<u>Climate Change and Gutters</u>

In a rainstorm, the size and capacity of each component of the roof drainage system is a critical factor. If any component of the system is undersized, an intense rainstorm can easily overwhelm them causing water to back up and/or spill out on the building façade and landscape in ways that can cause deterioration and damage both short and long term. However, the capacity of a system is not typically calculated once the system is on the building and for buildings of a certain vintage, the capacity may have never been measured. Preservation projects, for example, tend to favor the in-kind replacement of building materials and components and so the capacity calculations for system components tend not to be reviewed and simply replaced.

While the roof drainage system components tend to be static, the climate is constantly changing and storms are becoming more intense. A document produced by the Environmental Protection Agency entitled ñWhat Climate Change Means for Maineò (August 2016, EPA 430-F-16-021) noted that ñaverage annual precipitation in the Northeast increased 10 percent from 1895 to 2011, and precipitation from extremely heavy storms has increased 70 percent since 1958. During the next century, average annual precipitation and the frequency of heavy downpours are likely to keep rising.ò Recently completed climate research by a Historic New England consultant has shown that the intensity of rains has increased 25% in Maine over the last 40 years. With gutters on historic buildings generally being static and the weather getting actively more intense ï there must be a breaking point.

Historic New Englandôs research into the effect of climate change on our roof drainage systems was inspired by an article in *The Journal of Preservation Technology*, entitled ñWater Management for Traditional Buildingsò (Roger Curtis, Vol 47, No. 1, 2016, pages 8-14). This article discusses the need for new or enhanced preservation techniques when combatting weather change and preventing weather damage and notes that increased rainfall, especially at high-peak water-loading times, can result in overflow of gutters and downspouts, causing water to run down walls and saturate external masonry. The article suggests that the original capacity of most gutter systems is likely sufficient, but that subsequent repairs and replacements can decrease a systemôs capacity and thus its ability to protect the building. The article, whose primary focus is a broad overview of how climate change might be affecting the traditional buildings of Scotland, does not provide metrics for reviewing the capacity of the systems nor how to identify a successful roof drainage system. Historic New Englandôs intent was to use the article as a starting point for performing our own study using historic structures of New England.

In 2018, Historic New England completed the performance analysis of the roof drainage systems at seven of our museum properties and two private residential properties in Maine. This study focused specifically on three components of the roof drainage system ï gutters, outlets, and downspoutsï to determine whether these systems were sufficient to transport then-average rainfall away from the building and whether they would be adequate for future rainstorms. The results of this study are establishing a framework for understanding how certain historic roof drainage systems perform now, how they are likely to perform in the future, and what modifications might increase their effectiveness.

Background

The nine different sites studied in Maine included twenty-one different roof drainage systems. Each roof drainage system had three main components that were reviewed: the gutter, the outlet, and the downspout. A gutter is a long trough positioned parallel to and under the eaves of the roof that collects the water from the roof and is sloped to carry the water to a downspout. The downspouts are generally pipes or boxes that capture the water from the gutter and carry the water to the ground. There is typically a component called an outlet that connects the gutter to the downspout. Reviewing site drainage or capacity issues once the water leaves the downspout was not a part of the study.

There were several different types of wooden gutters in the study. Wooden gutters are the traditional New England gutter style and the study included two major forms: a built-in, or integral, gutter; and an attached, or eaves, gutter. A built-in gutter is often integrated into the cornice or other roofing detail at the time of construction. This style can be seen in Federal and Georgian architecture and became particularly popular starting with the arrival of Greek Revival houses. An attached gutter is generally applied to the building after construction. Although it could be original to an eighteenth- or nineteenth-century building, inevitably the gutters in our study all appear to be additions to the structure. What was not included in the study was a classic V-shaped trough gutter. This gutter style historically was found on early buildings and are still found today as an interpreted gutter form on many of our seventeenth-century structures. Unfortunately, there were no V-shaped gutters on any of Historic New Englandôs Maine properties.

The study also included several styles of metal gutters. These included metal half-round gutters, aluminum K-Style gutters, and several metal gutters that were fabricated to look like the wooden integral gutters they had replaced.

The outlets were predominantly round pipes of different diameters. The diameter of the pipe became the most important factor of the study. The downspouts in the study were often either metal pipes or aluminum rectangles.

The industry standard calculations for component capacity was documented in the study and can be found in several places on the internet including through the Copper Development Association. The industry standard for the amount of rainwater for which one should design a gutter system looks at two numbers: 1) rainfall intensity numbers for a ten-year storm of five-minute duration for the minimum capacity of a system component; and 2) a hundred-year storm of five-minute duration for the worst-case situation.

Findings

The findings presented below are combined from the commissioned study as well as Historic New Englandôs additional analysis. As will be seen from the statistics, while downspouts tend to be sized appropriately and can handle the flow of water for both the minimum and the worst-case storm situations, gutters and outlets are challenged. Although one needs to keep an eye on all gutter types, wooden ones are the most problematic from a capacity standpoint. The general findings are that wooden gutters only passed the test 50% of the time when looking at the minimum capacity calculation of a ten-year storm while 76% failed the hundred-year storm test. Likewise, outlets are a major choke point for the roof drainage systems. Simply put, if the pipe has a diameter of less than two inches it will inevitably fail. Outlets of a size greater than two inches can still be problematic depending on the roof area drained.

The statistics are as follows:

- 48% of the gutter components in the study failed the ten-year storm calculation while 76% failed the hundred-year storm. Of these, the numbers can be broken down as follows:
    - Eight of nine wooden gutters in the study failed the ten-year storm while nine of nine failed the hundred-year storm.
    - The wooden integral gutters replaced with metal performed well in both studies.
    - The half-round gutters performed well in the ten-year storm but were challenged by the hundred-year storm.
    - The k-style gutter held water well in the ten-year storm but failed the hundred-year storm.
- 45% of the outlet components failed the ten-year storm calculation while 55% failed the hundred-year storm.
    - The key factor is diameter of the tube. Outlets under two inches of diameter failed every time regardless of storm intensity. Over two inches in diameter passed almost every time.
- All of the downspouts in the study carried the water regardless of storm intensity.
- Obstructions around or in the outlets further restricted what could already be an undersized component. Bad solder or epoxy joints at the connection of the gutter and the outlet can block water and trap debris in the gutter. Bad solder joints should be repaired as a matter of simple recourse. De-icing cables running through the gutter and into the outlet and downspout restricted the amount of water allowed in the system. In most cases, these outlets were undersized to begin with so increasing the pipe size would greatly alleviate the concern of restricting the flow of water because of de-icing cables.
- Additionally, it became clear as part of the process that although there are several standard sources for calculating the capacity of a roof drainage system, these standards all use rain intensity data from the 1978. In our study area, the current rainfall intensity is 25% more than it was in 1978.
- An underlying premise of the study was the assumption that changes or modifications made to the gutter systems, like a wooden gutter lined with lead flashing or repairs to the outlets, were a primary cause of failure. Although modifications such as the ones noted could inhibit the flow of water, the study demonstrated that the components in the study were already undersized and so the modifications simply increased the degree of failure.

As noted, there is a high percentage of failure within the gutters and outlets included within the study. It should be noted that there are limitations to the study. The study, in the end, had a small sample size of only twenty-one systems with multiple variables. The biggest variable is the amount of roof that is being drained. The bigger the area, the more risk there is of a component failure. But the reverse is also true in that several components passed because they were draining a small area of roof, like a porch roof. Regardless of the sample size, there is ample evidence that points to the fact that Historic New Englandôs roof drainage systems are challenged by the more frequent and intense rainstorms we are experiencing.

<u>Recommendations for Mitigation</u>

There are interventions that could be considered to mitigate the impact of climate change on a historic New England roof drainage system. In each case, the impact of the intervention should be carefully weighed as to how it affects any character defining features and the architectural significance of the structure. For museum properties, the impact of the intervention should also be considered in the context of the propertyôs period of interpretation and period of significance. Most changes that are not in-kind to the existing materials and systems will inevitably require additional regulatory review by a historic district commission or easement holder.

Calculating the capacity of the roof drainage components can be complicated and complex. This may need to be the work of a consultant who understands the variables and complexities involved in making those calculations. These calculations must also be based on storm intensity weather that is gathered independently of the many online charts that are available. The study determined that many of the commonly available charts for calculating gutter sizing was using rain intensity data that was upwards of forty years old. Rain intensity has increased in Maine almost 25% since 1978 and so calculations based on older data will be inaccurate. The National Weather Service provides more up to date rain intensity numbers through their website; this data should be employed in any calculation of roof drainage capacity.

Although the standard for calculating the minimum capacity is to use the ten-year storm data, if we want to increase the capacity of the system for future-proofing the roof drainage system a new standard needs to be developed. Although we can measure the change of rain intensity over time, predicting future changes remains difficult with the scientific community quite divided over the metrics to use. To simplify this concept, Historic New England is experimenting with using the twenty-five-year storm data to calculate the new baseline minimum for capacity. Twenty-five-year storm data is the next available metric on the rain intensity scale and would reflect a moderate increase in sizing that we hope would allow for an increase in rain intensity over the next 30 years, or the predicted life-span of a new roof drainage system.

Basic preservation best practices dictate that any intervention should retain as much of the existing system as possible and assure in-kind replacement of any deteriorated materials. For example, if the gutter is appropriately sized but the outlet is not, then the gutter should be retained or, if deteriorated beyond repair, replaced in kind and only the outlet should be considered for a dimensional or material change.

Strategies for retaining existing dimensions

- Consider the installation of additional downspouts. Additional downspouts along a length of gutter will reduce the amount of water carried by the downspouts and outlets along the run. Practically speaking, the pitch of gutters feeding into any new downspouts will need to be re-oriented and the addition of downspouts will increase maintenance requirements for the system. Review of the potential impacts to the aesthetics of the site and the interpretation of character-defining details would be required for adding additional downspouts and changing the pitch of the gutter.
- Consider the installation of an overflow on the gutter. This would provide the gutter with a secondary means to release water, in case of intense rain activity. This method would need to be carefully studied and additional work may be necessary to mitigate the impact of the overflow on building or landscape materials. Design review would want to consider these impacts as well any aesthetic concerns.
- If more capacity is required, changing the actual material from wood to copper, for example, could increase the capacity of the system component tremendously without changing the actual outer dimensions. To continue the example, replacing a painted wooden gutter with a painted copper or synthetic gutter with the same profile may allow for greater capacity without sacrificing aesthetic details. Copper is a traditional material with a longstanding record of performance at roofs and gutters. Use of other synthetic materials is generally less widely tested. Review of this proposal should understand that alternative materials should be carefully evaluated on a case-by-case basis, considering differences in thermal expansion, UV reactivity, potential impacts on surrounding materials, maintenance requirements, reparability, longevity, and lifecycle cost. When using any alternative material, the character defining details of the gutter should be replicated to the greatest possible extent. Historic profiles, connections, and finishes should also be matched so that aesthetically the new element fits with the character of the materials around it.

Strategies involving change in dimensions

- Determine if historic materials and details can be replaced in-kind but at a larger size to create greater capacity. For example, copper half-round gutters come in standard sizes of 5 inches and 6 inches.
- Many historic roof drainage systems, especially those with wooden gutters, have narrow pipes acting as the outlet to the downspout. The general dimensions of these pipes vary widely but often have diameters of 2 inches or less. Research at Historic New England has shown that in almost every scenario, these pipes will need to increase in diameter to effectively move water from anything more than a small porch roof. Depending on how the gutter, downspout and outlet work together, a change in diameter of the pipe may be hidden by the downspout or other architectural elements. Increasing the diameter, however, might not work with a gutter of a smaller size and in those cases, the connection of the two elements will need to be considered. Additionally, many historic systems have a gooseneck, or angled pipe, to allow the gutter and downspouts to connect while working around an architectural element such as a cornice. Upsizing these pipes may be more visible and more integral to the architectural characteristics of the structure than ones that connect directly into downspout and are generally hidden from view.

- Design review for these different scenarios should consider whether the change in dimension could affect the appearance or character defining details of a building.

Inevitably, there are more options that can be developed to help increase the capacity of the roof drainage system components. These are just a few that might help prompt discussion.

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