UPLIFT RESISTANCE OF EXISTING ROOF DECKS:

RECOMMENDATIONS FOR ENHANCED ATTACHMENT DURING REROOFING WORK

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Abstract

The uplift resistance of roof decks on many buildings in the U.S. is quite limited, particularly at the perimeter and corners of buildings constructed prior to the mid-to-late 1980s. As greater attention is given to the wind design of roof coverings, an increasing number of deck failures will be experienced during high winds unless the uplift resistance of weak decks is increased. This article provides guidance for assessing the need to upgrade the uplift resistance of roof decks as part of the reroofing work.

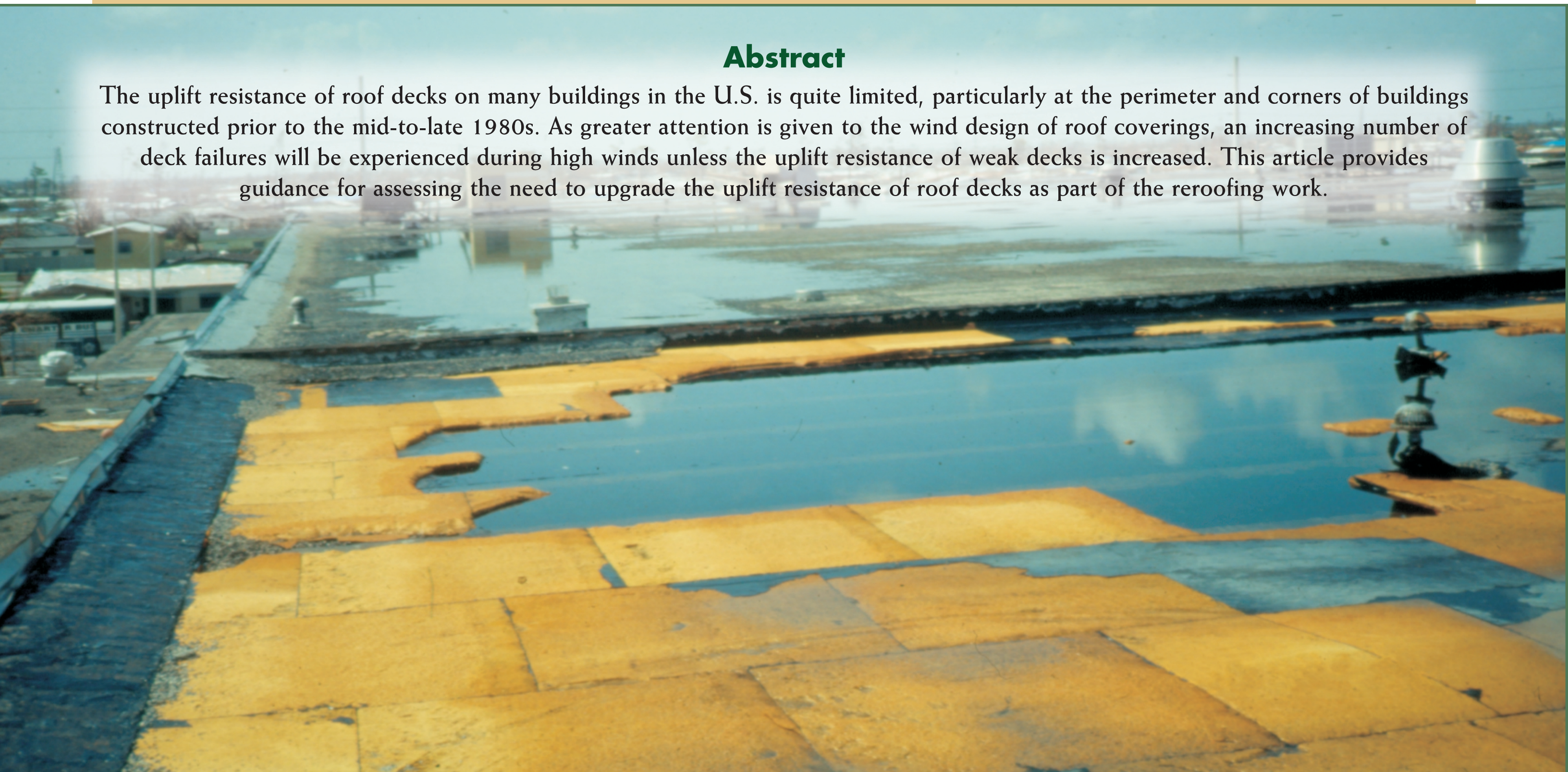

Photo 1: This aggregate-surfaced, built-up membrane blew off as a result of lifting and peeling of the metal edge flashing. Historically, lifting and peeling of edge flashings and copings (and subsequent membrane lifting and peeling) have been the most common wind failure modes for membrane roofs.

Introduction

Although deck failure has not been a common failure mode in the past, for a roof assembly to achieve good high-wind performance, the roof deck must be sufficiently strong and adequately attached to resist the design wind loads. The good historical performance of decks is primarily attributable to failure of the roof coverings (which is typically caused by lifting and peeling of the metal edge flashing or coping[1]), rather than good uplift resistance of decks (*see Photo 1*).

With loss of the roof covering, the uplift load on an air permeable deck (such as steel and wood) is substantially reduced. With greater attention being given to the wind design of roof systems and metal edge flashings and copings, it is reasonable to expect that for many roofs, the weak link in the uplift load path will be the deck attachment. Therefore, an increased incidence of failure of older decks will likely occur unless greater attention is given to their attachment.

Designers and contractors involved in reroofing projects currently have insufficient design guidance concerning upgrading the wind uplift resistance of roof decks. In some cases, the existing deck and attachment features are adequate to resist current design loads. However, more commonly, the deck attachment does not have adequate resistance. In some of the cases where the deck is inadequately attached, it is appropriate to strengthen the deck attachment as part of the reroofing work, while in others, it is appropriate to accept the existing connections as they are.

The decision to strengthen or not to strengthen the deck's uplift resistance depends on a variety of factors, including building code requirements, the magnitude of the current design wind loads compared to the uplift resistance of the existing deck attachment, the importance of the building (e.g., a hospital or an office building), whether or not the building is located in a high-wind region, and the type of deck and deck connection.

This article will explore these issues and provide guidance to assist designers and contractors involved in reroofing work.

Code Compliance

It is incumbent upon the reroofing designer to determine the building code requirements pertaining to the reroofing project. If there are ambiguities in the code requirement, the designer should seek clarification from the building official. As an example, the following are from the 2000 edition of the *International Building Code (IBC)*.

	Field of Roof	Roof Perimeter	Roof Corners
79 *UBC*	0.718 kPa (15 psf)	0.718 kPa (15 psf)	0.718 kPa (15 psf)
79 *SBC*	0.479 kPa (10 psf)	0.479 kPa (10 psf)	0.479 kPa (10 psf)
84 *B/NBC*	0.790 kPa (16.5 psf)	0.790 kPa (16.5 psf)	0.790 kPa (16.5 psf)
ASCE 7-98	0.718 kPa (15 psf)	1.149 kPa (24 psf)	1.77 kPa (37 psf)

Table 1: Design Uplift Loads in Southern Arizona

	Field of Roof	Roof Perimeter	Roof Corners
79 *UBC*	1.796 kPa (37.5 psf)	1.796 kPa (37.5 psf)	1.796 kPa (37.5 psf)
79 *SBC*	1.628 kPa (34 psf)	1.628 kPa (34 psf)	1.628 kPa (34 psf)
84 *B/NBC*	1.939 kPa (40.5 psf)	1.939 kPa (40.5 psf)	1.939 kPa (40.5 psf)
ASCE 7-98	2.538 kPa (53 psf)	3.878 kPa (81 psf)	5.506 kPa (115 psf)

Table 2: Design Uplift Loads at the Southeastern Tip of Florida

Section 1510.1 requires reroofing (either tear-off and replacement, or re-covering) to comply with Chapter 15 (which specifies requirements for roofs on new buildings). If up to 25% of the roof is reroofed in any 12-month period, the new work is to comply with Chapter 15, but the portion of the roof that is not reroofed can be left as is. If over 25% is reroofed, the entire roof needs to comply with the new roofing requirements. However, the provisions in 1510.1 apply to the roof covering (i.e., everything above the deck), not the roof deck.

Provisions in Chapter 34 pertain to the deck itself. Section 3401.2 states that buildings and parts thereof are to be maintained in conformance with the code edition under which they were installed. Hence, the intent of the existing structures chapter is to permit existing decks to remain as originally constructed. However, if the deck has deteriorated over time, Section 3402.2 is applicable. It states that if "unsound or otherwise structurally deficient" structural elements (including decks) are found, the elements shall be made to conform to the requirements for new structures. Therefore, if severely corroded decking is found, the decking must be repaired or replaced. The repaired or replaced decking must have sufficient strength to meet current load requirements.

In summary, for reroofing projects under the jurisdiction of the 2000 *IBC*, the roof covering must comply with the requirements for reroofing. However, upgrading, repairing, or replacing the deck is not required by the code unless the deck has deteriorated.

Compare Original and Current Wind Loads

Although the *IBC* does not require uplift resistance of the existing deck to be strengthened, it is prudent for the reroofing designer to compare the uplift loads derived from the building code under which the building was originally designed, to the uplift loads derived from the current building code. This is especially important if the building was designed to the 1979 (or earlier editions) of the *Uniform Building Code (UBC)* or the *Standard Building Code (SBC)*, or the 1984 (or earlier editions) of the *BOCA Basic/National Building Code (B/NBC)*. In these editions, a uniform uplift pressure was used throughout the entire roof area. However, in subsequent editions, substantially higher loads were applied to roof perimeters and corners. Therefore, decks and the deck support structure on buildings designed to these earlier code editions are often substantially under-designed in perimeter and corner areas when compared to current design uplift loads.

To illustrate the magnitude of the difference between current design practice and that of a few years ago, the following tables give the design uplift loads derived from the 1979 *UBC*, the 1979 *SBC*, the 1984 *B/NBC*, and from *ASCE 7-98*[2] (which is referenced in the *IBC*). The example building is 9.1 m (30′) high, with a low-slope mechanically attached roof membrane in a suburban exposure (Exposure B). The building for *Table 1* is located in southern Arizona. The building for *Table 2* is located at the southeastern tip of Florida. The glazing for this building is not protected against breakage from wind-borne debris.

Check Uplift Resistance

In addition to comparing the original and current wind design loads, it is prudent for the reroofing designer to evaluate the uplift resistance of the deck. (If the designer is not a licensed architect or engineer, the designer or building owner should retain a licensed architect or engineer to perform this evaluation.)

If drawings for the original construction are available, the design uplift resistance of the deck can be approximated. Information derived from the drawings (such as deck span, deck fastener type, and spacing) should be field verified. If drawings are not available, information for this evaluation will need to be obtained from a field investigation.

Evaluation of the deck's resistance may reveal that the deck has greater or less uplift resistance than would be expected by calculating the uplift loads derived from the code under which the building was originally constructed.

As part of this evaluation, spot checking the condition of the deck and deck attachment should be conducted during the reroofing design process to determine if the structural integrity of the deck and deck connections have been degraded by water leakage or condensation. Where possible, the underside of the deck should also be evaluated. The evaluation should be conducted by an investigator experienced with the type of deck used on the building.

If a tear-off is contemplated, the entire deck surface can be evaluated during the reroofing work. If a re-cover is contemplated, a more extensive evaluation should occur during the design process:

- Several large test cuts (600 mm x 600 mm [2 feet x 2 feet] minimum) should be taken. The number of cuts will depend on several factors, including the deck type, roof size, leakage history, and extent of wet insulation.
- Nondestructive evaluation (NDE) for moisture within the roof system should always be performed (except for those systems where NDE is not applicable). If wet areas are found, large test cuts should be taken in the wet areas to assess deck condition.

Photo 2: Because of inadequate joist attachment, the entire roof assembly (i.e., joists, plywood decking, and asphalt shingles) blew off as a single unit and landed about 135 m (450') from the building. The joists were merely toe nailed to the top plate of the wall.

Building Importance

The building's importance should also be evaluated when considering whether or not to upgrade the deck's uplift resistance. For example, if the deck is overstressed when current design uplift loads are applied, it may be appropriate to not upgrade the structure if it is an office building. But if it is an essential facility (i.e., a Category III or IV building as defined in ASCE 7-98), such as a hospital or school, it would be prudent to upgrade the deck's uplift resistance. Upgrading the deck's uplift resistance is also prudent on buildings that contain expensive equipment or critical operations (such as computer centers and research labs), even though these types of buildings are not designated as essential facilities.

For essential facilities and buildings that contain expensive equipment or critical operations, it is also prudent to consider uplift resistance of the deck support structure. If the deck is well attached to the roof framing, the attachment of the beams/joists may be the weak link in the uplift load path (*See Photo 2*), or buckling of the beams/joists may be the weak link. Upgrading the roof framing can be very difficult and expensive, but if high reliability is important, framing upgrade is sometimes necessary.

High Wind Areas

Deck uplift resistance becomes increasingly important as design uplift loads increase. For buildings located in areas with a basic wind speed (as defined in ASCE 7-98) greater than 40 m/s (90 mph) for a 3-second peak gust, upgrading the deck's resistance should be considered if its resistance is significantly lower than that required to meet the current building code.

Upgrading deck resistance on buildings in excess of approximately 30 m (100') should also be considered. Because cast-in-place concrete decks are common on tall buildings, and this type of deck typically possesses great uplift resistance, the need for deck upgrade on tall buildings is infrequent.

The decision to upgrade the deck resistance is usually based on economic considerations pertaining to property damage and interrupted use of the property, or because the building provides a vital service (such as a hospital). However, the decision to upgrade the deck on tall buildings may be based on concerns pertaining to injury or death from wind-blown roof debris. *(See Photo 3)*

Photo 3: This 14-story building had a built-up membrane attached to a lightweight insulating concrete (LWIC) deck that was cast over metal form decking. The LWIC was reinforced with steel mesh, but the mesh was near the lower portion of the LWIC (where it should have been able to resist gravity loads). However, during high winds, large windows at the top floor failed due to over-pressurization. This resulted in an increase in the internal air pressure in the floor below the roof and increased the uplift load on the deck. Because the reinforcing in the LWIC was not located in the upper portion of the deck, the LWIC broke apart and the roof membrane ruptured. Fortunately, during this particular storm, the 1.8 m (6') high parapet prevented most of the debris from blowing off the roof.

Deck Type and Connection

As noted above, cast-in-place concrete decks typically offer exceptionally good uplift resistance. However, this is not the case with precast concrete decks. Although precast decks are heavy, they can be lifted during high winds *(see Photo 4)*. The performance of these decks is very dependent upon the connection of the deck to the support structure (as is the case with most deck types).

If precast Tee decks are designed for gravity loads only, large uplift forces can cause failure once the uplift load exceeds the dead load of the particular element.

The uplift performance of other deck types primarily depends upon the adequacy of the attachment to the supports.[1] *(See Photo 5)* Many deck types designed in accordance with the 1979 *UBC*, 1979 *SBC*, or 1984 *B/NBC*, or earlier versions thereof, possess very limited uplift resistance.

Steel decks are commonly attached with puddle welds. Puddle welds are often poorly made, and are sometimes inadvertently broken during roofing work because the welds are inadequate to carry the loads induced during the work. During the reroofing design investigation as well as the reroofing work itself, if the deck is steel and attached with welds, special attention should be given to the adequacy of those welds. If broken or poorly executed welds are discovered, new attachments should be made. Screw attachment is recommended for greater reliability.[3]

Recommendations on the magnitude of safety factors for deck attachments on essential facilities are given in Reference 4.

Conclusion

Upgrading the deck's uplift resistance (particularly at the roof perimeter and corners) can be a prudent component of many reroofing projects. After giving due consideration, it may or may not be appropriate to upgrade. However, upgrading should always be considered, based on the factors discussed in this paper.

In most cases, the deck upgrade evaluation typically occurs during the reroofing design process because upgrading the deck from below is usually very difficult and expensive. However, for some buildings, such as essential facilities located in hurricane-

Photo 4: A precast concrete twin-tee deck panel was lifted and thrown back toward the center of this roof. Three large roll-up doors collapsed, which increased the internal air pressure in the building and increased the uplift load on the deck. Although precast deck panels are heavy, they need to be anchored to resist large uplift loads.

Photo 5: This 38 mm (1-1/2") deep 0.76 mm (22 gauge) steel deck was puddle welded at every other rib to steel beams, which were spaced at 2.1 (7') on center. Large areas of decking blew off at a corner and along one of the walls.

prone regions, it is often prudent to evaluate the deck's resistance prior to the need for reroofing. If the deck is a prime candidate for upgrading, it can be prudent to perform upgrading and reroofing before the existing roof reaches the end of its service life. ■

References

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