The Roof Drainage Epidemic

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ABSTRACT

Poor roof drainage can cause accelerated deterioration of a roofing system and in extreme cases, roof collapse. It is the authors' experience that roof collapses related to poor roof drainage are almost exclusively limited to low-slope roofs with parapet walls that prevent drainage over the roof edge.

For roofs with parapet walls, the proper function of the primary and secondary drain systems is essential for roof performance and safety. However, many buildings with parapet walls do not have adequate drain systems. The authors consider this to be an "epidemic", akin to the much-publicized deficiencies in public infrastructure.

With this study, we propose to discuss common roof drainage issues and to offer a set of conditions for the oversight and approval of roofing projects. For both new construction and existing buildings undergoing roof repairs, compliance with these roof drainage conditions should be mandatory and specifically enforced by the local building officials.

INTRODUCTION

Many commercial and/or high occupancy buildings, especially those with large roof areas, are constructed with low-slope roof systems. Examples of such buildings include those utilized for commercial/retail purposes, as well as hospitals and schools.

Problems associated with low-slope roof systems, or "roof failures", occur for various reasons. The authors' definition of the term "roof failure" is discussed below in the discussion section of this paper. It is the authors' experience that a large number of roof failures are caused by improperly designed primary and secondary roof drain systems, and by a lack of and/or improper maintenance. Additionally, it is our experience that extreme cases of roof failures, including roof collapses, are almost exclusively limited to low-slope roofs with parapet walls that prevent drainage over the roof edge. It is the purpose of this paper to present our findings for several roof failure cases that we have personally investigated.

It is our opinion that if proper oversight is performed during new roof construction and/or during the re-roofing of existing buildings, most extreme or catastrophic roofing failures can be prevented. Therefore, it is the intent of the authors to propose a set of standards for the oversight of new and existing roof construction. Our proposal will be limited to high occupancy buildings with low-slope roof systems. Additionally, we will propose a more strict set of standards for "important buildings" based on the International Building Code (IBC) occupancy categories and building use.

Low-slope roof systems. It is not the intent of this paper to detail low-slope roof systems; however, the authors feel it necessary to briefly describe the major components associated with these types of roofs. Generally, low-slope roof assemblies consist of a roof covering or membrane, insulation boards, and a roof substrate or decking. Insulation generally consists of rigid boards stacked one over another to achieve a desired thermal "R" rating. The insulation is sometimes tapered to accommodate drainage requirements. The substrate consists of the building superstructure framing and a deck over which the roofing assembly is installed. In some cases, the superstructure framing is sloped in lieu of tapered insulation.

The National Roofing Contractors Association (NRCA) categorizes low-slope roof coverings or membranes into six general categories: built-up, polymer-modified bitumen, thermoplastic, thermoset, metal panels, and sprayed polyurethane foam-based. The primary waterproofing mechanism of low-slope roofing systems is impermeability of the roofing membrane. In contrast, high-slope roofing systems rely on gravity shedding of water over semi-impervious roof coverings. The roof designer should select a roof membrane(s) for a particular project based on a set of criteria, as well as site and building-specific issues (NRCA, 2006).

Drainage. It is the authors' experience that drainage is the roof component that is most neglected and whose purpose or function is often misunderstood by roofers, owners, and even design professionals. Drainage generally consists of either an array of interior drains or perimeter drainage in the form of free-fall edges or thru-wall scuppers at parapet walls.

As noted earlier, the culprit for many roof collapse cases on roofs with parapet walls is poor roof drainage. Poor roof drainage can be caused by a number of different factors, including improper or deficient design. Typical design drainage requirements include a minimum number of drains based on service areas and the inclusion of secondary drains. Secondary drains are drains that will become active during an emergency situation where the main (primary) drains are not functioning properly and/or the design rainfall rate is exceeded. For low-slope roofs with parapet walls, secondary drains typically consist of overflow drains or scuppers.

The design of primary roof drainage is typically based on the 100-year hourly rainfall rate (theoretical) for a given location as specified in the International Plumbing Code (IPC) or from an approved local weather source. The IPC provides tables based on the design rainfall rate and horizontally projected roof area (or tributary area for a given drain), which allows the user to easily size primary drainage. Secondary drainage is sized using the same method; and flow through the primary system is not considered when sizing the secondary roof drain system (ICC, 2006).

Ponded water and roof collapse mechanism. Ponding takes place when rainwater does not drain properly and collects at confined spaces and in deflections or irregularities on the surface of a roof. Acceleration of ponding occurs when the weight of the collected water causes significant deflections in the roof framing, causing progressively more water to drain to the area and creating instability in the roof framing. Considering structural design of roof framing, the strength and stiffness of the roof framing and the drainage conditions must be adequate to prevent the acceleration of ponding at the roof. However, in extreme cases, ponding instability can occur; especially in the presence of poor roof drainage and in older structures which were not designed to comply with more recent building codes. While roof failure and collapse can occur without ponding instability, it is important to consider this mechanism when a given roof structure is analyzed.

DISCUSSION

The primary purpose of roof systems is to shed water off the roof assembly and prevent it from infiltrating the interior of the structure. Therefore, it is the authors' opinion that roof systems have failed if moisture infiltrates the interior of a structure as a result of the roof system and/or the roof does not adequately shed rain runoff, which results in ponded water on the roof surface. Ponded water that persists for an extended amount of time provides conditions conducive to roof deterioration, reducing the lifespan of the roof. NRCA states, "The criterion for judging proper slope for drainage is that there be no ponding water on the roof 48 hours after a rain during conditions conducive to drying (NRCA, 2006)". Structural failure of the roof framing, such as a roof collapse, is also considered to be a roof failure. As noted above, in extreme cases, poor drainage can result in roof collapse.

The authors have evaluated many low-slope roof failures related to poor drainage. Common roof drainage issues include poor design/construction of primary and secondary drain systems, lack of maintenance, improper roof repairs, and drain system modifications. The following case studies are presented to highlight some of the aforementioned drainage issues.

Poor design/construction. The subject structure in our first case study was a large public high school located in south Texas, near the Gulf of Mexico. The roof at the subject structure was a multi-level low-sloped roof with multiple roof areas that were bounded by parapet walls. **Figure 1** is an overall view of several roof areas at the subject structure. Roofing types included modified bitumen roofing (both smooth and granule surfaced) and built-up roofing with gravel ballast. The roof drain systems throughout consisted of primary roof drains and associated secondary scuppers along the roof edges.

Figure 1. General view of a portion of the school roof.

It was observed during our investigation that several of the scuppers were located approximately 4" to 7" above the adjacent roof drains. **Figures 2 and 3** are examples of two of the scuppers that were measured during our site visit. Previous building codes (dating back at least to the 1997 Uniform Building Code [UBC]) required that the secondary drain system be located 2" above the primary drains (ICBO, 1997). The requirements of the more recent IBC are based on the design of the roof structure and differ from the UBC prescriptive requirements. Regardless, it has been our experience that the 4" to 7" distance between the scuppers and primary drainage at the high school roof was too high. In our opinion, this condition was potentially unsafe if the roof structures were not designed for the hydrostatic loading from water accumulation to these heights. Additionally, the significant amount of water allowed to pond on the roof due to the location of the scuppers provided a condition conducive to significant water intrusion and accelerated roof deterioration.

Figure 2. Scupper is located approximately 5" above the roof surface.

Figure 3. Additional scupper located 7" above the roof surface.

Lack of maintenance. For our second case study, the authors investigated a commercial building with a low-slope roof that had been overlaid with a foam roof system. Roof drainage consisted of two (2) small roof drains that also served two (2) evaporator coil condensate lines, and six (6) thru-wall scuppers along the south side of the roof edge (roof was sloped towards this edge). There were no strainers over the roof drains.

There was a significant amount of debris along the south end of the roof around the scuppers. **Figures 4 and 5** below depict the debris build-up at the subject roof. The debris was obstructing the roof drainage. Vegetation was observed growing from the debris, indicating a long-term condition. Additionally, staining was observed at the roof consistent with previous standing water, and unevenness at the foam roof surface, which created several localized low spots for standing water. These conditions resulted in poor roof drainage, which contributed to roof failure and water intrusion at the building interior. Proper maintenance at the roof level would have prevented the significant debris build-up and provided conditions favorable for proper drainage.

Figure 4. Debris build-up at roof.

Figure 5. Debris build-up around scupper.

Improperly applied repair. Improper roof repairs can radically affect roof drainage. The subject structure in our third case study was a medical office building in Houston, Texas. The roof at the structure consisted of a ballasted built-up roof system. It was reported that the roof at the west side of the building was damaged during Hurricane Ike. The roof in this area had been replaced with a modified bitumen membrane prior to our site visit.

It was observed during our investigation that the roof surface around several of the drains had been patched; however, the strainers at most of these drains were missing. It was also observed that the overflow scuppers along the north parapet wall had been flashed over by a modified bitumen membrane repair, thus eliminating the overflow drain system. This created a potentially unsafe condition at the roof: if the primary drain system was to become impeded (more likely due to the lack of strainers), there would be no secondary means by which the roof could drain, which would create conditions conducive to a roof collapse. **Figure 6** shows an area at the roof where the overflow scupper had been patched over and **Figure 7** shows the same scupper as viewed from the exterior of the structure.

Figure 6. Patched over overflow scupper.

Figure 7. Non-functional scupper viewed from exterior.

Inadequate drain covers. The subject building in our fourth case study was a multi-story office building with recessed roofs at the three top-most floor levels, as shown in **Figure 8**. The recessed roofs consisted of rectangular gravel ballasted built-up roofs with perimeter parapet walls at three edges. The fourth edge consisted of a building exterior wall with windows over a low curb wall. An overall view of one of the recessed roofs can be seen in **Figure 9**. Drainage for each roof consisted of two pairs of primary and secondary drains. Drainage for roofs cascaded down from upper to immediately lower roofs. Therefore the bottom-most recessed roof received the drainage from all upper roof areas.

Figure 8. Recessed cascading roofs.

Figure 9. Ballasted built-up roof.

Water intrusion occurred at two of the roofs during a high precipitation storm. Improper/deficient drain strainers were reportedly clogged with debris. As a result, water ponded over the roofs to a height that exceeded the curb height adjacent to the exterior wall of the building. Water infiltrated over the curb and below the windows causing extensive water damage to the offices below the roofs. It should be noted that the secondary drains were sized appropriately even considering the cascading conditions of the roofs.

It was determined that improper drain strainers caused the drain systems to fail. **Figure 10** shows both primary and secondary drains that were reportedly cleaned after the storm event. Note that the primary drain strainer was installed flush with the drain and a square low-profile ballast retainer was located outside the drain. The ballast easily overcame the ballast retainer and clogged the primary drain strainer. There was no strainer at the secondary drain and more than likely it was also covered by debris during the storm. Neither the primary nor the secondary roof drains conformed to building code standards, including requirements that strainers or drain covers extend a minimum of 4" above the surface of the roof (ICC, 2006). This case exemplifies at least two typical roof deficiencies: improper drain strainers and/or deferred maintenance resulting in clogged drains.

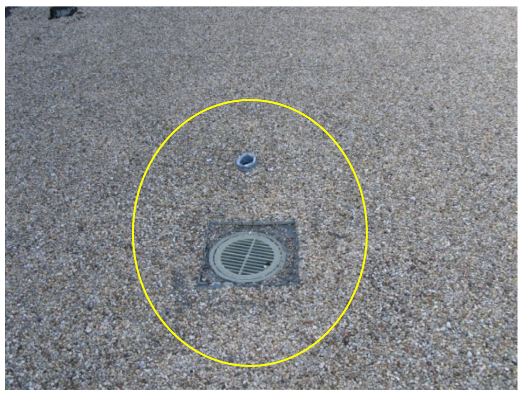

Figure 10. Primary and Secondary Drains.

Modified drainage. The subject building in our fifth case study was a nearly 100 year old retail strip-mall building. It had original wood truss roof construction with multiple layers of roofing membranes. The roof profile was unusual and consisted of low-sloped roof sections with gable-style cross-sections in an apparent attempt to direct water to the sides of the roof. Thru-wall scuppers were located on a high parapet wall at the downward slope of the roof. An overall view of the building can be seen in **Figure 11**. The roof partially collapsed during a storm event, as shown in **Figure 12**. Fortunately, there were no injuries.

Figure 11. Strip mall.

Figure 12. Partial roof collapse.

The cause of the collapse was determined as improper drainage. The roof drain system was modified upon the numerous re-roofing applications performed on the structure over the years. As **Figures 13 and 14** show, at some time the drain system changed from interior roof drains to exterior scuppers. The new scuppers became undersized due to the numerous re-roofing layers that reduced the available scupper cross-sectional drainage area and also by a reduction in size of the downspouts located on the exterior walls. Clearly, the original drain system was changed substantially and resulted in the partial collapse of the roof.

Figure 13. Modified drainage – scupper above sealed-over drain.

Figure 14. Reduction in downspout cross-section.

PROPOSED CHANGES

It is the intent of this paper to propose a set of standards for the oversight of new and existing non-residential low-slope roof construction with parapet walls. We exclude residential construction due to the lesser occupancy and the relatively low percentage of low-slope roofs with parapets, which may make additional oversight impractical. In addition, for "Important Buildings", which have higher occupancy and/or critical functions, we recommend a higher standard of review.

Important Buildings. Although the classification of "Important Buildings" is subjective, we propose that these "Important Buildings" include the buildings in IBC Occupancy Category IV and the following buildings from Occupancy Category III: schools, jails/detention facilities, and buildings with an occupancy load exceeding 5,000 (ICC, 2006).

We propose that for these "Important Buildings" with low-slope roofs and parapets restricting free drainage over the roof edge, the roof drain systems must be in compliance with the current building code at all times. This includes immediately following completion of new construction and/or re-roofing. For new construction, we propose that a drainage analysis be submitted to the city (or building official) of jurisdiction. This analysis will require signature and seal by a licensed Professional Engineer. Furthermore, we propose that the construction of the roof drain system must be certified by a licensed Professional Engineer or Architect.

To enforce these standards we propose that the issuance of a building permit be contingent on the submittal of the drainage analysis. Likewise, we propose that the issuance of the Certificate of Occupancy be contingent on the certified review of the constructed roof drain system by a licensed Professional Engineer or Architect.

For re-roofing of "Important Buildings" with low-slope roofs and parapets restricting free drainage over the roof edge, we propose that inspection of an existing roof shall be performed if greater than 25% of the roof area is repaired or replaced, or if the existing drainage system is changed in any way. This inspection should be performed by a licensed Professional Engineer or Architect. Also, we propose that any changes to the roof drain systems require a complete drainage analysis by a licensed Professional Engineer. Changes to an existing roof drain system would include removing, resizing or relocating drains, or altering drainage flow. Enforcement methods similar to those proposed above for new structures should be applied to existing structures, including the possible revocation of the Certificate of Occupancy if the roof drainage is not properly analyzed and certified. Finally, we propose that the owners of these "Important Buildings" be required to have periodic roof evaluation/maintenance by their personnel to ensure that the roof drain systems are performing and that the drains and scuppers are free from obstruction.

All other buildings. For all remaining non-residential buildings with low-slope roofs and parapets restricting free drainage over the roof edge, it is the objective of the authors' recommendations to increase the level of inspection following new construction and re-roofing projects.

For new construction, the roof drain systems should already be properly sized and designed; however, this is not always the case nor is it closely evaluated. We propose that all new construction for low-slope roofs with parapets restricting free drainage over the roof edge require a roof drainage analysis signed and sealed by a licensed Professional Engineer. After construction, we propose that the building official inspect the roof drain systems for compliance with the design, with special attention to the presence and location of the secondary drain system. We propose that the Certificate of Occupancy be contingent on this review.

For re-roofing projects on existing buildings, we propose that the city (or building official) require that the contractor submit information about the roof drainage with the permit application. The required information from the roofing contractor should include the type of roofing to be installed, the type of roof structure supporting the roof, the nominal roof slope that will be achieved, the number and size of the primary and secondary drains, and the proposed location of the primary and secondary drains (including the height of the secondary drains above the level of the primary drains). After construction, we propose that the building official perform an inspection of the roof drain system. It is likely not economically feasible to require inspection by a licensed Professional Engineer or Architect for all roofs (other than "Important Buildings", as noted above), so we propose that the building official use the building code as a guide for the drainage requirements.

It is also our opinion that a secondary roof drain system be required for all re-roofed low-slope roofs with parapets restricting free drainage over the roof edge. This includes existing buildings that do not have a secondary drain system. We propose that this requirement should take effect upon repair of more than 25% of the roof system or if the existing roof drain system is changed in any way.

SUMMARY AND CONCLUSION

Based on our experience, it is our opinion that a lack of roof drainage oversight for buildings with low-slope roofs and parapets restricting free drainage over the roof poses a safety concern to the general public. Therefore, the authors feel it is necessary to increase the level of inspection of roof drain systems for such buildings, both for new construction and for re-roofing projects. For "Important Buildings" that have essential functions or high occupancies, we recommend an even higher level of analysis and inspection to ensure proper roof drainage. We further propose that these increased standards be enforced by the city or building official of jurisdiction.

Based on our experience, it is the authors' belief that these higher standards can improve roof performance and significantly decrease the number of roof collapses. This is of great benefit to public safety and in most cases will not require a significant additional expenditure of money or effort.

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