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Reroofing Considerations

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Abstract

The following document on roofing system selection criteria was adopted from a monograph, published in 2001 by the National Council of Architectural Registration Boards (NCARB).¹ The author prepared the monograph and it received a Special Publication Commendation from the Construction Specifications Institute (CSI). There are two monographs – Low-Slope Roofing I and Low-Slope Roofing II. Low-Slope Roofing I focused on built-up roofing systems, and included discussions on roof decks and insulation. Low-Slope Roofing II focused on other types of low-slope systems and included the following chapters:

- Membrane Materials
- Design Considerations
- Reroofing Considerations
- Sustainable Design Considerations
- System Selection Criteria
- Warranty Considerations
- Key Elements of Specifications and Drawings
- Construction Contract Administration
- Problems after Job Completion

1. Introduction

Reroofing design is substantially more complex than designing roofs for new buildings because of several reasons, including:

- the building is finished and occupied, there is risk of water damage to the interior and in some cases there is risk of injury to occupants;
- existing conditions often present obstacles to good roofing practices;

- unknown conditions, such as deteriorated deck or poorly attached edge flashing nailers;
- the rare presence of friable-asbestos-containing fireproofing below the deck, on the underside of the membrane, or at flues.

It is therefore imperative that architects involved in reroofing design be diligent and thorough in their evaluation of the existing roof system, and in the selection, specification and detailing of the new system. If the architect does not have considerable reroofing design expertise and experience, it is prudent to consult with a professional roofing contractor or roof consultant.

- *Reroofing* is defined as the process of re-covering or tearing off and replacing an existing roof system.
- *Re-covering* is defined as the addition of a new roof system over an existing roof system.
- *Tear-off* is defined as the removal of the existing roof system down to the roof deck and the installation of a new roof system over the existing deck.
- *A partial tear-off* is defined as tear-off of the existing roof system in selected areas of the roof.

There are two variations of a partial tear-off. In one case, the existing roof system is removed down to the deck in selected areas of the roof (typically those portions that have wet insulation). Infill materials are installed at the tear-off areas and a new roof system is added over the infill areas and over the area where the membrane was not removed. In the second case, the membrane is torn off throughout the roof area, but the insulation remains (unless there are wet areas, in which case, the wet insulation is also removed). A new roof system is added over the existing insulation.

¹Copies can be obtained from NCARB using the order form available in the handout folder.

Substantial costs can be saved by reroofing before the existing roof insulation gets wet (because of the opportunity to retain the insulation), or before interior finishes, furnishings or equipment are damaged or destroyed. Unfortunately most roofs are not periodically observed, hence most problems go unnoticed until they become quite severe and costly to correct. See the "Construction Contract Administration" chapter for a discussion about semi-annual observations.

2. Design Considerations for Reroofing

Reroofing presents an opportunity for implementing improvements, such as enhanced thermal performance to reduce cooling or heating costs, improved drainage, and increased resistance to fire, snow or wind loads.

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- 2.1. Evaluation of the existing roof assembly
- 2.2. Repair or reroof
- 2.3. Tear-off versus re-cover
- 2.4. Temporary roof
- 2.5. Special reroofing design considerations
- 2.6. Reroofing above or adjacent to an existing roof
- 2.7. Special aspects of specifications and drawings
- 2.8. Special aspects of construction contract administration.

At the end of this chapter, publications are listed that provide further information on reroofing.

2.1 Evaluation of the Existing Roof Assembly

The first and most crucial phase of the reroofing design process is the evaluation of the existing roof assembly. The evaluation needs to be conducted by an investigator who is experienced in the type of roof system that is currently on the building. The purpose of the investigation is to determine the composition of the assembly, including the thickness of each type of insulation board within the assembly, the condition of the existing assembly and causes of failure. An aging failure is the desired failure mode. In this type of failure, the roof simply wears out after many years of exposure. However,

if the roof is failing prematurely, it is important to determine the causes of the premature failure so that the new roof can be designed to avoid replicating the problem. During the investigation, potential problems unrelated to the roof need to be investigated, such as leakage from walls that extend above a roof or leakage from rooftop HVAC units. If non-roof related deficiencies are causing leakage but not addressed, roof replacement will not solve the problem.

The extent of the problems identified during the field investigation needs to be determined. For example, does wet insulation occur only in isolated areas (in which case, selective removal and replacement may be appropriate) or is it widespread?

The potential for litigation should be discussed with the building owner prior to conducting the investigation. If litigation is possible, greater documentation is normally required, including documentation related to sampling. However, at the outset of an investigation, the potential for litigation is often unknown. Therefore, it is typically prudent to assume that litigation is possible, and conduct the investigation with this possibility in mind.

2.1.1 Field Investigation

Test cuts should be taken down to the roof deck to determine system composition and condition. Two-inch [50-mm] diameter cuts or small cuts (about 4 inches x 4 inches [100 mm x 100 mm]) can be made. At least one sample should be taken from each roof area where there is a possibility that a different system configuration or type occurs, or if different roof areas are believed to be of different ages. If a re-cover design is contemplated, additional large cuts should be taken as discussed below in section 2.5. If the roof is still under warranty, obtain authorization from the warrantor before taking test cuts; otherwise, the warranty may be inadvertently voided.

The field evaluation should include investigating for the presence of asbestos-containing roofing materials and the presence of asbestos-containing fireproofing on the underside of the roof deck. Built-up roofs constructed prior to September 1990 often used asbestos felts for the membrane or the base flashings. Prior to that time, asphalt roof cement typically contained asbestos, and some asphalt roof coatings also were asbestos-containing. Asphalt roof cement and coatings are still permitted to contain asbestos, but for the past several years, most of these products have not contained asbestos. Asbestos associated with built-up roofs is typically non-friable. Some early generation thermoplastic single-ply membranes had friable asbestos on the underside of the membrane. Friable insulation is occasionally found around older flue penetrations.

The investigation needs to include a careful assessment of the structural integrity of the deck; for example, has it been degraded by water leakage or condensation? In addition, it is often prudent to assess the roof deck and the supporting structure's resistance to current design seismic, snow or wind loads. The need and scope for this latter assessment are determined by the building's location, age and importance. For example, buildings in areas of low seismic, snow or wind loads would not normally need such an assessment. However, if a building is in a moderate or high seismic, snow or wind area, the architect should determine what building code (or other standard) was used to develop the original design loads and compare them with current load requirements. If the original design loads are significantly lower than current loads, upgrading the deck or supporting structure's load resistance may be prudent even though the upgrade is not mandated by the reroofing provisions in the current code. The building's importance should also be evaluated when considering whether or not to upgrade the structure. For example, if the roof structure of an office building is moderately overstressed when current design snow loads are applied, it may not be necessary to upgrade the structure. But if it were a hospital, school or a critical computer center, it would be prudent to upgrade the structure. For more information about deck uplift resistance refer to the document by Smith (2001).

2.1.2 Nondestructive Testing

Oftentimes the use of one or more of the three nondestructive evaluation (NDE) techniques are extremely helpful in determining the extent of moisture accumulation within the roof system. The following is a brief overview of these techniques:

- **Electrical capacitance:** Electrical capacitance meters create an electrical field below the meter. Moisture in the roof system causes the reading on the meter to increase. Some meters take readings as the meter is rolled across the roof. Other meters only take readings at distinct points. In this case, readings are taken on a grid (usually 10 feet x 10 feet [3 m x 3 m]). Wet areas are more likely to be discovered when a small grid is used, but the smaller the grid, the more costly the survey. Conductive surfaces such as foil-faced membranes and EPDM do not permit the use of capacitance meters.
- **Infrared thermography:** Infrared thermography equipment detects the roof surface temperature. Changes in temperature can indicate wet and dry insulation due to their different heat transfer and storage properties. When using this type of equipment, the entire roof surface is scanned. Infrared surveys can be performed from fixed wing aircraft or helicopters. Aerial work is economical

when a large number of buildings need to be surveyed, such as at a military base or university.

- **Nuclear hydrogen detection:** Nuclear hydrogen detection meters have a radiation source that emits high velocity neutrons when turned on. When the neutrons strike hydrogen atoms, the meter counts them. Water molecules and other materials, such as bitumen and concrete, contain hydrogen atoms. Nuclear meters take readings at distinct points, hence this type of survey is also performed on a grid. Because all three nondestructive techniques indirectly detect moisture, NDE surveys should always be verified by destructive testing, and they should be conducted by a person experienced with the type of technique used. The exception to destructive testing verification is when an existing roof is surveyed before and after new adjacent construction. In this case, destructive testing is only necessary if there is an apparent increase in moisture following the new construction.

2.1.3 Historical File

In addition to the field investigation, the evaluation should also include a review of the roof's historical file (which hopefully includes the as-built drawings and specifications, submittals, and previous leakage and repair reports). The investigator should also interview personnel who are familiar with the roof's history to determine, for example, under what conditions the roof leaks.

2.1.4 Checklists

The following resources provide checklists that can be of assistance when evaluating existing roofs:

- Manual of Roof Inspection, Maintenance, and Emergency Repair for Existing Single-Ply Roofing Systems (SPRI/NRCA 1992)
- Manual for Inspection and Maintenance of Built-Up and Modified Bitumen Roof Systems: A Guide for Building Owners (ARMA/NRCA 1996a)
- Manual for Inspection and Maintenance of Spray Polyurethane Foam-Based Roof Systems: A Guide for Building Owners (NRCA/SPFD 1998a).

2.2 Repair or Reroof

After the roof has been evaluated, the first decision to be made is whether the roof is a candidate for repair, or if it truly needs to be reroofed. Sometimes spending a few thousand or tens of thousands of dollars, depending upon the roof size, on repair is a prudent course of action. However, it is important to avoid making a significant expenditure on repairs that only provide short-term relief.

- For example, removal and replacement of a thousand or a few thousand square feet of insulation, depending upon the roof size, that became saturated because of a punctured membrane can be an appropriate solution if the remainder of the roof has several years of remaining service life. The distribution of the wet insulation can also influence the repair or reroof decision. For example, if the wet area is contiguous, the removal is more economical than if there are several areas of wet insulation. But if the roof membrane were at the end of its life, it would be prudent to reroof the entire building.

The repair or reroof decision may also depend upon the building owner's intentions.

- For example, if the owner intends to demolish or sell the building in the near term, repair of a poor roof may be justified, whereas if the owner intends to keep the building for many more years, reroofing would be appropriate.

If repair is contemplated, it may be wise to perform laboratory analysis of membrane samples (including field seams, depending upon membrane type). Reroofing is necessary when expenditures for repair become excessive, leakage becomes intolerable, the risk of leakage development is unacceptable (in the case of a computer center, for example), or there is catastrophic roof failure (such as wind blow-off or severe hail damage).

2.3 Tear-off versus Re-cover

After it has been decided that the roof will be reroofed rather than repaired, the next decision is whether the existing roof will be torn-off or recovered.

- **Tear-off Features:** Moisture within the existing roof system is eliminated. The entire surface of the roof deck can be checked for structural integrity and attachment.
- **Tear-off Cautions:** There is greater potential for water leakage and occupant disruption during reroofing. Increased cost related to demolition and debris disposal. Increased landfill demands. Increased demand for replacement materials such as new insulation to replace the existing.
- **Re-cover Features:** The potential for water leakage during reroofing is minimized. The R-value of the existing insulation is retained (so the building owner's original investment is not thrown away). If the new membrane leaks, the old membrane often prevents the water from reaching the interior of the building. However, this can also be a disadvantage, as minor leakage can go undetected for a considerable time, thus allowing water to migrate between the old and

new membranes for a considerable distance. In some instances, uplift resistance of the roof system is enhanced. This approach is less expensive because demolition labor and landfill disposal costs are avoided. Decreased landfill demands.

- **Re-cover Cautions:** There is potential for moisture entrapment, which could degrade the roof deck or other roof system components. There is limited opportunity for discovering and correcting deteriorated or inadequately attached deck.

2.3.1 Reasons not to Re-cover

In some instances it is unwise to re-cover. These are discussed below:

- **Building code limitations:** The local building code may not permit covering over wet insulation, or it may limit the number of permissible covers. Removal of just the roof membrane may overcome this latter limitation.
- **Wet insulation:** Re-covering over an existing wet roof system is not recommended.
- **Structural limitations:** Re-cover is not viable if the roof deck or deck support structure cannot accommodate additional dead load, unless part of the existing system is removed (for example, removal of the loose aggregate on a built-up roof). If the deck is deteriorated or inadequately attached, the existing roof system should be torn off so that the deck can be repaired.

2.3.2 Partial Tear-off

A variation on the re-cover approach is to remove the membrane, but retain the insulation. The advantage of the partial tear-off option is that the entire top surface of the insulation can be observed, which can facilitate detection of wet insulation. However, with this option, some of the advantages of the re-cover approach are sacrificed. In this variation, after removing wet insulation and infilling with new, a cover board is typically placed over the existing insulation and the new membrane is then installed. If the new membrane is fully adhered, the cover board is typically mechanically attached. If the new membrane is mechanically attached, the membrane fasteners may be sufficient to attach the cover board, depending upon the size of the cover board and the spacing of the fasteners. If the new membrane is ballasted, the cover board is typically loose-laid. A temporary membrane over the tear-off area is typically only required if the new membrane is not installed over the tear-off on the same day that the tear-off is made.

2.4 Temporary Roof

On most reroofing projects, a temporary roof is not necessary. Even on tear-off projects, typically a portion of the roof system is torn off and replaced with the new system the same day. However, in some cases it may be cost-effective for the contractor to remove all or a large portion of the existing roof and install a temporary roof. This approach is used when there is an unusual rain threat during construction or to facilitate construction (for example, it can be cheaper to perform tear-off all at one time).

Typically it is not necessary to specify a temporary roof. If the contractor desires to install a temporary roof to minimize cost or risk of water infiltration during construction, the contractor will propose a no-cost change. In this case, the contractor prepares a temporary roofing proposal for the architect's approval. The proposal should include details regarding the materials, temporary system design, and whether or not the temporary roof will remain in place. In rare instances, the architect may desire a temporary roof. This typically occurs when the roof covers a facility, such as a computer center, that is very sensitive to water leakage. In these cases, rather than rely on the contractor to propose a system, it is typically prudent to specify a conservative temporary roof (including surface preparation requirements prior to installation of the permanent roof).

2.5 Special Reroofing Design Considerations

The following special considerations are applicable to reroofing design:

- If the existing roof system failed prematurely, the new system design should respond to the problems that caused the premature failure. Otherwise, the new system may also fail prematurely.
- If portions of the existing roof system are removed, infill materials are needed in the affected areas. Roof insulation is typically needed and vapor barrier materials are needed. A membrane patch over the infill area may or may not be needed (this primarily depends upon construction scheduling). In most cases, it is appropriate to specify infill materials to match the existing. However, if the new system will be fully adhered, verify that the attachment of the infill materials complies with the current building code. Also, verify that the infill materials meet current building code fire performance requirements. If an existing component is no longer available, specify a suitable alternative.
- The new system should comply with building code provisions, including those provisions specifically related to reroofing. In particular, be aware of minimum roof slope requirements. Environmental loads (seismic, snow, rain and wind) and dead loads should also be considered, along with fire-resistance and energy-efficiency requirements.
- Dew-point calculations should be performed to verify that the dew point occurs in an acceptable location.
- The occupancy or under-deck conditions (such as the presence of asbestos-containing fireproofing or mechanical or electrical equipment adjacent to the deck) may dictate the method used to attach the new roof system. For example, if exposed fasteners are visually undesirable, or if driving fasteners through the deck could dislodge dust that would be detrimental to occupants or manufacturing operations, or if fasteners could penetrate electrical conduits, then an attachment method that does not rely upon fasteners would be preferable. Or, if fireproofing could be dislodged by use of heavy equipment during application, a ballasted system should be avoided.
- If wood nailers are to be reused (for example, at metal edge flashings or parapets), verify that they are in good condition and adequately attached to meet current wind uplift loads.
- Parapet substrates should be suitably prepared to receive the new roof system. Depending upon the type of new and existing roof systems, it is often prudent to install new preservative-treated or exterior fire-retardant-treated plywood to receive the new parapet flashing.
- If existing penetrations are awkwardly located (for example, a plumbing vent immediately adjacent to a parapet) it is prudent to relocate the penetrations, rather than try to execute details that are unlikely to provide long-term service. Alternatively a SPF system could be specified, as this system readily lends itself to awkwardly located penetrations and to roofs scattered with piping. If HVAC equipment is on sleepers or stands that are too low, the equipment should be raised. If door thresholds at doors leading out onto the roof are too low, they should be raised. If there are weep holes, the new system should not block the weeps (this may require modifying the wall to raise the weeps).
- Existing mechanical and electrical equipment and skylights that have been abandoned should be removed. If the equipment or sky-lights are curb-mounted, the curb should be removed and the deck opening filled in. Retaining the curb and providing a cover over the curb opening may be a less expensive option, but is not as desirable because a membrane penetration still occurs. If an abandoned curb is retained, a sheet metal covering over the curb can be

used if the opening is not too large. Insulation (and vapor retarder when needed) should be provided under the covering. Decking material is used to span larger curb openings. In this case, the decking is normally covered with the same roof system used for the field of the roof.

- If a more energy-efficient roof system is designed, consider upgrading the HVAC equipment as previously discussed in the Thermal Upgrade section.
- If the roof is on a historical building, special consideration may be necessary to comply with preservation goals, while delivering a roof system that offers higher performance. For example, use self-adhering modified bitumen in lieu of organic felt for underlayment beneath flat-seamed soldered architectural metal panels. This approach provides a high performance underlayment for secondary water infiltration protection while offering a roof covering that replicates the original metal roof.

In addition to the above, the following special considerations are applicable to re-cover design:

- NDE should always be performed (except for those systems where NDE is not applicable) during the design stage. Areas of wet insulation should be identified and specified for removal.
- Several large test cuts (2 feet x 2 feet [600 mm x 600 mm] minimum) should be taken to assess deck integrity and attachment during the design stage. The number of cuts will depend on several factors, including the deck type, roof size, leakage history and extent of wet insulation. Where possible the underside of the deck should also be evaluated.
- There are two basic ways to attach the new system. One approach is to keep it divorced from the existing roof. The other approach is to adhere the new system directly to the existing membrane. The divorced approach can be accomplished in several ways: by mechanically attaching a layer of insulation (or loose-laying it in the case of a ballasted system) between the old and new membranes; by using a fleeced-backed membrane that is ballasted, mechanically attached, or in a PMR configuration; or by installing a metal panel system over a new support structure above the existing roof. With a divorced system, the new system is not dependent upon the existing system for uplift resistance.

The adhered approach is commonly done with sprayed polyurethane foam. With this technique, both the existing and the new systems need to possess adequate uplift resistance. When such an approach is contemplated, extensive field uplift resistance testing should typically be performed during the design stage. If the existing system is inadequately attached, it may be possible to

mechanically attach the existing membrane and then adhere the new system to it. When a new system is adhered to the existing, attention needs to be given to cleaning the existing membrane. In most cases it is also prudent to specify priming of the existing membrane.

2.6 Reroofing Above or Adjacent to an Existing Roof

Sometimes a building will have one or more areas that are in need of reroofing, but other roof areas may not need to be reroofed. Reroofing above or adjacent to an existing roof that is not included in the reroofing project has the very great potential of causing harm to the roof that is to remain. If the roof that is not scheduled for reroofing has limited service life remaining, it is prudent to specify that it too be reroofed. If the roof has ample life remaining, the architect should consider the recommendations discussed below. Even when following these recommendations, however, the architect will find that saving an existing roof is challenging. In many cases it may be best to avoid the NDE and protective measures and include the roof area in the reroofing project.

- Have a non-destructive evaluation (NDE) performed shortly prior to construction. The purpose is to determine if there is wet roof insulation.
- Specify protection requirements. These will vary according to the type of existing roof and expected loading during construction. In *many* instances, installing plywood or OSB over a cushion [such as an inch (25 mm) of EPS] will suffice.
- If the roof is under warranty, contact the warrantor to determine if they have protection recommendations or requirements. Also determine if the warrantor desires to inspect the roof after construction is complete.
- During a pre-construction conference, discuss the importance of taking care of the roof, observe the roof with the contractor and agree on its condition before construction. Advise the contractor of the results of the NDE and advise that a NDE will be performed after completion of the work.
- After job completion, have another NDE performed and observe the roof. If the NDE shows new areas of wet insulation or if damage is observed, corrective work should be undertaken. Also if the roof is under warranty and the warrantor desires to inspect the roof after construction is complete, verify the inspection occurred and that the warrantor agrees to keep the warranty in force. Advise the building owner to have another NDE performed two years after job completion, as damage may not immediately manifest itself.

2.7 Special Aspects of Specifications and Drawings

In addition to information routinely included in specifications and drawings for new roofing projects, the specifications and drawings for reroofing projects should address the following:

- The existing system (including component materials and approximate thickness of each type of insulation) should be identified so that the contractor can adequately estimate the job.
- The documents should indicate if asbestos-containing roofing, fireproofing or pipe insulation materials occur. The documents should also provide guidance if asbestos-containing materials are unexpectedly found.
- If fireproofing on the underside of the deck is poorly attached and is likely to be spalled off by the reroofing work, the documents should address remedial fireproofing work.
- Specify that the contractor is to take photographs or a videotape of existing conditions, including interior and exterior building surfaces, sidewalks, paving and landscaping that might be misconstrued as damage caused by the reroofing work. Require submittal of the documentation prior to beginning work.
- Specify protection of persons from injury, and protection of the building, sidewalks, paving and landscaping from damage or soiling.
- Specify that the contractor coordinate work activities on a daily basis with the owner in those situations where the owner desires to place protective dust or water leakage covers over sensitive equipment or furnishings or where it is desired to evacuate people from underneath the work area.
- If deck removal is required, special requirements related to occupant protection and protection from leakage should be specified. Occupant protection typically can be achieved by evacuating occupants from beneath the work area. But in rare instances, very special protective measures may need to be specified. For example, where occupant evacuation is not possible, a protective platform can be constructed below the roof deck. If the building is located in an area that experiences very frequent snowstorms, rainstorms, a weather-tight work enclosure may need to be positioned over the work area.
- If HVAC equipment will need to be shut down during roof application, specify that the shutdown be coordinated with the building owner. If air intakes are in the work area and the work is likely to result in objectionable odors or fumes, specify that the intakes are to be shut down and covered while work is underway in the vicinity of the intakes.
- If fire detection devices need to be shut down (for example, duct or plenum smoke detectors) because of concern about activation due to dust or fumes, specify coordination of the shutdown procedures with the building owner. Specify if special measures need to be taken by the contractor during the deactivation of portions of the fire detection system, such as implementation of a fire watch or working only during special hours or days.
- Specify that each roof area has suitable roof drainage at the end of each day. For example, if roof drains are blocked during the day to keep out debris, they should be unblocked before the roofing crew leaves for the day. Also, if the existing drainage pattern is blocked by demolition or partial installation of the new system, some method for eliminating ponding needs to be incorporated so that nighttime rainfall does not result in roof collapse.
- If the new components, such as insulation or membrane, are mechanically attached, specify that fastener pull-out testing be performed in accordance with *Standard Field Test Procedure for Determining the Withdrawal Resistance of Roofing Fastener*, also known as *ANSI/SPRI FX-1*,² before installing the new system. Specify testing by the roofing contractor or by an independent testing agency. During design, some limited pull-out testing should be performed to provide data for design purposes.
- If a temporary roof is required or reroofing occurs above or adjacent to an existing roof, refer to sections 2.4 and 2.6 for additional specification and drawing requirements.
- Peer review should be considered on reroofing projects that are very complex, very costly or in those cases where the architect has limited expertise and experience with reroofing design.

2.8 Special Aspects of Construction Contract Administration

In addition to activities routinely associated with construction contract administration related to new roofing projects, the following are applicable to reroofing projects:

- During the pre-roofing conference, the roofing contractor's foreman should be advised under what conditions the architect should be consulted concerning unforeseen conditions. For example, deck integrity parameters should be established. Generally the architect would not need to be consulted if superficial surface corrosion is found. But if

² Copies can be obtained from www.spri.org

advanced corrosion is discovered, the need for corrective action should typically not be determined by the contractor.

- The architect (or other entity engaged to provide construction contract administration services) needs to be able to quickly respond to unforeseen conditions in order to avoid idling the roofing crew.
- The architect should check to see if appropriate measures are being taken with respect to occupant and leakage protection. Verify, for example, that the contractor is notifying the building owner about which areas are being worked on each day. Verify that excessively large areas of membrane are not being torn off. (In other words, the tear-off should be small enough for the contractor to make the area watertight in the event of rain.) And verify that air intakes are shut down when so needed.
- If the architect observes that satisfactory measures are not being taken to protect the building or grounds, the contractor should be advised.

3.0 Sources of Additional Information

- The NRCA Reroofing Manual. It is included in The NRCA Roofing and Waterproofing Manual.
- The Manual of Low-Slope Roof Systems by C.W. Griffin and R.L. Fricklas.
- Proceedings of the Low-Slope Reroofing Workshop by ORNL.
- Metal Roofing Systems Design Manual by MBMA.
- Smith, T. L., (2001), "Uplift Resistance of Existing Roof Decks – Recommendations for Enhanced Attachment During Reroofing Work." Proceedings of the International Conference on Building Envelope Systems and Technologies (ICBEST), Vol. 1, NRC, Canada.

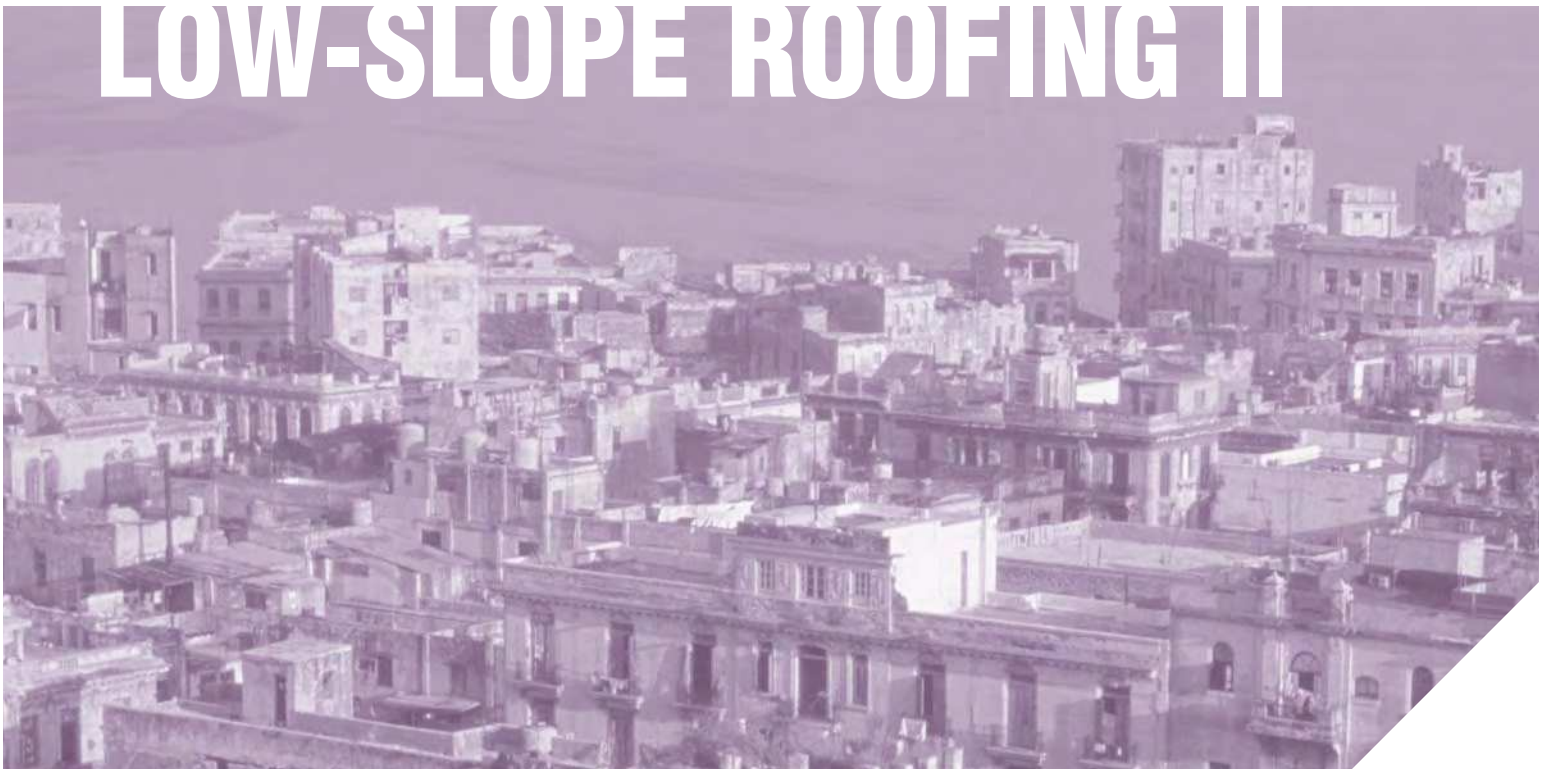
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