RETROFITTING STRUCTURAL

Today's retrofit designers and contractors face a changing landscape in providing new roof coverings over structural composite roof decks. The International Building Code (IBC) as well as the International Existing Building Code (IEBC) place new demands that must be met on the maintenance and repair of structural performing roof decks during the roof replacement process (i.e., retrofitting). Retrofitting is no longer just a simple matter of selecting and installing a new roof covering. These new demands place the required maintenance and repair of composite roof decks squarely within the purview of the roofing entities that are designing, specifying, and conducting the roof replacement. To comply with these code requirements, the owner, design professional, roof consultant, and roofing contractor need an updated and expanded knowledge of composite roof decks, how their composite action creates the structural properties required to support the building, and the maintenance or repairs necessary to maintain this performance. The purpose of this article is to provide an overview of this information.

LONG-TERM USE

Structural composite action (SCA) has been utilized in the construction industry for many decades. In roof decks, the first widespread use of SCA was the poured gypsum roof deck on bulb tees that began over 70 years ago. It was produced by several manufacturers such as United States Gypsum Co., Bestwall Company, and Georgia-Pacific Corp. Next came lightweight insulating concrete (LWIC) over galvanized form deck, which followed some years later and has now been around for 60 years.

The initial LWIC for roof decks consisted of a lightweight aggregate (usually either vermiculite or perlite) mixed with cement and an air-entraining agent. Aggregate manufacturers were the Zonolite Division of the W. R. Grace Company (vermiculite), Permalite Division of Great Lakes Carbon Company (perlite), and various independent vermiculite and perlite manufacturers. Today most LWIC relies on specialized air-entraining agents that create a foam mixture that eliminates the need for lightweight aggregates. The latest composite roof deck addition, Loadmaster composite steel roof decks, was developed and introduced 45 years ago. Loadmaster consists of high-tensile-steel sections, optional insulation, and a dense mineral board, all anchored together with engineered screw attachment patterns that create SCA.

Collectively, these composite systems

COMPOSITE ROOF DECKS

By Lynn Nunley and Dr. Larry Luttrell

Installing added attachments to existing steel form deck to meet IBC requirements.

have billions of square feet in service on thousands and thousands of buildings. With retrofitting being a process used after the life of the second roof covering expires (30 to 40 years after construction), one can see that retrofitting of all these composite systems is quite active today.

STRUCTURAL COMPOSITE ACTION

SCA is created by physical or chemical processes that unite the individual components of the roof deck assembly into a single-acting structural unit. This structural unit then supports larger design loads than the sum of the components can support. In some instances, this increased strength can be substantially greater than the sum of the components' strength. For example: 28-ga. Wheeling Tensile Form 50 can support a 30-psf uniform load on a 3-ft. span.[1]

Loadmaster mineral board has no load capacity. The same steel section with ½-in. mineral board in a Loadmaster composite deck assembly supports 63 psf[2]—a 33-psf improvement. Thus, SCA provides substantial increases in the structural capacity of the assembly and allows it to perform structural functions that the individual components could not perform. Gravity-load capacity, wind-uplift resistance, and diaphragm shear strength are structural functions that SCA increases in composite roof deck assemblies. These are the main structural functions the roof deck must perform to meet IBC requirements that stabilize the building under wind, gravity, and seismic loads. All three

Removal of wind-damaged LWIC from steel form deck.

Exposing steel form deck of wind-damaged LWIC roof deck.

composite roof deck systems mentioned above derive their structural performance capabilities from SCA.

Should a composite roof deck assembly lose its SCA, it will suffer a substantial loss of structural capacity. This will place the building in a non-code-complying state, and the building can be classified as dangerous per IBC statements (see below). Additionally, the building could become uninsurable or subject to policy cancellation in the event of a loss. So maintaining the structural capacity of the composite roof deck assemblies is not something to take lightly or to ignore.

Chapter 2 of the IBC defines a building as being "dangerous"[3] when there exists a significant risk of collapse. When the composite action of a composite roof deck has been damaged or lost on a building that relies on the composite roof deck to provide diaphragm shear resistance (which stabilizes the building under wind and seismic loads), then the building can be subject to collapse and, in accordance with the IBC, it is classified as "dangerous."

The composite roof deck must continue to satisfy both gravity and wind loads but also must distribute in-plane shear loads, as those loads tend to change the "building box" shape. Damages to the roof deck or its fasteners must be repaired. Considerable attention must be given to the diaphragm properties, and especially to shear stiffness, in order to maintain wall and roof deck deflections within design limits. In roofing retrofit operations, serious consideration must be given to these structural load-bearing requirements to keep the building safe and in compliance with building codes. Retrofitting is not just a simple matter of selecting and installing a new roof covering. Retrofitting composite roof decks involves evaluating the SCA performance of the roof deck per the IBC requirements and correcting any deficiencies found.

LWIC on Steel Form Deck

The SCA of LWIC roof decks is created by a chemical bond between the zinc in the galvanized coating of the form deck uniting with the cement in the LWIC. The minimum 2-in.-thick monolithic concrete slab poured over the corrugated form deck becomes chemically bonded to the zinc finish of the form deck. This bonding stabilizes the form deck ribs against distortion or rotation when placed under loads. This creates the SCA that provides gravity-load resistance, wind-uplift resistance, and diaphragm shear strength for the roof deck. To maintain this SCA, the LWIC must remain monolithic and bonded to the steel form deck.

During the operational life of the roof deck, the composite bond experiences wind loads that force the assembly upward, while at the same time, shear loads force the assembly into a warped shape. This combined loading can cause cracking in the LWIC and loss of bond between the LWIC and the steel form deck, compromising the SCA. Should the SCA be compromised or destroyed by these loadings or from deleterious conditions (such as water leakage resulting from a deteriorated roof covering), then the roof deck's structural capacities are diminished. If the building relies upon the composite roof deck assembly for diaphragm shear resistance, the building enters into a dangerous state as noted earlier.

Experience has shown that substantial structural damage to the LWIC roof deck that would compromise or destroy the SCA is easy to recognize. If the monolithic slab is broken into small pieces or has lost its bond with the steel form deck, then the SCA has been compromised or destroyed.

It has been noted that some LWIC retrofit operations, after removing the roof covering, have ignored unbonded and/or broken LWIC and proceeded with installation of a rigid board or insulation over the top of the failed LWIC, attached by screws through the LWIC into the steel form deck. A new roof covering was then installed over the rigid board. While this procedure may appear to provide a suitable surface to roof (with screw attachment that indicates wind-uplift resistance), it does not restore the necessary SCA. The building remains in a dangerous condition per the IBC and does not meet the code requirements. Repairs must be undertaken to restore the SCA of the roof deck assembly so that its gravity load capacity, wind-uplift resistance, and diaphragm shear strength are at the required levels; to do otherwise violates the IBC and would constitute negligence. Please consult Section 114.4 of the IBC.[4]

Loadmaster composite components installed over existing steel form deck.

Loadmaster Roof Decks

The SCA for Loadmaster is developed between the steel section and the dense mineral board surface of the assembly through several means. First, the long edge joints of the top mineral board are tongue-and-groove for a tight structural fit to prevent differential edge deflections. Second, butt ends of mineral boards are secured to a single rib of the steel section and firmly attached with an engineered screw attachment pattern designed to stabilize the joint under various types of load conditions. Third, using engineered screw attachment patterns, board components (insulation and mineral boards) are secured to the steel section with self-drilling screws designed to firmly attach board components and stabilize the ribs of the steel sections against deformation under loads. Through this design and special engineering, the assembly develops SCA that produces gravity-load resistance, wind-uplift resistance, and diaphragm shear strength. It is mandatory that the SCA remain intact and operational to meet the required IBC design loads for the building's safety.

Experience has shown that while subjected to normal design loads, the SCA of the Loadmaster roof deck remains intact

RCI/SMACNA Architectural Sheet Metal Quality Assurance Guide Review Period Begins

The public review period for the joint *RCI/SMACNA Architectural Sheet Metal Quality Assurance Guide* has begun. To review and/or make comment, follow this link.

https://www.smacna.org/resources/resource/2014/12/04/architectural-sheet-metal-quality-assurance-guide----45-day-public-review

All comments much be received by January 22, 2015 at 5:00 p.m. EST.

Installation of Loadmaster composite components after removal of existing roof coverings from Loadmaster roof deck.

Installation of roof covering over retrofitted Loadmaster roof deck.

and continues to function properly. This holds true even when exposed to major wind conditions such as hurricanes. Excessive concentrated loadings have been found to damage the components sufficiently to affect the SCA. Additionally, unattended roof leaks that allow moisture penetration during repeated freeze/thaw cycles can damage the system. During retrofit operations, removal of roof coverings by mechanical means can rupture the mineral board, and large areas of damage can negatively affect SCA. Retrofit operations that require removal of fully adhered membranes cause delamination of the mineral board facers, resulting in reduced strength of the mineral board and loosening of the screw attachments. This produces a loss of SCA that has a very negative effect on the diaphragm shear strength and shear stiffness of the assembly. Since retrofit operations pose a significant threat to the SCA and load capacity of the assembly, the manufacturer recommends that retrofit operations be conducted only by its certified and trained dealers.

When owners, roof consultants, or contractors have ignored the company's recommendations and made retrofit modifications of their own design with non-Loadmaster components installed by nontrained workmen to a Loadmaster roof deck, in most cases they have created assemblies that do not have the required SCA and do not provide the building with the necessary load capacities to meet IBC requirements for safety. In most cases they have left the structure in a "dangerous," non-code-compliant condition that is a direct code violation, making them collectively subject to penalties as prescribed by law. (See Section 114.4 of the IBC.[5])

Gypsum Roof Decks

Poured gypsum decks' SCA provides gravity-load resistance, wind-uplift resistance, and diaphragm shear strength. The components that create the SCA of the poured gypsum roof deck are steel bulb tees, a form board (usually composed of gypsum or fiberglass), wire reinforcing mesh, and the gypsum concrete. The bulb tees, which are very strong vertically but quite flexible horizontally, provide the long span strength. The gypsum concrete, which spans tee to tee, encases the tees and prevents them from rotating or deforming horizontally when under load, thus creating the SCA. Bulb tees of several shapes and sizes are used, depending on the loading conditions under design as well as the span of the tees.

However, when gypsum decks entered the marketplace, roof decks were not used as the normal method of providing diaphragm shear resistance to the building in many parts of the country. Steel bracing in the roof structure was the more common method of bracing the walls against wind and seismic loads. Using the roof deck as a structural diaphragm was a California development and worked its way across the nation in the late 1950s and early ’60s. Therefore, many poured gypsum roof decks were not designed and installed with diaphragm shear strength in mind; only gravity load and wind uplift loads were considered. In retrofitting a gypsum roof deck, one should evaluate the steel bracing of the roof structure to ascertain if the roof deck was, in fact, used as a structural diaphragm.

Poured gypsum decks provide stable structural properties if kept moisture-free. Damage that can cause loss of the SCA is most likely to come from leakage of water into the roof deck from unattended roof leaks. Free water will cause the gypsum concrete to decompose and lose structural strength. Too much water can cause the form boards, which are temporary form members for the gypsum, to soften and sag down below the bulb tees. In this condition, the gypsum concrete ceases to stabilize the bulb tee and allows it to rotate or bow under loads, thus losing its structural performance capacity. At this point, the SCA is gone. Repairs are necessary to restore the SCA and return the gypsum deck to its intended structural capacity.

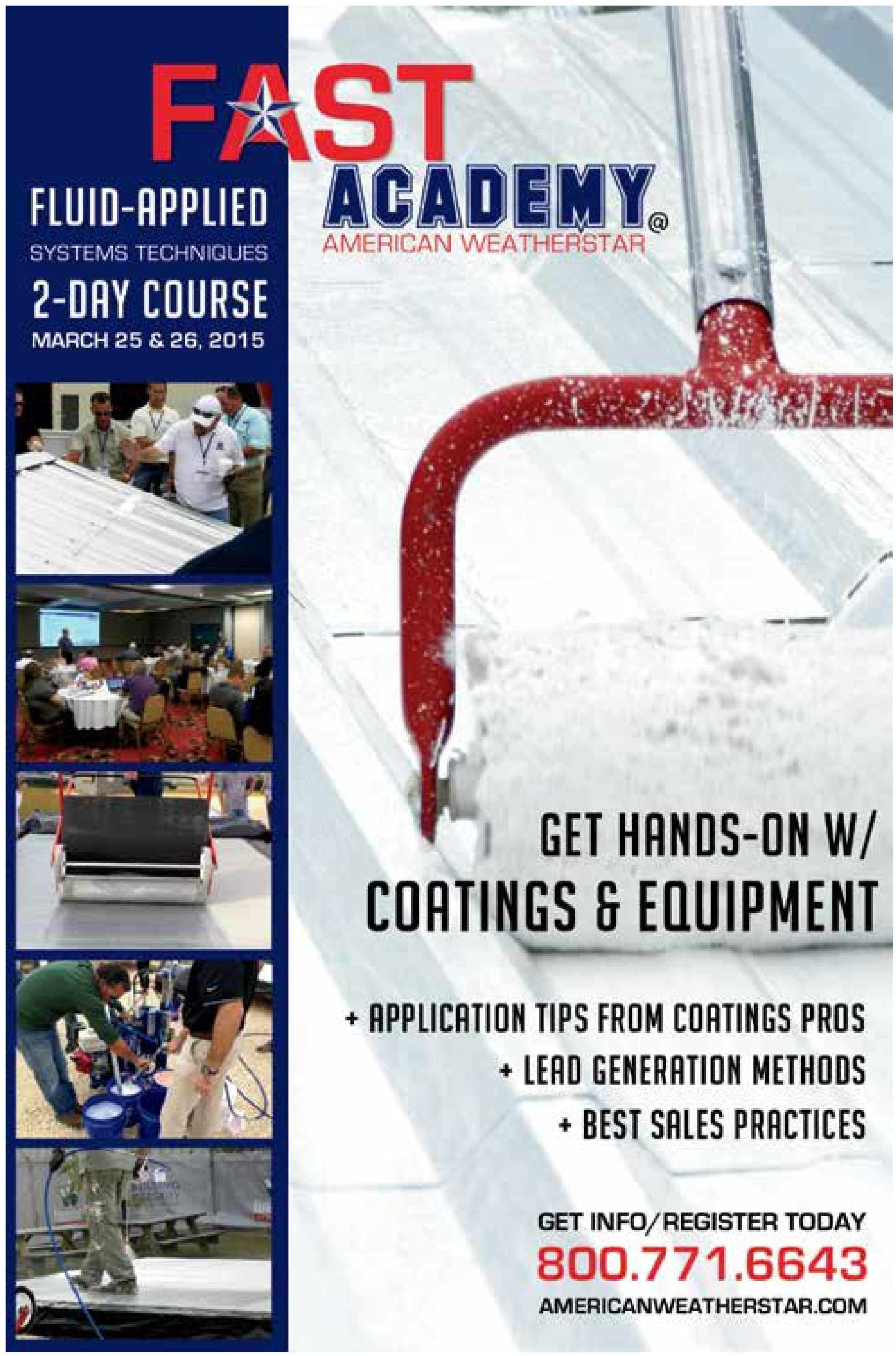
RESTORING STRUCTURAL COMPOSITE ACTION

Where evaluations have shown the SCA of a composite roof deck assembly has been destroyed or compromised, or where retrofit operations will damage or compromise SCA, remedial steps guided by the performance and engineering requirements of the IBC must be taken. These measures must be coordinated with removal of the existing roof covering and installation of the new roof covering to keep the building in the dry during operations.

LWIC SCA Restoration

Option No. 1: Replace the LWIC with new LWIC. If the damage to the LWIC was from wind loads (and most substantial structural damage to LWIC is from wind loads), the IBC requires a sealed evaluation by a licensed design professional[6] confirming the need for SCA renewal. If engineering studies confirm this to be an acceptable solution, remove the existing roof covering and the LWIC from the steel form deck. Replace any deteriorated or damaged steel form deck with new compatible materials. If the engineering study finds it necessary, update steel form deck attachment to comply with current combined loading requirements. Install water protection in the building below, including protection for ceilings, furniture, carpeting, light fixtures, etc. to protect from free water or flow-through of LWIC that will occur during LWIC replacement. Wire-brush the top of all steel form decking to expose the zinc finish. Remove all dust and loose concrete pieces to present a clean surface to accept the new LWIC and achieve the required composite bond of the zinc and cement. Allow the LWIC to remain open and to cure two or three days until it is ready to accept the new roof covering—all the time protecting the interior of the building from water and concrete damage. Install a new roof covering that meets IBC requirements.

This option presents the most challenging method for restoring the SCA of a LWIC composite roof deck.



Gypsum roof deck-damaged area removed.

Damaged area of gypsum deck being repaired with "dry option" components.

Option No. 2: Remove the roof covering and the LWIC. Convert the existing steel form deck into a Loadmaster composite deck system, creating the required SCA with dry installed board components and engineered screw attachment. After a thorough field inspection, Loadmaster will conduct the wind evaluation as required by IBC and engineer the new SCA to meet the building code requirements. Present the design, sealed by a design professional, to the building code official as required by the IBC and, upon approval, proceed with the installation.

Employ a licensed and trained dealer to remove the LWIC, replace any damaged steel form deck with compatible materials, and install additional attachment of the steel form deck areas as required to bring the SCA in compliance with the required combined design loads. Install optional insulation and the required dense mineral board, all attached with the properly engineered attachment pattern to complete the SCA formation. Install the new roof covering daily to keep the building in the dry.

This option is less challenging, does not require interior protection of the building, and is quicker to achieve.

Loadmaster Restoration

Retrofitting of a Loadmaster roof deck to either maintain or restore SCA requires use of proprietary materials and engineering—all furnished and installed by licensed and trained dealers. To ensure proper design and installation, the company recommends that a field survey be made of the existing project and submitted for engineering analysis. Experience has shown that damage from excessive concentrated loadings or unattended roof leaks on 30- to 40-year-old installations is usually confined to rather small areas and is easily repaired. Retrofit operations that remove a fully adhered roof covering cause a strength loss in the top mineral board and a loosening of screw attachments, which will compromise the SCA. Historically, wind has not caused significant structural damages to the system. Therefore, for such conditions, the IBC does not require an evaluation by a licensed design professional; however, Loadmaster can furnish such if required or requested.

After removing the roof coverings, any deteriorated or damaged steel deck sections should be replaced with new steel sections, and any damaged board or insulation materials should be replaced with new Loadmaster materials. Upon completion of repairs, optional insulation and a new dense mineral board should be installed over the entire surface of the assembly and attached with the engineered screw attachment pattern as recommended by Loadmaster to recreate the SCA necessary to meet current IBC structural requirements.

Since this process requires only removal of the existing roof coverings, installation of the new materials and the roof covering can occur immediately, providing little exposure of the interior of the building to the elements.

Gypsum Deck Restoration

Retrofit of gypsum decks poses a serious design question. Is the roof deck used as a shear diaphragm to resist wind or seismic loads? If an inspection of the structure by a licensed design professional produces a "no," then repair methods and techniques are simple. If the answer is "yes," then things become rather complicated.

For a "no" answer, the repair or restoration of the SCA needs to deal only with gravity loads and wind-uplift loads. Damaged areas can be removed and replaced in two different ways—the wet way or the dry way. The wet repair involves removing the damaged areas from the bulb tees, cutting the wire mesh and leaving a selvage edge, installing a new form board to match the existing, tying in new reinforcing mesh, and repouring the patch with new gypsum concrete. Protection of the interior of the building will be required to prevent liquid gypsum from coming through the roof deck. When the gypsum has set adequately, the new roof covering may be installed.

The dry way involves removing the damaged areas from the bulb tees, cutting the wire mesh and leaving a selvage edge, and installing a steel deck section perpendicular and attached to the bulb tees with screws at intervals sufficient to brace the bulb tees against rotation under loads. Install optional insulation and mineral board to the steel section at an elevation equal to the height of the surrounding gypsum with an engineered screw attachment pattern to complete the SCA. Roofing can be installed immediately. The steel deck section can be flat or corrugated and painted a color to match the underside of the deck. If needed, an additional layer of insulation can be installed over the entire roof deck assembly along with the roof covering.

For a "yes" answer on the diaphragm question, sufficient technical information has not been located by the authors of this article to make recommendations for repair. One option to consider is to remove the entire gypsum deck, including the bulb tees, and install a new roof deck system engineered to provide all the IBC structural requirements for the building. A second option is to design and engineer structural steel bracing for the structure to function in place of a structural diaphragm. Either of these two methods will provide reliable solutions to the problem.

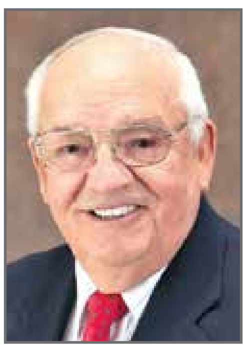
SUMMARY

From the above discussion, it is obvious that serious structural concerns exist in retrofitting structural composite roof decks, and these concerns require specific specialized attention. Chapter 34 of the IBC states plainly that maintenance required to keep a building in a safe condition is the responsibility of the building owner[7] or his or her designated agent. Further, Section 114.1 of the IBC states that it is unlawful for any person, firm, or corporation to erect, construct, alter, repair, or occupy a building in violation of the code.[8] And Section 114.4 states that those who do shall be subject to penalties as prescribed by law.[9] Clearly, when retrofitting a composite roof deck, owners, roof consultants, manufacturers, and roofing contractors share responsibilities that can produce both criminal and civil liabilities. The writers hope this article will help everyone avoid such unpleasant circumstances.

REFERENCES

1. Wheeling Corrugating Co. Steel Form Decks, page 7
2. *Loadmaster Design Manual*, Uniform Load Tables, page 3-1
3. 2012 International Building Code, Section 202, page 17
4. 2012 International Building Code, Section 114.4, page 9
5. 2012 International Building Code, Section 114.4, page 9
6. 2012 International Building Code, Section 3405.3.1, page 571
7. 2012 International Building Code, Section 3401.2, page 569
8. 2012 International Building Code, Section 114.1, page 9
9. 2012 International Building Code, Section 114.4, page 9

Note: While the 2012 edition of the IBC is referenced in this article, the referenced sections and requirements also exist in the 2009 version.



Dr. Larry Luttrell

Dr. Larry Luttrell is professor emeritus in civil and environmental engineering from the University of West Virginia, where he was a faculty member from 1965 through 1998. He received a PhD in structural engineering from Cornell University in 1965. In 1985, he was elected as a Fellow of the American Society of Civil Engineers. For years, Luttrell served as technical advisor for the Steel Deck Institute (SDI) and authored three editions of SDI's Diaphragm Design Manual. *He remains active in SDI today.*

Lynn Nunley

Lynn Nunley is the founder and president of Loadmaster Systems, Inc. He received a BS in mathematics with a minor in mechanical engineering from the University of Houston in 1960. In 1961, he joined the roofing industry as an estimator and later founded his own roofing, sheet metal, and roof deck business. In 1965, he purchased a perlite expanding plant and joined the LWIC roof deck industry, which led to the development of the Loadmaster Roof Deck System in 1970.

Construction Workplace Fatalities Decline

According to a Bureau of Labor Statistics report, construction fatalities decreased slightly in 2013, and fatalities in the industry have dropped 36% since 2006. There were 796 workplace deaths in the private construction industry in 2013 and 806 in 2012. That is equal to a 2013 fatality rate of 9.4 per 100,000 workers, down from 9.5 in 2012.