RAIN COLLAPSE:

A Roof Consultant's Nightmare

By Philip D. Dregger, RRC, FRCI, PE

Figure 1 – Roof collapse after very intense but less-than-code-level rain.

It's a roof consultant's nightmare. Right after an especially intense rain, you get a call. The owner of a building for whom you prepared reroof documents informs you that part of his roof just collapsed (*Figure 1*), and initial reports are that not only were the overflow scuppers covered by the base flashing, the primary scupper drain was found to be undersized by a factor of four (*Figures 2* and *3*). Bummer.

Worse yet, you remember thinking when you first looked at the project that the scupper drain and overflows seemed kind of small (*Figure 4*) considering the size of the drainage area (*Figure 5*). You were right. Perhaps if you had suggested to the owner to upgrade them as part of the reroof project, the roof would not have collapsed. You're probably right again.

Of course, no matter how small they are, it is never okay to cover overflow drains as part of a reroof project. But what about leaving existing drains the way you find them? Is it okay, in general, to leave existing drains and overflows the way you find them if they are undersized? Are undersized drains or overflows "grandfathered" as acceptable on a reroofing project? Or, strictly speaking, is upgrading undersized storm drainage systems to meet current code requirements required as part a reroof project?

Figure 3 – Roof base flashings covering overflow scupper drains of collapsed roof.

Figure 2 – Roof base flashings covering overflow scupper drains of collapsed roof.

Unfortunately, these questions are not easily answered and too often are not seriously looked into until a roof collapses and someone gets notice of an insurance claim or is served a subpoena.

The fact is, existing storm drainage systems on many older roofs fall well short of current storm drainage requirements and, sometimes, even short of the requirements that existed when the building was constructed. This is especially true whenever scuppers are used for primary drains and/or overflows. They are often too small by factors of two or three or more; and in the case of overflow scuppers, they are often positioned two or three times too high. In effect, these roofs represent nightmares just waiting to play out in real life.

Based on my experience, if the primary roof drains on ten 35- to 40-year-old commercial warehouse-type structures in the western states were completely blocked (e.g., by wind-blown plastic bags) when a code-level rainstorm hit, I wouldn't be sur-

Figure 4 – Scupper drain and scupper overflows of collapsed roof after reconstruction. Note: They were reconstructed the same size.

Figure 5 – Aerial view of roof overlaid to show collapsed area (blue) and scupper drain tributary area (dashed red line). Image from Google Earth Pro.

prised if at least two of the them collapsed because the overflows were undersized and/or positioned too high.

So what's a roof consultant to do? As the old adage goes, "The best defense is a good offense." I suggest:

- Understand basic roof storm drainage requirements.
- Make note of how existing roof drainage provisions compare to basic code requirements.
- Notify building owners if you suspect roof drainage provisions do not comply with code.
- Offer to check and to specify upgrades, if needed, to existing storm drainage provisions.
- At a minimum, clarify what the local jurisdiction requires as part of reroof projects.

Sometimes the local municipality makes it a little easier or at least a little clearer. Sometimes they interpret current building code provisions as requiring upgrading at least portions of existing storm drainage systems (e.g., adding overflows) as part of reroofing projects.

CODE REQUIREMENTS

Roof drainage requirements are included in both the building code and the plumbing code. This article references the 2009 International Building Code (IBC) and the 2009 International Plumbing Code (IPC). Code requirements adopted in some states and localities may vary. This article focuses on requirements related to sizing roof drains and scuppers. Although equally important, we will not discuss requirements related to sizing of the drainpipes that roof drains connect to.

IBC Section 1503.4, Roof Drainage, reads, "*Design and installation* of roof drainage systems shall comply with Section 1503 and the International Plumbing Code." (Italics added for emphasis.) The applicable portion of the IPC is Chapter 11, Storm Drainage.

In brief and simply put, these code provisions require roofs to have two separate storm drainage systems (i.e., a primary drainage system and an emergency secondary drainage system) and that each system be capable of safely handling 100% of the rain associated with one-hour storms having a 0.01 annual probability of occurrence—that is, a rain that comes around on average about once every 100 years. In my opinion, although these requirements are less than perfect, they have proven a reliable safeguard against roof collapse during many very heavy rainstorms.

SCUPPERS AS DRAINS

It may be surprising to hear that although both the IBC and the IPC talk about an option to use scuppers for secondary drainage, neither discusses an option to use "scuppers" as primary drains. The IBC/IPC don't say you can't use scuppers as primary drains, it is just that the methodology laid out to size primary drains only addresses "vertical drain pipes" (i.e., conventional bowl-style drains). For information about sizing rectangular scuppers for primary or secondary drains, readers are directed to methodology and equation included in the FM Global Property Loss Prevention Data Sheet 1-54, in the 2012 *SMACNA Manual,* Appendix G; and/or in ASCE 7-10, Chapters 8 and C8.

The familiar prescriptive option from prior-model Uniform Building Codes to simply make overflow scuppers "three times the area of the roof drains" and position them "two inches above the low point of the adjacent roof" is gone. In its place is a requirement—potentially onerous for reroof projects—to size and position the scupper to "prevent the depth of ponding water from exceeding that for which the roof was designed." (IBC Section 1503.4.2.)

Figure 6 – One-and-a-half-inch diameter overflow "hole" about 3.5 in. above a 5-in. drain.

Figure 7 – Five-inch-diameter overflow drain added near drain shown in Figure 5.

REROOF REQUIREMENTS

As hinted at above, it is less than clear how these requirements are intended to be applied to reroofing projects. If, for instance, as part of a reroof project, no one actually "designs or installs" any portion of a roof drainage system (see italicized wording four paragraphs back)—that is, if the reroof project just leaves the existing roof drainage system exactly the way it was—is that okay?

Some argue that the current language requires those who design or install roofs to proactively upgrade existing roof storm drainage provisions to comply with current requirements. Mark Graham, technical director for the National Roofing Contractors Association (NRCA), as part of his recent code change proposal (ICC 2012 Code Development Cycle Public Hearings, Section 1510.1), cautions that "[the current language] can be interpreted as requiring" such compliance. Others (including Graham) argue that such proactive and potentially costly action is beyond the intent of the building code and the scope of most reroofing projects. As a result of this ambiguity, lawsuits in the wake of rain-caused roof collapses often revolve around the question of how these code requirements were or should have been applied to reroofing projects.

13:03	54.9 °F	52.3 °F	29.21in	Calm		14.1mph	91%	0.12in
13:08	54.9 °F	52.6 °F	29.21in	WSW	5.4mph	14.1mph	92%	0.12in
13:13	54.9 °F	52.6 °F	29.21in	West	2.2mph	14.1mph	92%	1.22in
13:18	53.6 °F	51.3 °F	29.26in	NW	14.1mph	17.0mph	92%	3.07in
13:23	53.4 °F	51.5 °F	29.26in	Calm		8.1mph	93%	3.07in
13:28	53.6 °F	51.6 °F	29.26in	Calm		8.1mph	93%	3.07in
13:33	53.8 °F	52.1 °F	29.29in	Calm		8.1mph	94%	0.39in
13:38	53.6 °F	51.9 °F	29.29in	Calm		8.1mph	94%	0.39in

12:50	54.9 °F	53.8 °F	29.52in	SSE	7.0mph	9.0mph	96%	2.94in
12:55	55.4 °F	54.6 °F	29.54in	South	7.0mph	12.0mph	97%	3.31in
13:00	55.8 °F	54.4 °F	29.53in	SW	16.0mph	16.0mph	95%	0.19in
13:05	55.8 °F	53.2 °F	29.51in	WSW	21.0mph	21.0mph	91%	0.08in
13:10	55.7 °F	52.2 °F	29.50in	SW	18.0mph	24.0mph	88%	0.05in
13:15	54.7 °F	51.2 °F	29.52in	WNW	16.0mph	16.0mph	88%	0.00in
13:20	53.0 °F	50.7 °F	29.52in	NW	11.0mph	11.0mph	92%	0.00in
13:30	52.8 °F	51.1 °F	29.55in	NW	8.0mph	8.0mph	94%	0.00in

Figure 8 – Data recorded at five-minute intervals at two weather stations near "nightmare" collapse. Source: www.wunderground.com/wundermap.

OUNCE-OF-PREVENTION TIP

When specifying/designing a reroofing project, confirm with the authority having jurisdiction (usually the local building official) if leaving existing roof drainage provisions as they are is acceptable or if upgrading primary and/or secondary roof drainage systems is required.

Regardless of the answer you get, it remains important for roof consultants to inform appropriate parties (e.g., building owners) in the event they see roof drainage conditions that are clearly noncompliant (e.g., overflows that are clearly undersized and/or clearly positioned too high) and recommend that they be upgraded.

Figure 6 shows a 1.5-in.-diameter overflow opening positioned about 4.5 in. above a 5-in.-diameter drain on an elementary school. Before I left the site, I pointed out to my client that the overflows were clearly undersized and insisted to my client that the planned solar PV project about which I was there to consult include new code-compliant overflows. *Figure 7* shows the new overflow drain designed and installed by the school district shortly thereafter.

THE SCUPPER MUST HAVE BEEN BLOCKED

To illustrate how the code provisions work, let's look again at our nightmare roof collapse example. Let's assume the roof section we're looking at covers 26,000 sq. ft., is sloped at about 1/4:12, is served by one primary scupper drain, and is located where the design "100-year, 60-minute" rain event is 2 in. Based on this information, 2009 IPC Table 1106.2(1) tells us we need a 6-in.-diameter drain.

Note: It may not be immediately clear to some that this table is intended to control "per-minute" runoff rates to certain levels for certain "vertical pipe" diameters. For a 6-in. drain, the listed "maximum allowable horizontal projected roof areas" control the predicted runoff rates to 563 gallons per minute (gpm) or less. It may also not be immediately clear that this table assumes the rain falls more or less uniformly for the whole 60 minutes.

You might say, "No problem. Look at the photo in *Figure 4*; that roof section had a 6- x 6-in. scupper drain. Isn't that about the same as a 6-in.-diameter drain? The rain must have exceeded 100-year levels or the scupper drain must have been blocked!"

I think for a moment and reply, "Actually, scuppers don't discharge water nearly as quickly as vertical drains; the rainstorm that caused this didn't come close to 100-year levels, and the scupper drain didn't have to be blocked for this to happen."

You look at me doubtfully and say, "Okay, smart guy. Tell me what happened."

Three factors combined to produce the collapse. First, the scupper drain was undersized by a factor of four or more. Second, as you know, the way-too-small overflows were covered. Third, even though the storm was much less severe than "code-level" (i.e., less than 2 inches fell in one hour), it dropped more than the design "per-minute" amount of rain on the roof for at least 20 minutes. And 20 minutes with an undersized drain and no overflows was more than enough time for a lot of water to collect near the drain and overload the roof.

6-IN. SCUPPER < 6-IN. DRAIN

Standing water flows straight down a drain a lot faster than sideways out a scupper. One could say the full weight of the standing water helps push water down a drain, while the sideways push of water out of a scupper is a lot less.

Duration	Recorded Rain (in.)	Design Storm (100-yr., 60-min., in.)
5 min.	0.28 in. (908 gpm, 3.36 in./hour)	0.17 in. (540 gpm, 2 in./hour)
10 min.	0.52 in. (844 gpm, 3.12 in./hour)	0.33 in. (540 gpm, 2 in./hour)
15 min.	0.77 in. (833 gpm, 3.08 in./hour)	0.50 in. (540 gpm, 2 in./hour)
30 min.	0.92 in. (498 gpm, 1.84 in./hour)	1.00 in. (540 gpm, 2 in./hour)
60 min.	**1.15 in. (311 gpm, 1.15 in./hour)**	**2.00 in. (540 gpm, 2 in./hour)**

Figure 9 – Rainfall in inches as recorded and for the design storm. Values in parentheses indicate equivalent incremental runoff rates and rainfall intensities.

According to Table C8-1 in ASCE/SEI 7-10, "Minimum Design Loads for Buildings and Other Structures," water needs to stand about 3.5 in. deep above a 6-in. drain to flow at about 540 gpm (our "design" rate). In contrast, 3.5 in. of standing water will discharge water out of a 6- by 6-in. scupper at about 114 gpm (source: FM Global Property Loss Prevention Data Sheet 1-54).

To discharge water out of a 6- x 6-in. scupper at about 540 gpm, you need the water to stand about 16 in. deep. To discharge water at 540 gpm and keep the "head" (i.e., standing water) at 3.5 in., you need a 28-in.-wide scupper. As I said, the scupper drain was undersized by a factor of four or more.

RAINFALL DATA

Figure 8 shows data from two weather stations near our nightmare roof example. The rainfall totals are expressed in equivalent "hourly" rates for each five-minute sampling period. For example, "3.07 in." means 0.26 in. of rain fell during that five-minute period.

Data from the two weather stations were combined, adjusted for different sampling durations, selected to represent likely "maximum" conditions, and then listed in *Figure 9*.

The "recorded rain" column lists the amount of rain recorded during the indicated duration and also that same amount of rain expressed in its equivalent "hourly" intensity. For example, saying 0.28 in. fell in five minutes is the same as saying rain fell at an intensity of 3.36 in./hr. for five minutes. The "design storm" column lists rainfall amounts for the design storm, assuming it is distributed uniformly over the different time durations. The gallons-per-minute (gpm) runoff rates correspond to the indicated rainfall intensity falling on a 26,000-sq.-ft. roof.

"NIGHTMARE" BUT NOT CODE

Since the recorded one-hour rainfall total is well under 2 in., our nightmare storm scenario is not considered a "code-level" event—at least not the way "code level" is currently defined. For the first 20 minutes or so, the scupper drain was certainly convinced the rain was falling at higher than "code-level" rates. Now comes the really interesting part.

Figure 10 illustrates that for the first 20 minutes or so of the storm, the rainfall amounts exceeded the intensity of rain for which we design. For example, 0.77 in. of rain fell in 15 minutes, while we only design for 0.50 in. to fall in 15 minutes (2 in. per hour divided by 4). So, for at least 15 minutes, rain runoff was arriving at the drain at a rate of at least 833 gpm, while we only design for 540 gpm. Unless you have a perfectly flat roof, this can be a big deal.

If water arrives at a roof drain faster than the drain can take it away, it starts

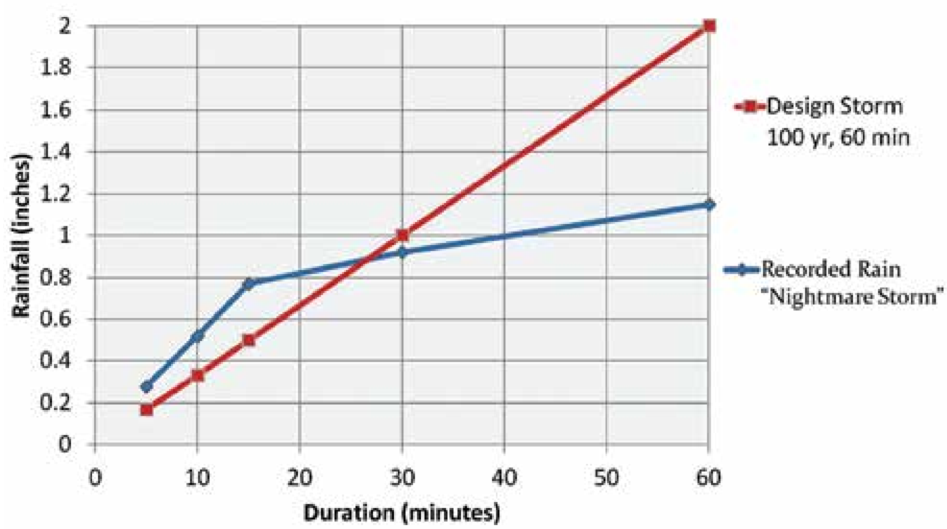

Figure 10 – Recorded and design (100-yr., 60-min.) rainfall amounts versus duration.

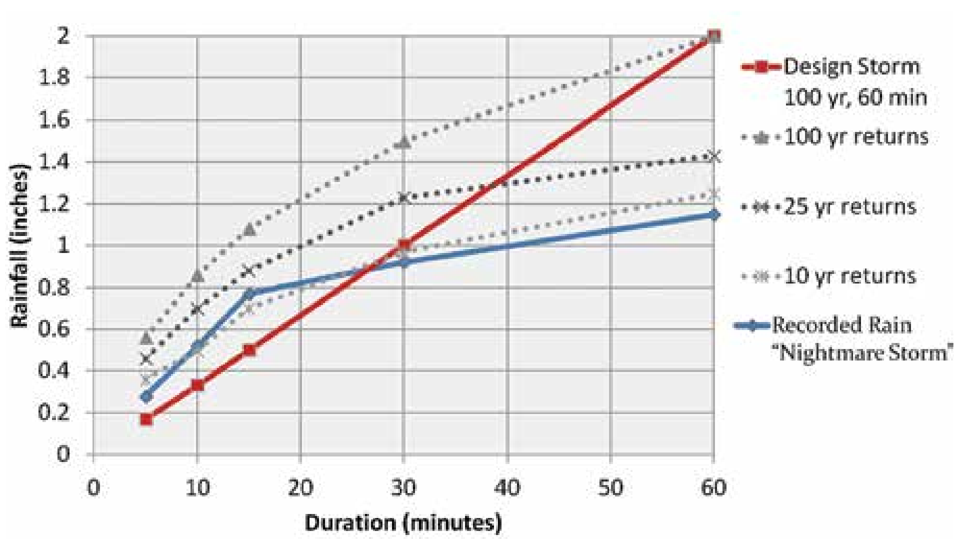

Figure 11 – Figure 10 overlaid with "envelope" curves (five storms) of rainfall data for indicated durations and return periods.

to back up. If the "faster-than-the-drain-can-take-away" condition lasts for only a few minutes, it is not a big deal. However, if it goes on long enough, the weight of the standing water collecting near the drain will exceed the weight the structure can handle, and the roof will collapse. For our nightmare example, it went on long enough.

Even if our nightmare example had a conventional 6-in. vertical pipe drain (540 gpm), the roof might still have collapsed, since the overflows were covered. The "extra" 293 gpm of runoff arriving at the drain for 15 minutes (833 gpm less 540 gpm) would have created standing water weighing more than 36,000 pounds. If so, even properly designed and "open" primary drains could be said to rely on overflow drains to help keep the depth of standing water in check when per-minute rainfall intensities exceed the design rates for extended periods of time.

It is sobering to realize that intense 15-minute-long rainstorms like this one are not all that rare. The "nightmare" storm is estimated to have a return period somewhere between 10 and 25 years and probably fairly close to 10 years (see *Figure 11*).

Figure 11 is *Figure 10* overlaid with rainfall curves for storms lasting less than 60 minutes and with return periods of less than 100 years. The 100-yr., 25-yr., and 10-yr. "return" lines indicate total rainfall amounts for five separate rainfall events, each corresponding to the indicated duration. For example, 0.46 in. is the amount of rain statistically predicted to fall during five minutes from a storm with a return period of 25 years. The 100-yr., 25-yr., and 10-yr. data were obtained from the *Rainfall Frequency Atlas of the United States*, Technical Paper No. 40.

BOTTOM LINE

Based on historical data, we should expect that the storm drainage system of just about every membrane roof system we design and/or install will get severely tested at some time during its life.

The 10-year return line of *Figure 11* indicates that about once every 10 years, most roofs will experience per-minute discharge rates at drains that exceed the 100-year, 60-minute, "per-minute" rate by more than 40 percent for up to 15 minutes (e.g., 757 gpm is 41 percent more than 540 gpm). And 15 minutes is long enough for serious depths of water to accumulate if the secondary drains are undersized and/or are less than fully functional.

I have personal experience investigating roof collapses as a result of rainstorms where the rainfall intensity exceeded the 60-minute, 100-year intensity for 10 to 15 minutes but where the 60-minute total accumulation was well less than 100-year levels.

The revelation that above-code-level runoff rates can be produced for up to 15 minutes by less-than-code-level rainstorms threatens to give me nightmares.

CODE CHANGE RECOMMENDATIONS

I had the privilege of peer reviewing the recently published paper "Storm Drainage System Research—Flow Rates Through Roof Drains" by Julius Ballanco, PE, published by the American Society of Plumbing Engineers Research Foundation. Among many other valuable contributions, the report recommends changes to plumbing codes. An excerpt follows:

> The plumbing codes must be modified to add new sizing requirements for storm drainage systems. The new sizing method should include sizing based on two rainfall rates. The 60-minute storm with a 100-year return period should remain the design criteria for storm drainage systems. In addition, a five-minute storm with a 10-year return period should be added to the plumbing codes.

OTHER CONSIDERATIONS

The above comments are true but general. In reality, roof drainage considerations are more complex. Roof slope, roof-surface "roughness" and "time of concentration," depths of sumps around drains, the type/style of "strainers," and even nondraining low spots can make a big difference. "Low spots" can lead to a progressive condition referred to as "ponding instability" and collapse, and the rain doesn't need to be particularly intense for this to happen.

Drains of the same diameter but by different manufacturers can have different maximum flow rates, and the phrase "maximum flow rate" is a misnomer. Most drains do not have a single "maximum" flow rate. Flow rates through most drains continue to increase with increasing head. And above certain heads, conventional "gravity" drains can go "siphonic."

To make matters worse, accumulations of debris around scuppers/drains have dramatic impacts. Readers are directed to the excellent paper by Jim Koontz, RRC, PE, "The Effects of Debris on the Flow Rates of Roof Drains and Scuppers," *Proceedings of the RCI 25th International Convention*, for more information. [Editor's note: This paper will be republished in the December issue of *Interface*.]

IN SUMMARY

When it comes to roof drainage as part of reroofing projects with no open edges, I suggest roof consultants take a proactive and cautious approach.

- Keep in mind that storm drainage systems on many older buildings fall short of current requirements.
- Notify the owner of any clearly noncompliant drainage conditions you observe (i.e., covered overflow drains) and recommend they be addressed as soon as practical.
- Consider clarifying in your consulting proposal that confirming the adequacy of the existing storm drainage provisions is not included in your proposal and/or that you recommend it be confirmed by a qualified person and/or that you are proceeding with the understanding that existing roof drainage provisions meet current code requirements.
- Confirm requirements, if any, that the authority having jurisdiction has for upgrading roof drainage provisions as part of reroof projects.
- If you offer to check existing storm drainage provisions, make sure you check for compliance with applicable provisions of both the building code and the plumbing code.

Editor's Note: This article is an updated version (refocused to apply more to roof consultants than to contractors) of an article originally published in two parts in the Nov./Dec. 2012 and Jan./Feb. 2013 issues of Western Roofing.

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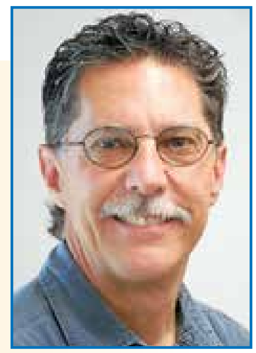

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IRS to Clamp Down on Work Misclassification

The Treasury Inspector General for Tax Administration (TIGTA) found in a recent study (http://www.treasury.gov/tigta/auditreports/2013reports/201330058fr.pdf) that many employers have not complied with IRS rulings on worker status. The report estimates that "employers misclassify millions of workers as independent contractors instead of employees…thus avoiding the payment of employment taxes." Each misclassification, the report says, can save employers approximately $3,710 a year in Social Security, Medicare, and federal unemployment taxes" (on an average annual income of $43,007).

The Determination of Worker Status Program (SS-8 Program) allows either a business or a worker to request a determination letter from the IRS regarding a worker's federal employment tax status as an employee or independent contractor. The TIGTA stated that "not all employers are complying with the determination rulings" of the SS-8 Program.

The IRS agreed to "form a team to assess potential avenues to improve employer compliance with SS-8 Program determination rulings."

State and federal governments see crackdowns as a means to collecting more payroll taxes.