of the sheet rolls to speed up the roof installation, thereby lowering installation costs. Unfortunately, the Structural Engineer of Record, and the steel deck and joist suppliers, are usually unaware of the concentrated load pattern of the roof membrane attachment. In fact, the architect of record may not be aware of the ramifications of such attachments. The Architectural roofing specifications may simply state that the roof membrane shall be installed per manufacturers recommendations. The roofing installers foreman is the one who generally decides on the exact layout of the membrane sheets on the roof. That decision is made based on what layout can be installed in the fastest and least expensive

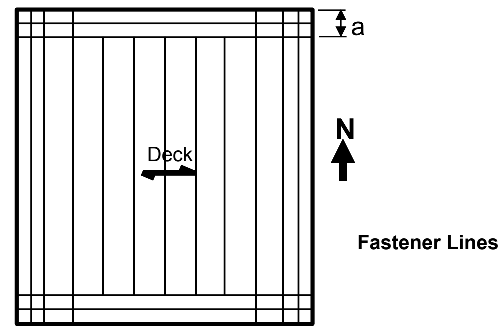

Figure 1. Typical membrane layout by roofers.

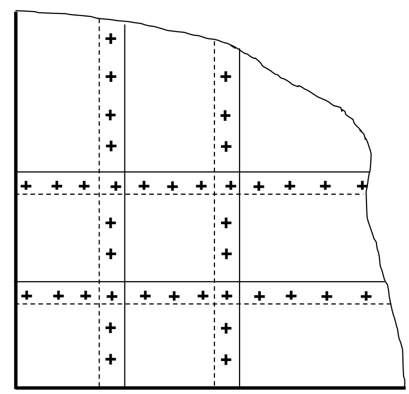

Figure 2. Typical fastener layout at corner zones.

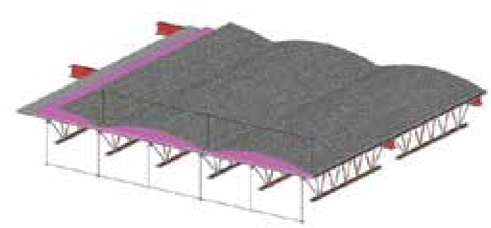

Figure 3. Line attached membrane under uplift. Courtesy of the Steel Deck Institute.

manner. Roofing suppliers and FM Global recommend the fastener line loads not be installed parallel to the deck ribs, but rather perpendicular to the deck flutes. Placing the lines of attachment parallel to the deck ribs will only load a one-foot width of the steel deck. This recommendation helps but may not eliminate potential severe overstress of the deck.

Currently, the Steel Deck Institute's (SDI) position paper, *Attachment of Roofing Membranes to Steel Deck* (**sdi.org**), states: "SDI does not recommend the use of roofing membranes attached to the steel deck using line patterns with large spacing unless a structural engineer has reviewed the adequacy of the steel deck and the structural supports to resist the wind uplift loads transmitted along the lines of attachment. Those lines of attachment shall only be perpendicular to the flutes of the deck."

Deck Strength Example

To illustrate the potential effect of the attachment pattern, determine the deck strength for the following conditions illustrated by *Figures 1* and *2*. Use Load and Resistance Factor Design (LRFD) Load Combinations and American Society of Civil Engineers' ASCE 7-1. Thus, the controlling ASCE Load Combination is 0.9D + 1.0W. (Wind calculations are not shown for brevity.)

Given: A roof system located in Kansas City, MO. Category II Building. Exposure C per ASCE 26.7.3. The building is an Enclosed Building with a flat roof (¼-inch per foot). The building is 100 feet by 100 feet in plan and has an eave height equal to 30 feet.

The metal deck is 1.5-inch 22-gage, wide rib (WR) deck on joists 6 feet on-center. F_y = 33 ksi. The roof dead load on the metal deck = 5 psf. The membrane is 10 feet wide in the interior zones and 5 feet wide in the perimeter zones.

From the SDI *Roof Deck Design Manual* (RDDM), ϕM_n (negative moment capacity) = 5.358 kip-inches, and ϕM_p (positive moment capacity) = 5.088 kip-inches.

Interior Zone (Field of Roof)

Uplift line loads are determined using Component and Cladding ASCE Requirements (ASCE Chapter 30).

The fasteners are placed perpendicular to the deck span and are spaced 1-foot on-center. Therefore, the membrane area is 10 square feet (1-foot x 10-foot-wide sheet). The uplift pressure is 33.3 psf.

Assume that, at some location in the field of the roof, the fastener line will be located at the center of a deck end span. From a structural analysis of a three span deck, the maximum moment occurs in the end span (positive moment); M_r = 4.85 kip-inches. For a uniformly loaded deck, the maximum moment occurs over the two supports (negative moment); M_r = 1.24 kip-inches.

East-West Perimeters (Attachments Perpendicular to Deck Span)

The first line load is 5 feet from the building edge and the second is 10 feet from the edge. The third is 20 feet from the edge.

First Line Load: The membrane area for the first line load = (5 foot) = 5.0 square feet.

Second Line Load: The membrane area for the second line load = (2.5 feet + 5 feet)(1.0 feet) = 7.5 square feet.

Third Line Load: The membrane area for the third line load = (5 feet + 5 feet)(1.0 feet) = 10.0 square feet. The uplift pressure is 55.8 psf for the first 10 feet from the building edge and 33.3 psf for the remainder of the three span deck.

The maximum moment is 4.32 kip-in and occurs in the second span as a positive moment. For a uniformly loaded deck, the maximum moment is 2.31 kip-inches (negative) and is located over the first support from the building edge.

North-South Perimeters (Attachments Parallel to Deck Span)

Note: Fasteners running parallel to the deck flutes is a severe condition and not recommended. If used, the following loading conditions occur.

Line Load: Parallel to Deck Flutes

The uplift pressure is 55.8 psf.

The membrane area for the line load = (5 feet) = 5 square foot.

Line Load on 1.0 foot of deck width = (5.0 feet)(55.8 psf)- 4.5 plf = 275 pounds per foot

Positive moment = $M_w = (0.08)wL^2 = (0.08)$ (0.275 kips per foot)(6.0 foot)^2 = 0.79 kip-feet = 9.50 kip-inches.

Negative moment: $M_w = (0.10)wL^2 = (0.10)$ (.275 kips per foot)(6.0 foot)^2 = 0.99 kip-feet = 11.9 kip-inches.

For a uniformly loaded deck, the maximum negative moment is 2.22 kip-inches.

Corner Condition Zone

The uplift pressure is 84.0 psf for the first 10 feet from the building edge, and 55.8 for the remainder of the three span deck.

Line load on 1.0 foot of deck width = [(5 feet)(84 psf)]/2-4.5 plf = 206 pounds per foot for first 10 feet. The division by 2 is to account for load distribution between fastener

Summary table of required deck strength to actual deck strength.

Zone	Moment Line Load, M_r (kip-inches)	$M_r/\phi M_p$ or $M_r/\phi M_n$	Moment Uniform Load, M_r (kip-inches)	$M_r/\phi M_p$ or $M_r/\phi M_n$
Interior	4.85[1]	0.95	1.24[2]	0.23
East-West Perimeter	4.32[1]	0.85	2.31[2]	0.43
North-South Perimeter	11.9[2]	**2.22**	2.22[2]	0.41
Corner	11.55[2]	**2.16**	3.48[2]	0.65

[1]Positive moment, [2]Negative moment.

ϕM_p = 5.088 kip-inches, ϕM_n = 5.358 kip-inches

lines. Then (5 feet)(55.8 psf)-4.5 plf = 275 pounds per foot beyond.

Based on a continuous beam analysis, the maximum negative moment equals 11.55 kip-inches and occurs over the second interior support from the corner. The maximum positive moment occurs within the third span and equals 9.64 kip-inches. For a uniform load, the maximum negative moment equals 3.48 kip-inches and occurs over the first interior support. The maximum positive moment occurs in the first span and equals 2.73 kip-inches. See Table for a summary of the conditions.

Conclusions

North-South Perimeters and Corner Zone failures occurred. It is interesting to note that, with the amounts of overload shown in these calculations, there are not more reported deck and joist failures. There may be a number of reasons for fewer reported failures. For example:

1) The design uplift anchorage of the deck to the joists, while increased for mechanical attachment as compared to adhered membranes, does not exceed the factors of safety in the design of the deck attachment fasteners.
2) The majority of roofs have not seen roof uplift loads of those predicted by ASCE 7 because the U.S. has not been impacted by a major hurricane in over 10 years.
3) The decks may have higher yield strengths than those used in the design example. The SDI RDDM tabulates roof deck capacity based on a lower bound yield stress of 33 ksi. Many manufacturers provide decks with yield stresses of 40, 50, or 80 ksi (limited to a 60 ksi design stress by the AISI S100 Standard). A design stress of 60 ksi versus 33 ksi will increase the deck flexural strength by about 70%.

Application When Re-Roofing

An important point to note is that, per NRCA, approximately two-thirds of the roofing installed every year is re-roofing of existing buildings. Buildings that are 20 to 30 years old are unlikely to have higher yield strength steel deck. Therefore, caution is required when evaluating roof deck when re-roofing.

Higher Wind Regions

The analysis described above was performed on a building located within the basic wind velocity zone of 115 mph per ASCE 7-10. Particular attention must be paid to the design of the deck for regions where the wind velocity is higher. At higher design wind speeds, a deck which is adequate to support an adhered membrane roof with uniform uplift deck loading may not be structurally adequate to support widely spaced line loads from a mechanically attached membrane roof.

FM Global Requirements

Often times, FM Approval Standard 4470, *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*, is required for roof systems. These requirements are more stringent with respect to deck spans and thicknesses because the FM Standard uses a Factor of Safety of 2 (see sidebar for updated information), whereas the AISI S100 Standard mandates an ASD Factor of Safety of 1.67 for flexure. These requirements can be found on their RoofNav website. Go to **www.roofnav.com** and select **Reference Materials** followed by **Approval Standards**. The FM Standard provides wind ratings based on fastener row spacing, deck spans, deck thicknesses, and deck yield strengths.

For the above example, for a 33 ksi, 1.5-inch. WR deck spanning 6 feet, a 20-gage deck is required to obtain a 60 rating (30 psf ASD).

Recommendations

Design recommendations for single-ply roofing when concentrated line securements are used to

Clarification

This article refers to FM Approval Standard 4470 regarding steel decks and a Factor of Safety of 2. In fact, the FM Global requirements for steel deck is covered in FM Approval Standard 4451, *Approval Standard for Profiled Steel Panels for Use as Decking in Class 1 Insulated Roof Construction* and FM Global Property Loss Prevention Data Sheet 1-29. FM Approval Standard 4451, Section 4.3.1.6 states, "Stresses induced to steel roof decking shall be determined by rational analysis using Allowable Strength Design (ASD) principles and shall not exceed the allowable stresses per the latest edition of the *North American Specification for the Design of Cold-Formed Steel Structural Members*, AISI S100-2007." FM Global Property Loss Prevention Data Sheet 1-29, Section 2.2.3.2 includes tables that are based on ASD principles and the allowable stresses per AISI S100-2012. This section also allows for "a performance-based approach" with the required assumption (Subsection C), "Assume maximum allowable stresses are determined using allowable strength design (ASD) in accordance with AISI S100-2012, or comparable standard outside the United States." Therefore, the FM Global requirements are no more stringent than AISI S100 for steel deck spans and thicknesses.

This confusion may have been the result of interpretation of the definition of Service Wind Load within FM Approval Standard 4470 which states, "The uplift load resulting from a windstorm that a roof assembly must resist. The service load is equal to one-half of the rated load in psf (kPa)." As part of the FM Approval process covered by this Standard, Simulated Wind Uplift Pressure Testing is performed on roof assemblies. The rated load achieved by a particular roof assembly in uplift pressure testing is equivalent to two times the uplift pressure from a windstorm the roof assembly is required to resist. Therefore, the factor of safety of 2 applies only to the performance of a roof assembly during uplift pressure testing. It does not apply to deck span calculations.

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connect the membrane to steel roof deck instead of uniformly distributed securements include:

1) When FM Global requirements are to be followed, maximum deck spans, deck thicknesses, and deck yield strengths as required by FM Global must be used.
   a) Based on the maximum concentrated line loads determined from FM Global, specify the required joist net uplift.
   b) Coordinate your design requirements with the general contractor and the architect.
2) When FM Global requirements are not required:
   a) Determine the uniform net uplift forces based on the building code in force.
   b) Using the spacing between the lines of fasteners for the membrane, perform a structural analysis of the deck as a 3-span beam, placing the first concentrated load at the mid-span of the first deck span. The subsequent loads are placed according to their spacing. This analysis will produce a moment diagram that is close to the maximum that would be achieved from an influence line analysis.
   c) From this analysis, specify a deck that has a flexural capacity that exceeds the maximum positive and negative design moments.
   d) If no deck is found that will work, change the spacing of the supports (joists) or alter the spacing of membrane fastening. Changing the spacing of the membrane fastening is something that requires coordination with the entire roofing team (specifier, manufacturer, and installer).
   e) Determine the net uplift requirement for all joists based on the final selected line securement spacing and forces.
   f) Specify these requirements to the joist manufacturer.
   g) Coordinate your design requirements with the general contractor and the architect.

Economics

Based on experience, using the wide attachment spacing may not be economical when one considers the increase in deck costs and joist costs as compared to the labor savings using the wide securement spacing. For any given project, these cost comparisons should be made.▪