WE-01

Roof Deck: Key to Roof System Performance

Board Approval for Continuing Education Hours: DBPR/CILB No. 0009358
DBPR Course Provider: No. 0003200
Hanley Wood Exhibitions, 6191 N. State Hwy 161, Irving, TX 75038

presented by

Mark Graham

NRCA

INTERNATIONAL ROOFING EXPO

March 6-8, 2007 ✧ Las Vegas Convention Center ✧ Las Vegas, Nevada

Mark Graham
Associate Executive Director of Technical Services
NRCA

Mark Graham, Associate Executive Director of Technical Services for the National Roofing Contractors Association (NRCA) is responsible for inquiries for technical information and assistance, serves as the association's technical liaison with outside organizations, and develops and maintains the association's technical documents, including The NRCA Roofing and Waterproofing Manual. The NRCA's Technical Services Section staff represents NRCA on the technical aspects of roofing.

Considerations for concrete roof decks

by **Mark S. Graham**

Q: *What is the difference between normal-weight structural concrete and lightweight concrete used for roof decks?*

A: Normal-weight structural concrete—concrete that weighs about 150 pounds per cubic foot (2400 kg/m³)—is composed principally of portland cement, coarse and fine aggregates, and water. Structural concrete's primary attribute is its high compressive strength; the proportions of structural concrete's ingredients can be tailored to develop specialized properties to suit specific project needs.

There are two types of lightweight concrete—*structural* and *insulating*—each with different properties.

Lightweight structural concrete's density is about 85 to 120 pounds per cubic foot (1360 to 1920 kg/m³). Its physical properties and composition are similar to that of normal-weight structural concrete, except relatively lightweight aggregates, such as expanded shale, clay and slate, are used instead of other coarse aggregates used in a normal-weight concrete mix.

Lightweight insulating concrete is composed principally of portland cement, either lightweight insulating aggregates (i.e., perlite, vermiculite or polystyrene beads) or an air-entraining agent (e.g., cellular concrete), and relatively large amounts of water. The compressive strength of lightweight insulating concrete is considerably lower than that of structural concrete, but its insulating properties (e.g., R-value) are higher.

Q: *How long should a newly poured structural concrete roof deck be allowed to cure and dissipate its mixing water before roof system application is appropriate?*

A: Because of the large number of concrete mix designs, weather conditions and wide variety of methods of forming, placing and curing concrete, it is difficult to establish a general rule for the recommended curing time for structural concrete decks.

Concrete mix designs and the amount of water in concrete mixes vary significantly among projects and throughout the United States.

While concrete is being poured and curing, the temperature, humidity and wind speed can greatly impact the rate of water loss from the new concrete.

Concrete forming and placement methods also affect the rate at which water will dissipate from newly poured concrete. If the concrete forms are removed shortly after the concrete has taken an initial set (a somewhat common practice), moisture will dissipate from the slab's bottom much more quickly than if the concrete forms were left in place for several weeks.

Methods of protecting and curing the top of newly poured concrete also will affect the rate at which water dissipates from the concrete. For example, if a polyethylene film or similar means is used to temporarily protect a concrete slab and assist in retaining water for concrete curing, the rate at which moisture will dissipate from the concrete will be much slower than if no topside covering is used. Similarly, the use of a concrete curing compound typically retards the loss of moisture from concrete.

For these reasons, designers are encouraged to specify curing and drying times for concrete roofing and waterproofing substrates that are appropriate for the concrete mix design, climatic and environmental conditions and specific work practices of the particular project.

Q: The NRCA Roofing and Waterproofing Manual *and some manufacturers' product literature state that certain concrete-curing compounds are incompatible with some roofing materials. What is the nature of this incompatibility, and how do I ensure compatibility with the particular roof system I am installing?*

A: Concrete curing compounds sometimes are used over newly poured concrete surfaces to aid the curing process. Curing compounds generally are intended to assist in retaining moisture (water) in the concrete mix until the portland cement's hydration is complete.

The primary concern relating to roofing and waterproofing systems is that certain concrete-curing compounds develop a wax-like seal or oily coating on the concrete's surface that can prevent bitumen and adhesives from adequately adhering to the substrate.

With certain curing compounds, there also is a potential for chemical incompatibility between the curing compound and some of the materials used in roofing and waterproofing systems.

On newly placed concrete where roofing or waterproofing materials will be installed, designers are encouraged to closely evaluate the necessity of a curing compound. If a curing compound is necessary, the designer should verify the curing compound's compatibility with the particular roofing or waterproofing materials specified. The manufacturer of the concrete-curing compound should be able to provide information regarding compatibility of materials, as should the roofing or waterproofing materials' manufacturer. PR

Each month in this column, Terrance R. Simmons, RRC, or Mark S. Graham, both NRCA deputy directors of technology and research, will answer readers' technical questions. If you have a specific question that you would like answered in this column, send it to Professional Roofing, *10255 W. Higgins Road, Suite 600, Rosemont, Ill. 60018-5607; or fax (708) 299-1183.*

Differences among steel roof decks

by **Mark S. Graham**

Steel roof decks commonly are used as components in low-slope roof assemblies. Most roofing professionals know there are visual differences among roof deck types. However, you may not be aware of nonvisual differences among steel roof decks, which significantly can affect roof deck performance. Some of these differences follow.

Loads and spans

The Steel Deck Institute (SDI) publishes span tables based on structural properties of roof deck sections computed according to "Specification for the Design of Cold-formed Structural Steel Members," published by the American Iron and Steel Institute. Uniform loads determined for these tables are based on single-span and equal, adjacent two- and three-span conditions. Spans typically are governed by calculating theoretical allowable maximum deck deflections under construction loading prescribed as a 200-pound (900-N) concentrated load at the midspan of a 12-inch- (304-mm-) wide deck section.

ASTM E936, "Standard Practice for Roof Assemblies Employing Steel Deck, Preformed Insulation and Bituminous Built-up Roofing," provides another method for determining deck span. With this method, an 18-inch- (457-mm-) wide deck strip is analyzed for span based on concentrated loading, deflection caused by uniform loading and stress caused by total load. The resulting maximum allowable span value is the least of these three computations.

FM 4451, "Approval Standard for Steel Roof Decking," provides yet another method for determining deck span. In this method, deck spans are limited to the wind-resistance requirements for a roof assembly or maximum allowable deflection under loading, whichever is less. The maximum deflection under loading is determined using a two-span condition with a concentrated load of 300 pounds (1.3 kN) applied at the center of one span.

Compliance of steel roof decks with FM 4451 specifically is required by FM 4450, "Approval Standard for Class 1 Insulated Steel Roof Decks," which provides the basis for FM's I-60, I-90, etc., ratings for roof systems installed over steel roof decks.

Generally, FM 4451 is considered the most conservative analysis method.

Steel type

Steel roof decks typically are manufactured from steel that has a minimum yield strength of 33 ksi (230 MPa) and conforms to ASTM A1008, "Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability," or ASTM A653, "Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process."

In certain instances, steel roof decks with yield strengths of 80 ksi (550 MPa) or higher are specified because they typically provide for greater fastener-withdrawal resistance values. Some FM approvals for 10- to 12-foot- (3- to 3.7-m-) wide mechanically attached single-ply membrane roof systems require such steel roof decks.

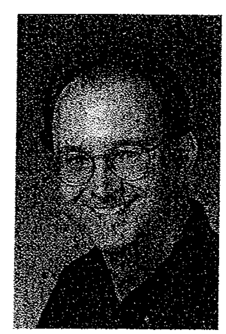
ASTM A653, Grade 80 designates steel with a minimum 80-ksi (550-MPa) yield strength. "Grade E" steel decks that comply with ASTM A611, "Standard Specification for Steel, Sheet, Carbon, Cold-Rolled, Structural Quality," previously also met the minimum 80-ksi (550-MPa) yield-strength requirement. ASTM A661 was discontinued in 2000 and replaced with ASTM A1008. Currently, ASTM A1008, Grade 80 is the appropriate designation for 80-ksi (550-MPa) minimum yield-strength steel.

Closing thoughts

Those who design roof systems to be installed over steel roof decks should be knowledgeable of the properties, including deck span, load capability, and steel grade or yield strength, of specific roof decks that are incorporated into their roof assembly designs.

If a deck's properties cannot be readily determined, such as would commonly be the case in reroofing situations, I recommend a conservative approach be taken when designing the new roof assembly. Such an approach should include assuming a steel roof deck is not FM-approved. This would largely preclude the ability to install an FM-approved roof assembly. Similarly, steel roof decks should not be assumed to have yield strengths significantly greater than 33 ksi (230 MPa). This largely eliminates the ability to install most widely spaced, mechanically attached, single-ply membrane roof assemblies in approved configurations.

Mark S. Graham is NRCA's associate executive director of technical services.



Considerations for steel roof deck

by **Mark S. Graham**

Q: *My company will be involved in a roof system replacement project where deteriorated steel roof deck will be replaced as necessary. The existing deck's individual pieces typically are supported by four joists (i.e., they span three joist spaces). If only a portion of an existing deck panel is deteriorated (e.g., over only one span), is it appropriate to cut out and replace a single-span portion of a multiple-span piece of deck, or is it necessary to remove and replace the entire piece?*

A: A review of the load tables in the Steel Deck Institute's (SDI's) *Design Manual* reveals that the design load capacity for most types of steel roof deck supported by two joists (i.e., one span) is only about 80 to 85 percent that of the same type of steel deck supported by three or more joists (i.e., two or more spans).

Changing the span condition will reduce the deck's load capacity. Unless it can be determined that the steel deck was designed with excess capacity to offset this reduction, replacing a single-span portion of a multiple-span deck is not recommended.

To determine if the steel deck has excess load capacity, the specific type and gauge thickness of deck, design loads and spans need to be known. From these variables, the design and excess load capacities can be determined using the appropriate load tables from the specific steel deck manufacturer or SDI's *Design Manual.*

Determination of design and excess load capacities is best left to a professional engineer or someone knowledgeable of steel roof deck design.

***Editor's note:** SDI's* Design Manual *is available from SDI, P.O. Box 9506, Canton, Ohio 44711; telephone (216) 493-7886.*

Q: *What type of finish is recommended for replacement steel deck: prime-painted or galvanized?*

A: At a minimum, the finish on replacement steel roof deck should be the same as that of the material being replaced.

SDI recommends that steel roof deck be prime-painted, galvanized or aluminized. In the event prime-painted steel deck is used, the primer coat is intended to protect the steel for only a short time in ordinary atmospheric conditions. In addition, it should be considered an impermanent and provisional coating.

"NRCA recommends that steel roof deck be factory-galvanized or -coated with aluminum zinc alloy ..."

NRCA recommends that steel roof deck be factory-galvanized or -coated with aluminum zinc alloy for corrosion protection. Galvanizing should conform with ASTM A 525, Class G-60 or G-90; G-90 provides greater corrosion protection. Aluminum zinc alloy protection should conform with ASTM A 792; an aluminum zinc alloy provides greater corrosion protection than a G-90 galvanized coating.

For steel roof deck in highly corrosive or chemical atmospheres, special care should be taken when specifying protective finishes, and individual deck manufacturers should be contacted for specific recommendations.

Q: *Why is the notation made in the* NRCA Construction Details *that the use of a recessed sump pan at a roof drain in steel roof deck is not recommended? Isn't a sump at a roof drain desirable to aid drainage?*

A: A conventional recessed sump pan, which typically is provided by the steel deck fabricator, measures 33 inches (825 mm) by 29 inches (725 mm). The resulting drain sump measures 24 inches (600 mm) by 20 inches (500 mm) by 1½ inches (38 mm) deep; the drain is intended to be placed in the approximate center of the sump pan.

NRCA's concern with these conventional-sized recessed sump pans is that the sump's depth and its relatively small size result in a complex, sloped geometry that makes proper termination of the roof membrane difficult. This is especially the case with adhered membrane systems. These systems are particularly difficult to conform to the sump geometry while keeping the membrane firmly bonded to the substrate. Also, conventional sump pans typically allow for the use of little or no thermal insulation, resulting in a risk of condensation forming around the drain.

The preferred drain installation method is placing a roof drain with an appropriate metal drain receiver directly in a metal deck panel opening using a suitable underdeck drain clamp. Metal drain receivers typically are available from the roof drain supplier as an optional drain component. They have a recessed opening to smoothly receive a roof drain's outside flange.

The drain receiver and roof drain are intended to be placed directly on steel deck or on top of the roof insulation, depending on the detail configuration. Then, any roof insulation around the drain can be tapered gradually to provide a drain sump.

Where additional structural support of the roof deck at the drain opening is required, the use of a flat sump plate (available as an accessory component from most steel deck fabricators) or suitable underdeck framing is recommended. PR

Each month in this column, one of NRCA's deputy directors of technology and research will answer readers' technical questions. If you have a specific question that you would like answered in this column, send it to Professional Roofing, *10255 W. Higgins Road, Suite 600, Rosemont, Ill. 60018-5607; or fax (708) 299-1183.*

Attaching plywood and OSB sheathing

by Mark S. Graham

In March, APA—The Engineered Wood Association (APA) updated its fastening schedules for wood structural panel sheathing—plywood and oriented strand board (OSB)—for steep-slope roof applications. APA Data File Form No. T325D, "Roof Sheathing Fastening Schedules for Wind Uplift," offers prescriptive sheathing fastening recommendations to provide resistance to wind-uplift pressures as required by most current building codes.

Although it generally is understood roofing contractors are not responsible for the attachment of structural panel sheathing to underlying wood framing, proper nailing is an important consideration in the overall performance of steep-slope roof assemblies, particularly in high-wind regions. Therefore, I encourage you to be familiar with these new fastener schedules.

Basis

The recommendations provided in the APA data file were developed through engineering analysis and full-scale testing of wet and dry specimens of plywood and OSB structural panels that were evaluated for full-panel withdrawal under uniform loads.

The fastening schedules assume use of ⅝-inch-thick or thinner plywood or OSB structural panels on sloping structural framing members spaced 24 inches on center or less over enclosed structures in an ASCE 7-02, "Minimum Design Loads for Buildings and Other Structures," Exposure B region with a mean roof height of 35 feet or less.

Fasteners listed are minimum 8d common nails with smooth or ring shanks that comply with ASTM F1667, "Standard Specification for Driven Fasteners: Nails, Spikes, and Staples."

Fastener schedules reflect the differences in wind-uplift pressures over various zones on steep-slope roof systems. Zone 1 represents the field; Zone 2 represents the perimeter; and Zone 3 represents the corners. Zones 2 and 3 will need to withstand higher wind-uplift pressures and, as a result, require more restrictive fastening spacing than at Zone 1.

Proper nailing is an important consideration in the performance of steep-slope roof assemblies

Slightly different fastening schedules are provided for three wind-speed regions—90 mph, 120 mph and 150 mph—based on the basic wind-speed map contained in ASCE 7-02.

Fastening schedules

The fastening schedule for the 90-mph wind-speed region prescribes nailing at 6 inches on center at supported panel edges and 12 inches on center over intermediate panel supports except in the corners of the roof area (Zone 3) where 6-inch on-center spacing is needed over intermediate panel supports.

For the 120-mph wind-speed region, the fastening schedule prescribes nailing at 6 inches on center at supported panel edges and 12 inches on center over intermediate panel supports in Zone 1, 6 inches on center in Zone 2 and 4 inches on center in Zone 3.

For the 150-mph wind-speed region, the fastening schedule prescribes nailing at 6 inches on center at supported panel edges and over intermediate panel supports in Zone 1, 4 inches on center in Zone 2 and 3 inches on center in Zone 3. Portions of roof areas that overhang beyond buildings' exterior walls (eaves) should use Zones 2 and 3 fastening.

Also, for gable-shaped roofs where sheathing bears over gable end wall framing, special fastening is required. In the 90-mph region, fastening in a 6-inch on-center spacing over the gable end wall is prescribed. In the 120-mph region, fastening in a 3-inch on-center spacing is prescribed. In the 150-mph region, fastening in a 3-inch on-center spacing using 10d ring shank nails is prescribed.

Closing thoughts

APA Data File Form No. T325D provides updated fastener schedules for plywood and OSB structural panel sheathing used for roof decks of steep-slope roof assemblies.

APA Data File Form No. T325D can be downloaded from APA's Web site, www.apawood.org. Questions relating to plywood and OSB structural panel sheathing can be directed to APA's product support help desk by calling (253) 620-7400 or e-mailing help@apawood.org.

Mark S. Graham is NRCA's associate executive director of technical services.

Nail pull-out testing in plywood and OSB

by Mark S. Graham

NRCA has just completed limited testing of nail pull-out resistances in plywood and oriented strand board (OSB) roof sheathing. The purpose of the testing was to determine the influence specific fasteners and sheathing thicknesses have on the pull-out values for nails used to attach asphalt shingles.

Testing

NRCA obtained sheets of three thicknesses of plywood sheathing and three thicknesses of OSB sheathing for the testing. All the sheathing was obtained through typical distribution sources and labeled as being exterior-grade, performance-rated products suitable for roof sheathing applications.

NRCA also obtained quantities of two commonly available 1½-inch- (38-mm-) long, hand-driven shingle nail types: a ring-shank shingle nail complying with ASTM F1667, "Standard Specification for Driven Fasteners: Nails, Spikes and Staples," and commodity-grade, smooth-shank shingle nail.

The sheathing samples were conditioned to standard laboratory conditions; test specimens were prepared; and nail pull-out testing was conducted according to ASTM D1761, "Standard Test Methods for Mechanical Fasteners in Wood." The results of the testing are shown in the figure.

Review of the test results reveals the pull-out values increase with the thickness of the sheathing tested and ring-shank nails provide noticeably higher pull-out values than smooth-shank nails. Also, though the pull-out values for the smooth-shank nails nearly are identical for similar thicknesses of plywood and OSB, the rink-shank nails provide substantially higher pull-out values in OSB.

Average fastener withdrawal load and standard deviation

	Nail type			
	Smooth shank		Ring shank	
	Load (lbf)	Standard deviation	Load (lbf)	Standard deviation
Plywood				
⅜-inch (Three-ply)	45.5	17.9	63.6	21.1
15/32-inch (Three-ply)	46.7	14.0	94.0	51.9
19/32-inch (Four-ply)	56.3	14.6	106.3	34.1
OSB				
7/16-inch	32.0	9.2	101.8	34.0
½-inch	45.1	12.7	116.9	36.6
19/32-inch	58.7	18.7	175.1	47.7

The reported loads are averages of a minimum of 20 specimens tested for each sample. To calculate the metric equivalents, multiply load (lbf) by 4.45 to achieve Newtons.

In evaluating this data, it is important to realize these values apply only to the particular sheathing and fasteners tested. The values should not be used for design purposes. Specific design values are provided in the American Forest & Paper Association/ American Wood Council's *National Design Specification® (NDS) for Wood Construction*.

Recommendations

The testing illustrates the importance of specific roof sheathing type and thickness and nail type in the pull-out resistance of nails used to attach asphalt shingles. For this reason, NRCA makes specific recommendations regarding roof deck sheathing and fasteners used in asphalt shingle roof assemblies.

NRCA recommends the use of a minimum of 15/32-inch- (12-mm-) thick (½-inch [13-mm] nominal thickness) exterior-grade plywood or OSB. Plywood roof sheathing is recommended to be labeled for compliance with U.S. Product Standards PS 1-95, "Construction and Industrial Plywood."

OSB sheathing is recommended to be labeled for compliance with PS 2-92, "Performance Standard for Wood-based Structural-use Panels" or The Engineered Wood Association (APA) standard PRP-108, "Performance Standard and Policies for Structural-use Panels."

For shingle nails, NRCA recommends 11- or 12-gauge galvanized steel or similar corrosion-resistant roofing nails with ⅜-inch (10-mm) head size and shanks that are barbed, ringed or otherwise deformed for added pull-out resistance.

Nails should be long enough to penetrate through all layers of roofing materials and the underside of sheathing or penetrate at least ¾ of an inch (19 mm) into wood plank or board decks. Nails should comply with ASTM F1667, Type I, Style 20.

Mark S. Graham is NRCA's associate executive director of technical services.

Buckling of plywood roof decks

by **Mark S. Graham**

Q: *What causes buckling in a plywood roof deck?*

A: Buckling of structural panel wood sheathing, such as plywood and oriented strand board, can result when dry panels are subjected to increased moisture, which causes them to expand. Panel buckling is likely to appear between the structural framing that supports the panels or along the supports between the panel fasteners.

Such structural panel buckling typically is caused by excessive construction-related moisture, leakage in the roof covering, excessive moisture within the building or inadequate ventilation of internal building moisture.

Similar to all wood products, structural wood panel sheathing absorbs moisture or releases it to the environment until the panels reach moisture contents that are in equilibrium with their surroundings. This results in gradual swelling or shrinking of the panels as moisture content changes.

For typical structural wood panel sheathing applications, the relative humidity may vary between 40 and 80 percent, with the panels' corresponding equilibrium moisture contents ranging from about 6 to 14 percent. Under these conditions, an unrestricted 4- by 8-foot (1219- by 2438-mm) panel's total dimensional change will be about ⅛ of an inch (3 mm). If conditions cause panels to have higher moisture contents, greater dimensional changes can occur. Dimensional changes in installed panels are partially restrained, however, by fasteners, adjacent panels and framing.

To accommodate dimensional changes, it is important that panel ends and edge joints be spaced properly during sheathing installation and that panels be fastened adequately. Generally, spacing of about ⅛ of an inch (3 mm) is recommended at all panel edges and ends. For ordinary sheathing applications, fastener spacings of 6 inches (152 mm) on center (o.c.) at all supporting edges and 12 inches (305 mm) o.c. at intermediate supports, are adequate to hold panels flat under most circumstances. Other fastener spacings may be necessary for certain engineered constructions (e.g., roof diaphragms, high wind areas).

It also is important that structural wood panel sheathing decks be vented adequately. This prevents the development of excessive heat and humidity that may result in increased moisture content in the sheathing. Information regarding attic ventilation was provided in "Adequate attic ventilation critical for performance," June 1995 issue, page 52.

Aside from buckling, other factors can cause a wavy appearance in structural wood panel sheathing (buckling is just one cause of waviness); these include inadequate attachment of the panels or improper alignment of or movement in the structure that supports the panels.

Q: *Short of replacing the deck, can a buckled plywood deck be repaired?*

A: Because buckling in itself typically does not affect the structural properties of wood panel sheathing, it sometimes is possible to repair a buckled deck without replacing large areas of deck sheathing.

If buckling of wood sheathing is suspected, and repair is being considered, it should be determined that the deck's waviness is not actually caused by improper alignment or warping of the structural framing. (Framing that is misaligned or warping may make sheathing appear wavy.) It also should be determined that the panels are fastened properly to the framing.

If buckling is identified, it is important to discover and correct its cause. For example, if buckling occurs after the building has been roofed and occupied, inadequate ventilation or excessive moisture from within the building should be suspected. The source of the moisture then should be located and appropriately corrected.

Once the cause of the buckling is corrected, deck repair can be implemented. Although no repair technique has been 100 percent effective for correcting buckling, the following techniques have been successful:

- Tightly butted edges or ends of structural panels may be saw-cut to relieve pressure and provide a gap adequate for future expansion.
- Wood blocking may be added under buckled areas or unsupported panel edges. Sheathing then can be flattened and fastened to the new blocking.
- A panel clip can be inserted at the joint between the buckled panels to bring adjacent panels into alignment. This may be done by cutting a small hole at the joint, inserting the clip and sliding it into the desired position within the joint.
- Where buckling occurs between fasteners along a common support, additional fasteners can be added to force the panel down to the supports. If buckling is severe, a short saw-cut in the panel edge can relieve pressure.

Editor's note: *Additional information regarding the use and application of structural wood panel sheathing is available from APA The Engineered Wood Association, 7011 S. 19th St., P.O. Box 11700, Tacoma, Wash. 98411-0700; telephone (206) 565-6600.* PR

Each month in this column, one of NRCA's technical services staff members will answer readers' technical questions. If you have a specific question that you would like answered in this column, send it to Professional Roofing *magazine, 10255 W. Higgins Road, Suite 600, Rosemont, Ill. 60018-5607; or fax (847) 299-1183.*