Low –Slope Roofing Study Report

Division of Capital Asset Management

Office of Planning, Design, and Construction

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May 20, 2004

PURPOSE OF STUDY

This study is initiated in response to a number of recent failures of low-sloped (L/S) roofs[1]on Commonwealth-owned buildings. The study is intended to address potential remedies for these failures and to propose procedures which could be put in place for new low-sloped roofs.

For the purposes of this study, "roof" refers to the entire roofing system made up of, but not limited to, the structural substrate, the insulation, the roofing membrane, the membrane protection (if any) and appurtenances, such as flashings, expansion joints, vents, curbs, and sleepers. Roofing failures usually result from the failure of one or more of these components.

This study looks at roofing problems from the following five points of view. Recommendations are included at the end of each section:

1.0 Condition Assessment (existing conditions)
2.0 Roofing Specifications
3.0 Design and Detailing
4.0 Installation
5.0 Warranty Management, and Maintenance

The information contained herein is compiled from roofing consultants, other institutions, roofing materials manufacturers, and DCAM/OPDC staff..

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[1]ASTM Standard E 1918-97 describes a Low-Slope Roof as having a slope of 2:12 inches or less. Surfaces with a slope greater than 2:12 are considered to be Steep-Slope Roofs.

1.0 CONDITION ASSESSMENT

The intended design life of a L/S roof is approximately 20 years, although, some components, such as the substrate, may last far longer. Currently, many roofs experience failures within five years of installation and well within the warranty period. Most roofing failures are discovered by the building managers in terms of water leaking into their occupied spaces or by OPDC staff during or immediately after installation of the roof.

A failure in one part of the roofing system often quickly affects other elements of the roofing system making diagnosis of the failure's causes difficult. A failure of a minor part, such as a flashing or a membrane seam, can have a major impact, such as the need to replace insulation over much of the roofed surface. Regular inspections and prompt repairs can minimize much of the additional damage.

Roofing failure remedies are often more complex than the initial installation because the repair/replacement solution may leave major portions of the original roof intact. These remedies may impair the full life of the roofing system and make maintenance and warranty management more difficult.

Repairs are often disruptive, and can be costly in terms of both emergency repairs expenses and staff time of the user-agency and DCAM. Additionally, emergency repairs may occur during the winter, resulting in unsatisfactory repairs.

Warranties generally require annual professionally documented roof inspections and special inspections following roof damage repairs to keep the warranty in force. A yearly assessment and reporting procedure could be developed to include overall inspection, and , if necessary, infra-red scanning (if insulation damage is suspected), and limited destructive testing (such as roof cuts, etc.).

RECOMMENDATION: Each roof should be inspected and reported on annually to keep the warranty in force. More frequent inspection may be warranted if traffic has been heavy. Prompt repairs can avoid further damage to roofs. Inspections may require the availability of greater expertise for unusual repairs. Relevant maintenance and warranty data will be stored on CAMIS.

2.0 ROOFING SPECIFICATIONS

There are a number of roofing system types, all having unique specifications and certain limitations. Properly designed, installed and maintained, most types of roofing systems can provide satisfactory service. Traditional and modern built-up roofs (BUR's) account for approximately 30 % of roofs being installed. Single-ply roofing systems of various types account for the balance of L/S roof installations on Commonwealth-owned buildings.

OPDC is presently preparing a modified bitumen specification as the preferred standard. The specification will require this preferred roof type with the understanding that the Designer may choose to recommend deviation from the DCAM preference depending on a situation which may be unique to the project or application. These situations may include winter installation, compatibility with existing roofing materials (such as, a major portion of the existing roof is a recently installed EPDM roof), and historic compatibility (such as, slate or copper), to name a few.

Because the roofing system includes a number of elements and because specifying practices generally require open specification of components, great care must be exercised in specifying a roofing system of compatible elements. Descriptions of the key roofing system elements and factors involved with proper installation are described below.

a) Substrate – The substrate supports and protects the roofing system from the under-side. The substrate can also provide slope-to-drain for the entire roofing system. The substrate must support the roof to within acceptable tolerances of the roof system, including any post-installation loading of the roof surface. The substrate may be called upon to protect the underside of the roof from excess moisture penetration into the system, which could damage the insulation. Though more expensive, a concrete/metal composite roof deck is more stable and therefore may be more desirable than a metal roof deck. A metal roof deck generally is designed with more flexure which can stress the elements of the roof and their attachments, affecting the condition of the roof membrane. If the membrane is compromised, the metal roof deck flutes tend to hold water and can contribute to retained moisture problems.
b) Moisture barrier – The moisture barrier protects the warm-side of the roofing system from the infiltration of moisture. Very moist environments can be especially destructive. However, normal levels of moisture in an occupied space can produce condensation within the insulation. If a moisture barrier is installed immediately above the substrate, it can provide temporary protection of the building until the remainder of the roofing system is installed.
c) Insulation – The slope of the upper surface of the insulation is critical to roof performance as it is essential to prevent water ponding on the surface. This can be accomplished by either sloping of the structure and the application of a uniform thickness of insulation or tapering of the insulation material. If the insulation is to experience any compressive loading (foot traffic or materials storage), it must be

protected by a protection board. Compressed insulation, such as under roof trafficways, will compromise thermal properties, provide impaired support for the roofing membrane and may compromise the ability of the roof to drain. Foot traffic can delaminate the adhered membrane from the insulation. Protection board applied over the insulation provides greater resistance to this delamination. The minimum slope of the top surface of the insulation to drain should be ¼" per foot.

d) Roofing membrane – The roofing membrane and all appurtenances must be free of penetrations for the design life of the roof, at least twenty years. The drainage surface must slope positively to drain from all points. The membrane must receive adequate support from both the insulation and the substrate. Patches should be limited to not more than 1 per 100 square feet of surface area. All roofs should be flood tested for continuity of roofing membrane and for positive slope to the drain. Roofs should not be accepted unless both continuity and slope are established[2].
e) Membrane protection – Normal traffic on a L/S roof can be destructive to the roofing membrane. Walkway pads should be placed to accommodate normal traffic patterns. However, traffic frequently leads to other areas of the roof. Protection is rarely sufficient around mechanical equipment and points of roof access. Excessive surface traffic should be limited for all membrane roofs.
f) Surface Color -- In general, roofs should be specified with a white or light surface. Such a roof can be 60 to 70 degrees cooler in summer months, which both extends the roof life and reduces to load on air conditioning systems.

Roofing innovation and practice – Roofing practice continues to evolve to take advantage of improvements and changes in materials, design, and installation. Systematic investigation and evaluation of evolving roofing methods may provide a means of assuring overall roofing quality on DCAM jobs. A mechanism should be available for consideration of innovations, including specialty roofs, such as green roofs. However, these specifications will demand thorough review prior to acceptance.

RECOMMENDATION:

1. For <u>new</u> roofs, we recommend the use of a modified bitumen roof (SBS[2], not APP[4]) as the standard for all new low-slope DCAM roofs. Modified bitumen roof specifications have the advantage of multiple-layers for added puncture protection, can be competitively bid,

[2]Flood testing specifications for roofs requires careful scheduling to be performed prior to application of interior finishes. Other concerns are the season of the year and the structural capabilities to bear the exceptional loads.

[3]Styrene Butadiene Styrene, a rubber additive which when mixed with roofing asphalt allowed the modified asphalt to be stretched up to 6 times its original length. When allowed to relax, it will return to the original length.

[4]Atactic Polypropylene, a plasticizing agent which when mixed with roofing asphalt allowed the modified asphalt to be stretched up to 50% of its orininal length without breaking. When allowed to relax, it will retain the shape into which it has been stretched.

and have a proven track record of good performance for a twenty-year warranty. Other roof types may be required for specific conditions or for re-roofing. (Continued on the following page.)

2. Also, we recommend that consideration be given to using a composite concrete-topped steel deck substrate. This type substrate offers exceptional stability to the entire roof assembly.

3. We recommend that a total roof warranty be required, to include insulation, protection board, roofing membrane, and flashings. If a single-ply membrane is required, then a protection board needs to be installed under the membrane to prevent puncture. In some cases, depending on winter conditions, a temporary roof will need to be installed during construction, and replaced later in the project.

4. All products and materials to be utilized in the fabrication of any roof system or sub-component shall meet or exceed the standards established in Appendix N of DCAM's Form 9, *Instructions for Designers* for requirements by Construction Specification Institute (CSI) Division, maximum VO content of coatings, adhesives, and sealants, and additional compound limitations. Removed roofing materials are to be separated from other construction and demolition wastes and, where possible, recycled.

3.0 DESIGN AND DETAILING

Many of the roofs installed by DCAM have failed in part due to inadequate design and detailing for the specific application. Building designers often do not possess the knowledge and experience for the Commonwealth's complicated roofing design applications. The expertise required must be applied to all factors listed herein affecting roof performance. This could be accomplished through a peer review process using both internal and external reviewers.

Frequent roofing design failures have been related to the following:

1) Lack of thorough roof analysis, including the specific DCAM/User Agency design application or the existing conditions of the roof
2) Structural roof design that does not consider
   a) Roof deck substrate type, and substrate structural design,
   b) Snow loading
   c) Wind up-lift calculations
3) Inadequate insulation design concerning–

   a) slope of top surface and density of insulation
   b) Inclusion of dew-point calculation for the roofing assembly
   c) Sloped structure vs. tapered insulation
   d) Protection board – mechanical fastened vs. adhesive
4) Inadequate drainage calculations -- Positive drainage plan submission and plan review
   a) Roof drain type – cast iron, not plastic
   b) Number of drains
5) Incorrect roof membrane selection – exposures to weather, traffic, installation temperatures
6) Improper roof penetration selection/design
   a) Roof vents
   b) Mechanical units – sleepers and curbing
   c) Lightning arrester details
   d) Flashings of all types – edge, cap, expansion joints
7) Insufficient walkway protection system
   a) Type selected
   b) Placement
   c) Walkway surface maintenance

A listing of issues follows which would be helpful in maximizing the life cycle of roofs. Such issues may be referenced in the standard specifications:

1) Multi-point Roof Design Guidelines for use by designers and review by OPDC
2) Installation
   a) Inspection
   b) Video taping of insulation installation
3) Temporary protection of roof during construction – weather and traffic
4) Roof commissioning to train facility staff,
   a) Signage at roof access with critical information – type of roofing system, manufacturer of principal components with contact information (telephone number), number of plys, year installed.
   b) Warranty management, including yearly inspections
   c) Roof log of required inspections and of major work on roof by others.

d) Drain cleaning schedule

RECOMMENDATION: We recommend that the designer or DCAM employ an expert roofing consultant during the design process for peer review of the proposed roof design and to ensure that the design can be maintained during the warranty period.

We recommend development of a collection of successful DCAM roofing details for use on future jobs.

Because of extensive roof damage over time due to access and maintenance of rooftop mechanical equipment, we recommend consideration of the cost benefits of fully enclosed mechanical spaces which are accessed from occupied spaces and not requiring roof traffic.

4.0 INSTALLATION

For various reasons, the designer or the field engineers do not perform thorough inspection of roofing installation. This can allow liberties to be taken in materials installation and in protection of installed materials. Assurance of proper roof installation is of major importance to the success of the roof, requiring full-time inspection during installation by an inspector with expertise in the type roof being installed, regardless of the roof type specified.

The roofing inspector would document all roofing conditions as installed to serve as part of the job record, to support the roof warranty, and to aid in warranty management and maintenance.

RECOMMENDATION: We recommend that a full-time expert roofing inspector be on-site during the installation of the deck, the insulation assembly, the membrane, the flashing and other appurtenances, and when a survey of the roof and roof drains is conducted. Such inspection will ensure the protection and acceptance of the final roof.

5.0 WARRANTY MANAGEMENT AND MAINTENANCE

Contractors generally provide a 20-year warranty on roofs. To keep the warranty in force, a roof needs regular maintenance of roof drains, yearly inspection records, and documentation

of all roofing flashings and penetrations by authorized personnel. Similar inspection is required immediately after a failure is observed and repaired.

DCAM has a major role in "commissioning" roofs. Specifically, DCAM informs facility managers about their responsibilities for roof warranties and precautions required to ensure that the roof system achieves its expected useful life. A more comprehensive roof commissioning processes could be developed with a minimum of effort.

RECOMMENDATION: We recommend that roofing commissioning be initiated for the roofing installer to review important roofing matters with the user agency. A copy of each roofing warranty will be retained by the user agenda and by DCAM for each facility. Relevant maintenance and warranty data will be stored on CAMIS. A communication system should be established between the user agency and DCAM that alerts DCAM when a yearly warranty inspection is required and when a failure occurs.

We recommend installation of roofing signage at entry points to the roof listing type of roofing system, manufacturer, date installed, and holder of the warranty.

CONCLUSION

This report recommends immediate changes in the following areas:

1) development of a thorough standard roof specification covering inspection during construction of the substrate through final inspection
2) peer review of the proposed roof design, including existing conditions assessment for re-roofing
3) use of an expert roofing inspector during roofing installation
4) roofing commissioning for the user agency and DCAM covering roofing care and warranty management requirements
5) Annual roof inspection and documentation

Because of the importance of roofing performance to DCAM's mission to provide comprehensive building construction services in accordance with the highest technical standards, the committee recommends that unusual emphasis be placed on producing successful roofs and on educating OPDC staff and consultant designers on advanced roofing practice.

Because the recommendations included in this report will require changes in current DCAM practices, the committee recommends that OPDC put in place an internal standing group to

develop a strategy to implement the above recommendations and to develop a roofing reference library.

RELATED TOPICS FOR FUTURE CONSIDERATION

1. Discussion of the conditions suggesting destructive and non-destructive testing and testing alternatives.
2. Standards for roof protection around rooftop equipment.
3. Discussion of substrates, their design parameters, inspection and assessment
4. Seasonal installation issues of roofing systems
5. Developing a method of recognizing and accepting innovations which may achieve better performance than what is specified.
6. Exploration of increased involvement of roofing material manufacturers in peer reviews of proposed designs and in observation during installation.
7. Certification/qualification of roofing installers. This possibly could be achieved by specifying that the proposed installer be required to furnish evidence of having installed other, similar roofs.

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