

# Why Does My Roof Pond?

By Scott D. Coffman, PE, SECB

*Figure 1 – Excessive ponding water on a roof.*

## INTRODUCTION

In evaluating building enclosure problems, the author has encountered many newly constructed, wood-framed, low-slope roofs and exterior balconies and decks that exhibit excessive/sustained ponding of water (*Figure 1*). These conditions can lead to interior water damage through premature deterioration of roof coverings and/or excessive deflection of roof framing members. The ponding (and associated creep of the framing) can be so significant that it may ultimately lead to failure of the roof framing.

The purpose of this article is to provide insight into the most likely causes of these problematic ponding conditions as they relate to commonly accepted design and construction methods.



*Figure 2 – Ponding typically occurs prior to reaching discharge points.*

## BUILDING CODE REQUIREMENTS

We will start with building code requirements, which are typically at the “base-ment” level of the design/construction process. Specifically, the intent of the building codes is to provide proper design and construction practices to ensure at a minimum: safety, durability, and preservation of property value. For the purposes of this article, the author has considered the International Building Code (IBC), which addresses performance-based (rather than prescriptive) design and construction methods commonly associated with commercial-type construction.

Chapter 15 in the 2015/2018 IBC contains construction guidelines that permit a design slope of  $\frac{1}{4}$  inch in 12 inches for certain types of roof coverings. Specifically, the building code text reads, “...roofs shall have a design slope of not less than one-fourth unit vertical in 12 units horizontal (2-percent slope) for drainage.”

The stated and intended purpose of the code-specified  $\frac{1}{4}$ -in-12 slope is to provide drainage; however, ponding water is often observed on these low-slope roofs—even when the initial slope appears to have been provided during original construction. Specifically, water ponding occurs some short distance prior to reaching the free edge, scuppers, and/or drains (Figure 2). Four primary reasons are identified that contribute to the observed ponding. Each reason for the disparity between the intent of the design and the resulting condition is discussed.

### REASON 1: MISINTERPRETATION OF ROOF SLOPE AS DESIGN SLOPE

The most influential reason water ponds on a low-slope roof is a possible misinterpretation of the  $\frac{1}{4}$ -in-12 minimum slope in the building code. This misinterpretation affects the design process because there is a difference between “design slope” used by the code and “roof slope” found in *Minimum Design Loads for Buildings and Other Structures* (ASCE 7), which is referenced by the code. Significant insight may be found in ASCE 7, Section 8.4, as referenced in the 2015 IBC, Section 1611.2. ASCE 7-10 attributes ponding water to the deflection of relatively flat roofs and identifies a susceptible bay for ponding as a “roof slope” less than  $\frac{1}{4}$  in 12. ASCE 7-10 further clarifies, “Roof surfaces with a slope of at least  $\frac{1}{4}$  in. per ft. (1.19°) towards points of free drainage need not be considered a susceptible

bay.” ASCE 7-10 recognizes relatively flat roofs deflect when subjected to a load. A structural member designed and installed to a  $\frac{1}{4}$ -in-12 “design slope” deflects under the initial short-term dead load to create a roof surface (slope) less than  $\frac{1}{4}$  in 12 that is susceptible to ponding.

ASCE 7-16 (2018 IBC) omits the ASCE 7-10 sentence that attributes ponding water to the deflection of flat roofs. However, ASCE 7-16 continues to identify a susceptible bay to include “bays with a roof slope less than  $\frac{1}{4}$  in. per ft. (1.19°) when the sec-

ondary members are perpendicular to the free drainage edge.” Secondary members are defined as joists, purlins, or rafters. Commentary for ASCE 7-16, Section 8.4, alludes to ponding from secondary member deflection and states the  $\frac{1}{4}$ -in-12 limit is based upon a maximum deflection-to-span ratio of  $L/240$ . Therefore, ASCE continues to recognize that flat roofs deflect when subjected to load, and a “roof surface” less than  $\frac{1}{4}$  in 12 should be investigated as a susceptible bay for ponding water.

It seems most roofs are designed to a

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Figure 3 – Dead load from paver system.



Figure 4 – Dead load from mechanical units.

¼-in-12 or two percent slope to “meet the code” and eliminate a ponding analysis. However, it appears the code misinterpreted the ASCE 7 definition of a ¼-in-12 slope, which contributes to observed ponding. In general, a code-specified “design slope” is absent of member deflection, whereas the ASCE 7 “roof slope” reflects the actual in-service deflected condition.

#### REASON 2: IMPROPER DEFLECTION LIMITS

A structural member or roof surface will deflect below the initial installed plane under its own weight and permanently installed components (dead load), and when a live load is applied. For a floor, the deflection is below a level line, whereas the deflection for a roof is below the slope surface. The

building code and industry standards publish deflection limits expressed as maximum deflection-to-span ratio to help ensure the building components and systems perform satisfactorily. The ASCE 7-16 commentary identifies the maximum deflection-to-span ratio of L/240 for the ¼-in-12 roof surface. However, a structural roof member is often designed, and performance evaluated to the L/120 and L/180 published code deflection ratios. The code deflection table footnotes caution that published deflection limits do not ensure against ponding. Therefore, low-slope applications susceptible to ponding should be analyzed with stiffer deflection limits than those published in the building code.

#### REASON 3: INITIAL DEAD LOAD DEFLECTION NEGLECTED

As noted for Reason 2, ASCE 7-16 states the ¼-in-12 roof slope limit is based upon a maximum deflection-to-span ratio of L/240. The author interprets the words “maximum deflection” to be total load that includes short-term and long-term deflection from dead load, in addition to live-load deflection. Framing members with a roof slope of ¼ in 12 should be analyzed for the total anticipated load at a deflection ratio of L/240 or stiffer.

The “D + L” column in published code tables for deflection limits is for live-load and long-term deflection (creep); deflection associated with the initial short-term dead load is not considered. Specifically, the code does not require the weight of the framing members, decking, insulation, roof cover, and mechanical units that contribute to the overall deflected shape of a member to be part of the deflection analysis that is checked against the maximum deflection-to-span ratio (Figures 3 and 4). The initial dead-load deflection contributes to the overall deflected shape of the member and creates a roof surface less than the design slope. Therefore, the weight of the framing system, including MEP loads, should be used in the deflection check.

**REASON 4: THE CREATED “BOWL”**

Field observations and investigations by the author have found members installed to a “design slope” of 1/4 in 12 often deflect from the initial dead load to create a “flat” area toward the low end (Figure 5). The author investigated the deflected shape of a member when the maximum midspan deflection was set to published code-deflection ratios.

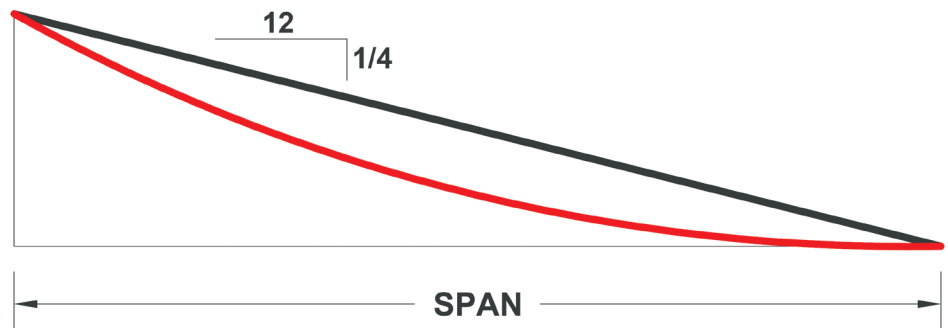


Figure 5 – Deflected shape of low-slope roof.

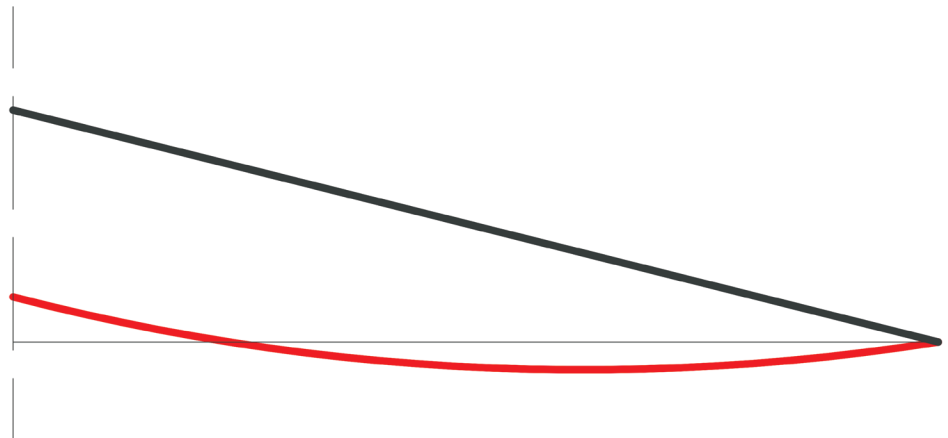


Figure 6 – Low-end “bowl” created for code-permitted roof deflection ratios.

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Figure 7 – Roof valley ponding.

Figure 8 – Balcony ponding.



The relative “flat” region retards and/or prevents free drainage. As the code-permitted L/120 or L/180 ratios are approached, the deflection curve extends below a horizontal datum to create a “bowl” (Figure 6). The “bowl” becomes more prominent for structural members susceptible to long-term deflection (creep). The author found the “bowl” is eliminated for members designed to the ASCE 7-16 maximum deflection-to-span ratio of L/240. However, the deflection curve remains relatively “flat” (less than ¼ in 12) at the low end to inhibit free drainage.

#### WHY DOES WATER POND IN A VALLEY?

ASCE 7 defines the ¼-in-12 roof surface to be toward the free drainage edge. The phrase “toward points of free drainage” is critical because it gives meaning to what is meant by a slope of ¼ inch per foot. A valley is not a free edge; it simply redirects the flow towards a drainage point. Additionally, the valley slope will always be less than the primary roof slope into the valley (Figure 7). For example, two roofs designed to a ¼-in-12 slope that intersect perpendicularly create a valley slope of approximately ⅓ in 12. Therefore, the primary roof slope should be increased to ensure a valley slope is sufficient for drainage.

#### WHAT ABOUT A BALCONY?

The building codes and industry standards are silent relative to slope guidelines for exterior balcony design. For a balcony floor exposed to weather over a habitable space, the ¼-in-12 low-slope roof parame-

ters are often the default. The ¼-in-12 may originate from the historic Uniform Building Code section for waterproofing weather-exposed areas that included balconies and occupied roofs. However, ponding characteristics common to roofs are found on exterior balconies (Figure 8).

The 2018 IBC begins to address this issue for wood structural members that support moisture-permeable floors or roofs exposed to the weather. The code text reads, “The structure supporting floors shall provide positive drainage of water that infiltrates the moisture-permeable floor topping.” The 2018 IBC does not provide, however, a recommended minimum slope and/or deflection-to-span ratio.

#### WHAT IS THE SOLUTION?

The common practice of a ¼-in-12 design slope, combined with the maximum code-permitted deflection limit (L/120 and L/180), inhibits drainage. In fact, analysis found ponding should be expected when using these code parameters! The deflected shape creates a nearly flat area at the low end of the sloped member that may become a “bowl.” The solution is to use a “design slope” greater than the code-minimum ¼-in-12 and a stiffer deflection limit to compensate for member deflection.

The author recommends a minimum roof design slope of ½ in 12 for members perpendicular to the free drainage edge. The increased slope is consistent with the

building code footnotes, and the ½-in-12 recommendation agrees with the Unified Facilities Criteria (UFC) for planning, design, and construction criteria published by the United States Department of Defense (DOD) for all DOD projects. UFC Section 2-3 pertains to low-slope roofing requirements and addresses minimum slope for positive drainage. Specifically, “The minimum slope for construction of new buildings is ½:12 to achieve positive drainage.”

In addition to the increased “design slope,” total load deflection checks should include short-term dead load, long-term dead load, and design live loads. At minimum, the calculated deflection should be compared to the L/240 ratio found in the ASCE 7-16 commentary. Roofs designed to a ½-in-12 slope and L/240 maximum total load deflection mitigate the flat area and “bowl” at the low end, which promotes drainage. The increased slope ensures a valley functions as intended by directing water to the designed drainage point.


With respect to balcony design and construction, the author suggests the supporting floor structure be sloped to provide positive drainage that permits the moisture-permeable surface to be installed at minimal, if any, design slope. This is consistent with the aforementioned 2018 IBC. In the absence of specific code parameters, the balcony framing members may be sloped between ⅓ in 12 and ½ in 12, depending on

the finish slope of the moisture-permeable finished surface. The ½-in-12 slope should be used for a “level” finished surface. An L/480 or stiffer deflection-to-span ratio is suggested for the total load deflection check. The total load includes short-term and long-term dead load and design live load. The dead load should consider the “taper” thickness of the moisture-permeable surface supported by the framing member installed on a slope when the finish surface is “level.”

### CONCLUSION

For decades, the building code has permitted a minimum roof design slope of ¼ in 12 to provide drainage; however, ponding remains common. The reason is a possible misinterpretation by the code of the ¼-in-12 “roof slope” in ASCE 7 to “design slope.” The initial dead load of the roof system deflects to create a roof surface that will be less than the design slope. Roof framing members that approach the code-permitted L/120 or L/180 deflect below a horizontal datum to create a “bowl” that results in ponding. The slope is also significantly reduced along the valley of two intersecting planes designed to a ¼-in-12 slope. Therefore, ponding should be expected when using the minimum code-permitted slope and deflection ratio parameters.

The proposed solution to mitigate ponding is to increase the design slope and member stiffness. A minimum ½-in-12

design slope is consistent with the UFC for framing perpendicular to the free edge. The increased design slope also mitigates ponding in a valley. The calculated total load deflection should be compared to the deflection-to-span ratio of L/240 found in the ASCE 7-16 commentary. Total load is short-term dead load, long-term dead load, and design live load. Similar design slopes and an L/480 total load deflection limit are suggested for exterior balconies. 



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