Roof Drainage and the Florida Building Code

Instructors:
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and Jorge Gamoneda
Why is roof drainage so important?

- The roof system is less susceptible to leakage.
- Generally, the roof system is more durable.
- Ponding instability is avoided.
- Structurally safer.
- Roof collapses are prevented if primary and secondary drainage systems are designed properly.
- There are 3000 roof collapses a year in the USA, many because of inadequate drainage.
Life safety issue *

Roofs are typically designed for a 30 psf live load within the HVHZ (1616.1). (20 psf or less outside HVHZ, 1607.11.2)

One square foot of water, one inch deep, weighs 5.2 lbs.

The maximum depth of water typically allowed in the HVHZ is 5”, weighing 26 lbs./ft.².

It would take only one hour at the design rainfall rate for 5” to accumulate on a roof with blocked drains.
What is Ponding Instability *

Where water may accumulate as ponds on relatively flat roofs, the roof deck tends to deflect allowing a deeper pond to form, causing the roof deck to deflect even more allowing a deeper pond. This progression continues if the deck lacks sufficient stiffness until failure by overloading takes place.
Minimize Instability

* Slope the roof sufficiently.
* Design sufficient primary and secondary drainage.
* Limit the amount of deck deflection.
Gymnasium roof collapses after two days of heavy rain.
Properties of water

- Water weighs 8.33 lbs./gal.
- There are 231 in.³ in one gallon.
- There are 7.48 gallons in a cubic foot.
- A cubic foot of water weighs 62.4 lbs.
- A rainfall of 1 gpm = 8.02 ft.³/hr
Where do we find drainage information to ensure compliance?

- Chapter 15, Building Volume
- Chapter 16, Building Volume
- Chapter 11, Plumbing Volume
- ASCE 7-02
Drainage design requires the careful coordination of the Architect, Structural Engineer and Plumbing Engineer.
Architect *

Is familiar with:

- Building Construction
- Parapets
- Walls
- Chase locations
- Available head room for pipes
- Roof construction and waterproofing
Structural Engineer *

The structural engineer is familiar with:

- Structural support layout
- Roof slopes
- Column orientation
- Footing sizes and depths
- Maximum allowable roof loading
Plumbing Engineer

The Plumbing Engineer can provide:
- Maximum roof areas per drain
- Placement, sizing and location of drains
- Minimize horizontal piping
Chapter 8 Code of Miami-Dade County *

- Requires that roof slope, drains, gutters, crickets and overflow scupper calculations appear on the framing plans. *
**FRAMING PLAN INFORMATION**

(Required that same orientation as Floor Plan be used)

**TABLE INSET:**

<table>
<thead>
<tr>
<th>Scale:</th>
<th>1/4&quot; = 1'-0&quot; minimum for all buildings of less that 5,000 sq. ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions:</td>
<td>All structural elements, their sizes and reinforcing (rafters, trusses bracing, beams, girders, and similar). Columns occurring below beam level, roof mounted equipment, skylights, hatches, dashed outline of structures below this level, Section cuts, roof chimneys, and similar.</td>
</tr>
<tr>
<td>Design:</td>
<td>Pressures for wind design. Loads and load transfer calculations required by the Code.</td>
</tr>
<tr>
<td>Drainage:</td>
<td>Roof slope, drains, gutters, crickets, overflow scupper calculations required by the Code.</td>
</tr>
<tr>
<td>Material:</td>
<td>Roofing and sheathing material (Including Product Approval Number).</td>
</tr>
<tr>
<td>Ventilation:</td>
<td>Attic ventilation calculations.</td>
</tr>
</tbody>
</table>
### ELECTRICAL, PLUMBING AND H.V.A.C. INFORMATION

#### TABLE INSET:

<table>
<thead>
<tr>
<th>Scale:</th>
<th>1/4&quot; -- 1'-0&quot; minimum for all buildings of less than 5,000 sq. ft. or equivalent metric scale.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td>Non-typical outlets, fixtures and conditions.</td>
</tr>
<tr>
<td><strong>Outlets/Fixtures System:</strong></td>
<td>Electrical Show all interior and exterior receptacles, fixtures, switches, electrical exhaust and ceiling fans, attic fans, or roof top receptacles, fixtures or equipment, all electrical equipment, (water heaters, a/c equip., pumps, and similar).</td>
</tr>
<tr>
<td></td>
<td>Plumbing Show all fixtures, sanitary drainage, vents, water supply, water heaters, and similar.</td>
</tr>
<tr>
<td></td>
<td>H.V.A.C. All ducts and diffuser sizes, fan coil and condensing unit location, specifications, and CFM's per outlet.</td>
</tr>
<tr>
<td><strong>Service/Panel:</strong></td>
<td>Electrical All items circuited as the code.</td>
</tr>
<tr>
<td><strong>Schedules/Riser</strong></td>
<td>Panel size, all circuits with use, load, wire, breaker and conduit size indicated. Diagram with size of service, meter, ground, disconnect switches, feeders, and panels.</td>
</tr>
<tr>
<td></td>
<td>Plumbing Diagram with size of all lines and location of all fixtures and the number of fixtures units of the fixture groups they serve. In commercial work provide isometric drawings of the sanitary drainage, water supply and the storm drainage piping.</td>
</tr>
</tbody>
</table>
| | H.V.A.C. Equipment may be coded and have their specifications listed on a schedule.
FBC design rainfall rate *

- The FBC uses a storm frequency of 100 years with a 60 minute duration.
- For Miami this results in a rainfall rate of 4.7” (Appendix B Plumbing Volume)
- Other frequencies and durations are recorded but are not required to be used by this Code.
  - 100 year/5 minute storm. (9.84”)
  - 100 year/15 minute storm. (8.80”)
  - 10 year/5 minute storm. (7.69”)
FIGURE 1106.1
100-YEAR, 1-HOUR RAINFALL (inches)
EASTERN UNITED STATES
Frequency-Intensity-Duration

- **Frequency** - Number of years after which a rainfall intensity is likely to be equaled or exceeded. (recurrence interval)
- **Intensity** - Is stated in terms of inch per hour.
- **Duration** - Period of time over which the specified rainfall is received.
Intensity and Duration

If 2.5” of rainfall is collected in a rain gauge over a 15 minute duration, it is stated as a 15 minute duration, 10 in./h rainfall.

A 10-minute duration 9 in./h rainfall indicates that during the 10-minute period, 1.5” of rainfall was collected.
Frequency

- 100 year frequency represents an annual probability of $1/100 = 0.01$.
- For example, it can be expected that more intense rainfalls will occur over a 100 year period than over a 10 year period.
- Probability is just like flipping a coin and is the same with rainfall recurrence interval.
Rainfall Intensities

- As the frequency increases the rainfall intensities increase.
- Decreasing duration results in increasing intensities.
When are roof drains required? (HVHZ) *

- Unless roofs are sloped to drain over roof edges, roof drains shall be installed at each low point of the roof. (1514.4)
- All roof systems must be installed to ensure positive drainage. (1515.2.2.1)
- In new construction the minimum deck slope shall be ¼ : 12. (1515.2.2.1)
When are roof drains required? (Non-HVHZ) *

- Design and install per Plumbing Code. (1503.4)
- In new construction the minimum deck slope shall be ¼ : 12. (1507.10.1)
- Coal Tar installations need only provide a 1/8 : 12 slope.
- Doesn’t seem to be an imperative to install roof drains, but it is implied.
- Chapter 15 Non-HVHZ mentions only scuppers.
Could a scupper be used as a primary roof drainage element? *

Where required for roof drainage, scuppers shall be placed level with the roof surface in a wall or parapet. (1514.4)(1503.4.2)

The scupper shall be located as determined by the roof slope and contributing roof area. (1514.4)(1503.4.2)
Scupper as primary drainage element, continued *

- Parapet wall roof drainage scupper location shall comply with the Florida Fire Prevention Code. \((P1106.5)\) *
- Design and install per FBC Plumbing. (1503.4)(Non-HVHZ)
- Size per ASCE 7 and 1617. (HVHZ)
- So the Code does allow scuppers as primary elements.
- Table 1106.7 is for sizing scuppers that are primary elements.
TABLE 1106.7
SIZING SCUPPERS FOR A 5-INCH
PER HOUR RATE OF RAINFALL

<table>
<thead>
<tr>
<th>HEAD IN INCHES</th>
<th>HORIZONTALLY PROJECTED ROOF AREA (SQUARE FEET)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LENGTH OF WEIR IN INCHES</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>230</td>
</tr>
<tr>
<td>2</td>
<td>641</td>
</tr>
<tr>
<td>3</td>
<td>1153</td>
</tr>
<tr>
<td>4</td>
<td>1794</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4 mm.

Note: To adjust this table for other than a 5-inch design rain fall rate multiply the square footage on the table by 5 then divide by the local design rain fall rate.

Example: For 4 inches of design rainfall rate, a 4-inch long scupper with a 1-inch head would accommodate 287 square feet. 
\((230 \times 5) \div 4 = 287\).
When is secondary or overflow drainage required? *

- When roof drains are required. (1514.4.2)
- When other means of drainage of overflow water is not provided. (1503.4.3)
- When roof perimeter construction extends above the roof, where water would be entrapped if the primary drains allow build-up for any reason. (P1107.1)
- When parapets or curbs are constructed, water build-up in excess of that considered in the design shall be prevented. (1617.1)
Placement of Secondary Scuppers *

- Secondary drains are to be installed 2”-4” above the “finished roofing surface”, low point of the roof. (1514.4.2) (1503.4.2)
- Shall be located as close as practical to required vertical leaders, conductors or downspouts. (1514.4.2) (1503.4.3)
- When recovering, reroofing or repairing an existing roof, the existing number of scuppers and/or roof drains shall not be reduced, unless a new drainage system is designed by an architect or engineer, in compliance with the provisions of this code. (1514.4.2.2)
Primary scupper could be easily blocked. Overflow provisions are not provided.

Plumbing vent Stack could provide some relief but it is against code.
Height of Plumbing Stacks *

- P904.1 Roof extension.
- All open vent pipes that extend through a roof shall be terminated at least 6 inches (152 mm) above the roof and *not less than 2 inches (51 mm) above the invert of the emergency overflow*, except that where a roof is to be used for any purpose other than weather protection, the vent extensions shall be run at least 7 feet (2134 mm) above the roof.
All three roof drains on this section are obstructed. No overflow provisions were provided.
Roof drains vs. scuppers *

- Scuppers are more easily blocked.
- A drain will continue to work even when debris has collected around the strainer.
- Scuppers are more economical to install. (design for more intense rainfall)
- Scuppers are more difficult to waterproof.
- Scuppers often disturb the appearance of a building.
- Water flow from scuppers can be a nuisance.
Roof Drains *

P1102.6 requires that roof drains conform to ASME A112.21.2M or ASME 112.3.1.

Strainers shall extend not less than 4” above the roof. (P1105.1)

Strainer inlet shall not be less than 1.5 times the area of the conductor. (P1105.1)

Flat strainers inlet shall not be less than 2 times the area of the conductor. (P1105.2)
Debris blocked scupper. No overflow provisions.

About a 10” high parapet
This strainer is blocked with debris, but flow through the top of the strainer is still possible.

Contrary to general belief roof drains are less susceptible to blockage than scuppers.
We often hear about roof collapses when roofers are on the job, why?

- Roof drains are intentionally blocked to keep debris out. Blocking is left in place when the roofers go home, or leave the roof suddenly.
- Blocking of the drains is omitted and construction material and debris is allowed to obstruct the drains.
Additional Reasons

- Drains and overflows are covered over with roof coverings, for later detailing.
- Scupper openings are often restricted by added material.
- The roof is used as a staging area, rain loads in combination with roof-top stored materials can cause collapse.
Counter-flashing is restricting the primary drainage scupper.
Re-roof underway, all overflow scuppers are covered. Strainers were off the primary drains, debris on roof would float into and block the main drains.
Single ply material is not adhered to the inside of the scupper openings. Wind billows the loose material, effectively closing off the scuppers. Primary scupper set too high.
FBC roof drainage structural concerns *

- Roofs shall be designed for the maximum depth of water... (1101.7)
- No accumulation in excess of that considered in the design. (1617.1)
- Shall be designed to sustain the rain load if the primaries were blocked. (1611.1)
- No more than 5" of water accumulation when not designed per 1616.1. (1617.2)
- Depth caused by hydraulic head needed to cause flow through the secondary drain shall be included in determining the load. (1617.2) (1611.1)
Formula

Formula to calculate volume of ponding water on a roof:

\[ V = \frac{4 \pi}{3} \times \frac{W}{2} \times \frac{L}{2} \times \frac{D}{2} \]

- **V** = Volume in Cubic Feet
- **W** = Width
- **L** = Length
- **D** = Depth

Depth must be expressed in feet or decimal of feet
FBC roof drainage structural concerns *

Roofs shall be designed to preclude instability due to ponding. (1617.5)

Roofs with a slope less than ¼ :12 shall be investigated by structural analysis to ensure adequate stiffness. (1611.2)

By providing roofs with a slope of ¼ in./ft. or more, ponding instability can be avoided. (ASCE 7-02 C8.4)

This seems to form the relationship between the prescriptive new construction slope requirement in Chapter 15 and the underlying structural issue.
What is the projected area for sizing the drain on the lower roof?
Solution

- LOWER ROOF PROJECTED ROOF AREA
  \(50 \times 50 = 2,500 \text{ sq.ft.}\)

- VERTICAL WALL AREA
  \(50 \times \frac{60}{2} = 1,500 \text{ sq.ft.}\)

- PROJECTED ROOF AREA USED TO SIZE LOWER ROOF DRAIN
  \(2,500 + 1,500 = 4,000 \text{ sq.ft.}\)
How is the size of a primary roof drain established?

- Determine the design rate of rainfall.
- Rainfall rate for Miami is 4.7″ and is typically rounded up to 5″. (Plumbing Commentary)
- Calculate the projected roof area contributing to the drain. Include ½ the area of any wall that will divert rainwater to the roof. (P1106.4)(1617.3)
- Use Table 1106.2 to cross reference rainfall rate and projected roof area, then read necessary drain size from the Table.
Example #1, roof slope is $\frac{1}{4}$ in./ft. to a single interior drain.
Size the primary drain for Example #1.

- Roof area: $90' \times 85' = 7650 \text{ ft}^2$
- Rainfall rate for Miami = 5”
- Read down the 5” rainfall column of Table P1106.2 until a projected roof area figure that is equal to or greater than the sample roof area is found. Then read across the Table to find the required drain size.
- A 6” drain is found to be appropriate.
- Does the FBC require that a certain number of drains be used?
<table>
<thead>
<tr>
<th>Diameter of Leader (inches)</th>
<th>Horizontally Projected Roof Area (square feet)</th>
<th>Rainfall rate (inches per hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>2,880</td>
<td>1,440</td>
</tr>
<tr>
<td>3</td>
<td>8,800</td>
<td>4,400</td>
</tr>
<tr>
<td>4</td>
<td>18,400</td>
<td>9,200</td>
</tr>
<tr>
<td>5</td>
<td>34,600</td>
<td>17,300</td>
</tr>
<tr>
<td>6</td>
<td>54,700</td>
<td>27,350</td>
</tr>
<tr>
<td>8</td>
<td>116,000</td>
<td>58,000</td>
</tr>
</tbody>
</table>

TABLE P1106.2

SIZE OF VERTICAL CONDUCTORS AND LEADERS
Six Inch Roof Drain

- Would two 3” roof drains be the equivalent of a single six inch drain?

\[ A = \pi r^2 \quad r = d/2 \]

- \[ r = 3”/2 = 1 \frac{1}{2}” \]
- 2-3” roof drains have an area of \( 3.14 \times (1 \frac{1}{2}” \times 1 \frac{1}{2}”) = 7.065 \text{ sq. in.} = x \text{ 2 drains} = 14.13 \text{ sq. in.} \]

- \[ r = 6”/2 = 3 \]
- 6” roof drain has an area of \( 3.14 \times (3 \times 3) = 28.26 \text{ sq. in.} \)

- Clearly, 2-3” roof drains will not provide the equivalent drainage of a single 6” roof drain.
Could overflow scuppers be used to provide secondary drainage?

- Closest distance from drain to parapet, 42.5’
- \[42.5’ \times \text{tangent of the angle} \times 12 = 10.62”\]
- If the primary drain were to be blocked, the depth of water above the drain would be 10 5/8” before the water would reach the parapet.
- Maximum depth of water allowed - 5” in the HVHZ, less outside HVHZ.
- As a result, overflow scuppers could not be used, unless the deck was specifically designed for this load.
- A plumbed secondary drain would then be necessary for this roof.
The rain load at the maximum depth would be 55 lbs./sq. ft.

Water weighs 5.2 lbs. per square foot, per inch of accumulation.
How are the overflow scuppers and drains to be sized?

- Secondary roof drain systems shall be sized the same as the primary drains (P1107.3).
- Overflow scuppers shall be sized to prevent the depth of water from exceeding the roof design.
- Oversizing the secondary system is no longer required.
- Secondary flow can be no less than the primary. (ASCE 7-02 Section 8.2)
Secondary Roof Drainage

- Piping must be separate from the primary. (P1107.2)
- Secondary must discharge above grade. (P1107.2)
- Discharge must be in a location where it would be normally observed. (P1107.2)
- Height placement of the invert of the secondary drain must be above the depth of water of the primary drain at its design flow. **This requirement seems to be implied by the Code, though not explicit.**
(Example #1 Cont.) A secondary drain will be required.

- Since it is established that based on the roof design, a secondary scupper cannot be used.
- Sizing of the secondary drain is now the same as for the primary drain.
- No over sizing of the secondary system is required.
Plumbing design for Example #1

Based on the projected area and the rainfall rate, Table P1106.2 establishes the required drain sizes.

- Primary drain – 6” diameter.
- Secondary drain – 6” diameter.
- Sizing of the drains, complies with the FBC.
- Does this plumbing design comply with the structural rain load requirements of the Code?
Plans Examiners responsibilities

- Plumbing will verify primary drain and secondary drain sizes based on the rainfall rate and the projected areas.
- Even if the drains and overflows are sized per the Plumbing Code, the installation still may not comply with the rain load requirements of the Building Code.
- Structural must verify the placement of the secondary drainage to ensure that the depth of water that could accumulate, anywhere on the roof, in excess of the design.
- Who looks at primary and secondary scupper sizes and placement?
Reminder of the applicable Code requirements

- No more than 5” of water accumulation when not designed per 1616.1. (1617.2)
- Depth caused by hydraulic head needed to cause flow through the secondary drain shall be included in determining the load. (1617.2) (1611.1)
The hydraulic head of water

Table C8-1 is in ASCE 7-02

- Hydraulic head is the depth of water above a drain needed to cause the design flow.
- Hydraulic head is considered zero for a roof that drains over the eaves.
- Table C8-1 establishes heads of water for various sized drains and scuppers.
- The table is based on rainfall in gallons per minute, not inches per hour.
- The FBC uses rainfall rates in inches per hour.
- The first step in determining hydraulic head is to convert inches per hour of rainfall into gallons per minute.
Flow rate conversion constant

- One inch of rainfall per hour, over one square foot, equals 144 in.\(^3\) of water.
- There are 231 in.\(^3\) in one gallon of water.
- First, determine the accumulation of water in gallons per hour, per inch of rainfall, by dividing 144/231.
- Then determine gallons per minute, by dividing the result by 60.

\[
\frac{144}{231}/60 = 0.0104 \text{ conversion constant.}
\]
Converting inch/h to GPM

\[ Q = 0.0104 \cdot A \cdot i \]

- \( A \) = roof area served by a single drainage system in square feet.
- \( i \) = design rainfall intensity as specified in the code having jurisdiction.
- \( Q \) = flow rate out of a single drainage system, in gallons per minute.
- 0.0104 is the conversion constant.
Example #1, roof slope is $\frac{1}{4}$ in./ft. to a single interior drain.

3’ High Continuous Parapet
Example #1 hydraulic head at the primary drain

To establish rainfall in gallons per minute. Multiply square footage, by the rainfall rate, then multiply by the conversion factor. \((Q = 0.0104 \times A_i)\)

\[7650 \times 5 \times 0.0104 = 398 \text{ gal/min.}\]

Refer to ASCE 7-02 Table C8-1.

Hydraulic head for a 6” drain, that must drain 398 gal/min., falls between a 3” and 3.5” hydraulic head.

Interpolation is necessary to establish an exact hydraulic head.
<table>
<thead>
<tr>
<th>Drainage</th>
<th>1</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>4” dia. drain</td>
<td>80</td>
<td>170</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6” dia. drain</td>
<td>100</td>
<td>190</td>
<td>270</td>
<td>380</td>
<td>540</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8” dia. drain</td>
<td>125</td>
<td>230</td>
<td>340</td>
<td>560</td>
<td>850</td>
<td>1,100</td>
<td>1,170</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6’ wide channel scupper</td>
<td>18</td>
<td>50</td>
<td>70</td>
<td>90</td>
<td>115</td>
<td>140</td>
<td>167</td>
<td>194</td>
<td>321</td>
<td>393</td>
</tr>
<tr>
<td>24” wide channel scupper</td>
<td>72</td>
<td>200</td>
<td>280</td>
<td>360</td>
<td>460</td>
<td>560</td>
<td>668</td>
<td>776</td>
<td>1,284</td>
<td>1,572</td>
</tr>
<tr>
<td>6”x 4” closed scupper</td>
<td>18</td>
<td>50</td>
<td>70</td>
<td>90</td>
<td>115</td>
<td>140</td>
<td>167</td>
<td>177</td>
<td>231</td>
<td>253</td>
</tr>
<tr>
<td>24”x 4” closed scupper</td>
<td>72</td>
<td>200</td>
<td>280</td>
<td>360</td>
<td>460</td>
<td>560</td>
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<tr>
<td>6”x 6” closed scupper</td>
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<td>70</td>
<td>90</td>
<td>115</td>
<td>140</td>
<td>167</td>
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<tr>
<td>24”x 6” closed scupper</td>
<td>72</td>
<td>200</td>
<td>280</td>
<td>360</td>
<td>460</td>
<td>560</td>
<td>668</td>
<td>776</td>
<td>1,212</td>
<td>1,372</td>
</tr>
</tbody>
</table>
Interpolation procedure to establish the hydraulic head at the primary drain

\[ 3 + \frac{398-380}{540-380}(.5) = 3.06" \]

In order for the 6” drain to handle the necessary flow, there will be a depth of 3.06” of water above the primary drain at its peak design flow.

The secondary drain is typically placed about 1/2” above the depth of water above the primary at its design flow.

In this way, the secondary does not activate under peak design flow and debris is not carried into or block the secondary.
Establish the hydraulic head above the secondary drain

- Hydraulic head for a 6” drain, that must drain 398 gal/min., falls between a 3” and 3.5” hydraulic head.
- \[3 + \left(\frac{398-380}{540-380}\right)(.5) = 3.06”\]
- If the primary drain could not handle the peak flow for any reason, the secondary would accommodate the design flow.
- At the design rainfall rate, there would be a depth of water 3.06” above the secondary drain.
<table>
<thead>
<tr>
<th>Drainage</th>
<th>1</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>4” dia. drain</td>
<td>80</td>
<td>170</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6” dia. drain</td>
<td>100</td>
<td>190</td>
<td>270</td>
<td>380</td>
<td>540</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>8” dia. drain</td>
<td>125</td>
<td>230</td>
<td>340</td>
<td>560</td>
<td>850</td>
<td>1,100</td>
<td>1,170</td>
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<td></td>
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</tr>
<tr>
<td>6’ wide channel scupper</td>
<td>18</td>
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<td>90</td>
<td>115</td>
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</tr>
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<td>460</td>
<td>560</td>
<td>668</td>
<td>776</td>
<td>1,212</td>
<td>1,372</td>
</tr>
</tbody>
</table>
Are the structural rain load requirements of the Code met?

- Depth above the primary = 3.06”
- Placement of the invert of the secondary = 4” above the low point.
- Depth of water above the secondary = 3.06”
- $3.06” + .44” + 3.06” = 6.56”$
- This depth of water exceeds the maximum 5” for the HVHZ rain load and the 20 psf live load elsewhere.

Even though the plumbing requirements are met, the structural requirements are not. What are the options?

Enhance the design of the structure, more drains, more overflows or both.
Establishing the rain load

- $R = 5.2 \, (ds + dh)$ (ASCE 7) and (Equation 16-37)
- $dh = \text{Additional depth of water on the undeflected roof above the inlet of secondary drainage system at its design flow (i.e., the hydraulic head), in inches (mm).}$
- $ds = \text{Depth of water on the undeflected roof up to the inlet of secondary drainage system when the primary drainage system is blocked (i.e., the static head), in inches (mm).}$
- $R = \text{Rain load on the undeflected roof, in psf (kN/m}^2). \text{ When the phrase “undeflected roof” is used, deflections from loads (including dead loads) shall not be considered when determining the amount of rain on the roof.}$
Example #1 Rain Load

\[ 3.06'' + .44'' + 3.06'' = 6.56'' \]

\[ R = 5.2(3.5 + 3.06) = 36.7 \text{ psf} \]

Maximum allowable in the HVHZ is 26 psf. Unless the roof has been designed for additional rain load.

Outside the HVHZ design loads could be as low as 12 psf.
100 year 5 minute storm

- Why doesn’t the Code require a roof drainage design that would handle the more conservative 100 year, five minute storm?
- The Code represents a minimum standard, but:
- In effect the Code has made provisions for the chance that an intense burst of rainfall will be experienced.
100 year 5 minute storm example.

3’ High Continuous Parapet
100 year 5 minute example

Typical Drainage Design:
- Roof area: 60’ x 100’/2 drains = 3000 ft.$^2$
- Rainfall rate for Miami = 5”

Read down the 5” rainfall column of Table P1106.2 until a projected roof area figure that is equal to or greater than the sample roof area is found. Then read across the Table to find the required drain size.
- A 4 drain is found to be appropriate.
<table>
<thead>
<tr>
<th>Diameter of Leader (inches)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2,880</td>
<td>1,440</td>
<td>960</td>
<td>720</td>
<td>575</td>
<td>480</td>
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<tr>
<td>3</td>
<td>8,800</td>
<td>4,400</td>
<td>2,930</td>
<td>2,200</td>
<td>1,760</td>
<td>1,470</td>
</tr>
<tr>
<td>4</td>
<td>18,400</td>
<td>9,200</td>
<td>6,130</td>
<td>4,600</td>
<td>3,680</td>
<td>3,070</td>
</tr>
<tr>
<td>5</td>
<td>34,600</td>
<td>17,300</td>
<td>11,530</td>
<td>8,650</td>
<td>6,920</td>
<td>5,765</td>
</tr>
<tr>
<td>6</td>
<td>54,000</td>
<td>27,000</td>
<td>17,995</td>
<td>13,500</td>
<td>10,800</td>
<td>9,000</td>
</tr>
<tr>
<td>8</td>
<td>116,000</td>
<td>58,000</td>
<td>38,660</td>
<td>29,000</td>
<td>23,200</td>
<td>19,315</td>
</tr>
</tbody>
</table>
Could overflow scuppers be used to provide secondary drainage?

- No.
- Crickets would be installed and typically at a slope of $\frac{1}{2} : 12$ if the roof is sloped at $\frac{1}{4} : 12$.
- Distance of drain to parapet is 25’.
- So the cricket height at the parapet would be 12.5”. 
How are the drains to be sized?

- Secondary roof drain systems shall be sized the same as the primary drains (P1107.3).
- Over sizing the secondary system is no longer a Code requirement.
Plumbing design for 100 year, 5 minute storm example

Based on the projected area and the rainfall rate, Table P1106.2 establishes the required drain sizes.

- Primary drains – 4” diameter.
- Secondary drains – 4” diameter.

Sizing of the drains, complies with the FBC.

Does this plumbing design comply with the structural rain load requirements of the Code?
Establish the hydraulic head

To establish rainfall in gallons per minute. Multiply square footage, by the rainfall rate, then multiply by the conversion factor. \((Q = 0.0104 \times A_i)\)

- 3000 per drain \(\times\) 5 \(\times\) 0.0104 = 156 gal/min.
- Refer to ASCE 7-98(02) Table C8-1.
- Hydraulic head for a 4” drain, that must drain 156 gal/min., falls between a 1” and 2” hydraulic head.
- Interpolation indicates 1.85”, set invert of secondary at 2.5”. 

82
<table>
<thead>
<tr>
<th>Drainage</th>
<th>1</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>4” dia. drain</td>
<td>80</td>
<td>170</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6” dia. drain</td>
<td>100</td>
<td>190</td>
<td>270</td>
<td>380</td>
<td>540</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>668</td>
<td>776</td>
<td>1,284</td>
<td>1,572</td>
</tr>
<tr>
<td>6”x 4” closed scupper</td>
<td>18</td>
<td>50</td>
<td>70</td>
<td>90</td>
<td>115</td>
<td>140</td>
<td>167</td>
<td>177</td>
<td>231</td>
<td>253</td>
</tr>
<tr>
<td>24”x 4” closed scupper</td>
<td>72</td>
<td>200</td>
<td>280</td>
<td>360</td>
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<td>560</td>
<td>668</td>
<td>776</td>
<td>1,212</td>
<td>1,372</td>
</tr>
</tbody>
</table>
Are the structural rain load requirements of the Code met?

- Yes.
- The primary drains have a hydraulic head of 1.85”.
- Likewise, the secondary drains have a hydraulic head of 1.85”
- 1.85” + 1.85” + .65” separation = 4.35”
  maximum depth of water at the design rainfall rate complies with the HVHZ structural requirements.
How does this system handle the 100 year 5 minute storm?

It is considered that the primary and secondary drains would work in combination to handle the short duration intense rainfall of 10” that the 100 year 5 minute storm would produce.
Explanation

- 3000 per drain x 10 x 0.0104 = 312 gal/min.
- On our example roof the primary and secondary drains on each section of the roof would accommodate the 312 gallons per minute that would be produced for that section.
- Each drain is handling 156 gpm with a 1.85” head. 156 + 156 is about equal to 312 gpm.
- A depth of less than 5” is maintained.
Example #2, Monoslope, is to be drained by two primary scuppers.
Size the two primary scuppers

- Convert rainfall to gallons per minute.
- $\frac{5000}{2}$ scuppers $\times$ 5” rainfall $\times$ 0.0104 = 130 gpm
- For sizing of scuppers see Table 1106.7. This Table shows projected areas drained.
- ASCE 7-02 Table C8-1 shows gallon per minute per depth of hydraulic head.
- Over sizing scuppers is prudent because of the low cost of installation involved.
- Its more difficult for a large scupper to be obstructed.
Sizing Scuppers

- In the past a designer might start to experiment with scupper sizes by taking a guess and then performing the calculations.
- In the 2004 edition of the FBC Plumbing there is a new Table 1106.7.
- This table provides projected roof areas in sq. ft. for various sizes of scuppers with an assortment of hydraulic heads.
- It can be seen that it is the width of the scupper that primarily establishes the flow.
Scupper Rules of Thumb

- Length of the scupper should be 4 times the hydraulic head.
- In closed scuppers, the clear height above the head should be 2”.
- It is prudent to design scuppers for lesser duration more intense rainfall rates.
Table 1106.7

- The table is prepared based on Table C8-1 of ASCE.
- This table is established using an assumed rainfall rate of 5” per hour.
- Instructions are given to calculate projected roof areas for rainfall rates other than 5” per hour.
- This table is accurate for primary as well as secondary scuppers.
- It provides a good starting point for scupper sizing.
### TABLE 1106.7
SIZING SCUPPERS FOR A 5-INCH PER HOUR RATE OF RAINFALL

<table>
<thead>
<tr>
<th>HEAD IN INCHES</th>
<th>HORIZONTALLY PROJECTED ROOF AREA (SQUARE FEET)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LENGTH OF WEIR IN INCHES</td>
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<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>230</td>
</tr>
<tr>
<td>2</td>
<td>641</td>
</tr>
<tr>
<td>3</td>
<td>1153</td>
</tr>
<tr>
<td>4</td>
<td>1794</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4 mm.

Note: To adjust this table for other than a 5-inch design rain fall rate multiply the square footage on the table by 5 then divide by the local design rain fall rate.

Example: For 4 inches of design rainfall rate, a 4-inch long scupper with a 1-inch head would accommodate 287 square feet. \((230 \times 5) \div 4 = 287\).
Example #2

Each primary scupper must drain 2500 SF of projected roof area.

In the HVHZ, typically we have 5” of water depth that can be accommodated by the deck.

A .5” separation between primary and secondary scuppers would allow compliance with P1107.2.

Refer to Table 1106.7 and find a hydraulic head of 2” and read across until a column is found containing a projected roof area of at least 2500 SF.
### TABLE 1106.7
SIZING SCUPPERS FOR A 5-INCH PER HOUR RATE OF RAINFALL

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>LENGTH OF WEIR IN INCHES</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>230</td>
</tr>
<tr>
<td>2</td>
<td>641</td>
</tr>
<tr>
<td>3</td>
<td>1153</td>
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<td>4</td>
<td>1794</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4 mm.

Note: To adjust this table for other than a 5-inch design rain fall rate multiply the square footage on the table by 5 then divide by the local design rain fall rate.

Example: For 4 inches of design rainfall rate, a 4-inch long scupper with a 1-inch head would accommodate 287 square feet. (230 × 5) / 4 = 287.
Example #2

- In this case the primary scupper selected is 16” wide and will develop a hydraulic head of 2”.
- The secondary scupper will also be 16” wide and will be placed with its invert located 3” above the low point of the deck.
- In this case the 5” maximum depth of water is not exceeded at the design rainfall rate.
Design flow rate = 130 gpm

2” hydraulic head at the primary scupper

Invert of the secondary placed 3” above the deck. (1” clearance above depth of water at primary)

2” hydraulic head develops at the secondary, if the primary were to be obstructed.

A maximum depth of 5” would not be exceeded.
Interpolation of Table 1106.7

How can flow through a scupper size other than those shown in Table 1106.7 be determined?

- An 18” wide scupper
- Use flow figures for a 20” wide scupper and multiply those flows by 18/20.

18/20(1153) = 1037.7 SF
<table>
<thead>
<tr>
<th>HEAD IN INCHES</th>
<th>HORIZONTALLY PROJECTED ROOF AREA (SQUARE FEET)</th>
<th>LENGTH OF WEIR IN INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>230</td>
</tr>
<tr>
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<td></td>
<td>641</td>
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</tbody>
</table>

For SI: 1 inch = 25.4 mm.
Note: To adjust this table for other than a 5-inch design rain fall rate multiply the square footage on the table by 5 then divide by the local design rain fall rate.
Example: For 4 inches of design rainfall rate, a 4-inch long scupper with a 1-inch head would accommodate 287 square feet. (230 \times 5) / 4 = 287.
Example #3
Roof Dimensions = 100’ x 50’
Primary Drainage System = Two Roof Drains
Secondary Drainage System = Two Closed Scuppers
Size the primary drainage system for Example #3

- **Roof area**: 100’ x 50’ = 5000 ft.²
- **5000/2 roof drains = 2500 SF per drain**
- **Rainfall rate for Miami = 5”**
- **Read down the 5” rainfall column of Table P1106.2 until a projected roof area figure that is equal to or greater than the sample roof area is found. Then read across the Table to find the required drain size.**
- **A 4” drain is found to be appropriate.**
<table>
<thead>
<tr>
<th>Diameter of Leader (inches)</th>
<th>Horizontally Projected Roof Area (square feet)</th>
<th>Rainfall rate (inches per hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>2,880</td>
<td>1,440</td>
</tr>
<tr>
<td>3</td>
<td>8,800</td>
<td>4,400</td>
</tr>
<tr>
<td>4</td>
<td>18,400</td>
<td>9,200</td>
</tr>
<tr>
<td>5</td>
<td>34,600</td>
<td>17,300</td>
</tr>
<tr>
<td>6</td>
<td>54,000</td>
<td>27,000</td>
</tr>
<tr>
<td>8</td>
<td>116,000</td>
<td>58,000</td>
</tr>
</tbody>
</table>
Establish the hydraulic head at the primary system

- To establish rainfall in gallons per minute, multiply square footage, by the rainfall rate, then multiply by the conversion factor. \( Q = 0.0104 \cdot A \cdot i \)

- \( 2500 \times 5 \times 0.0104 = 130 \) gal/min.

- Refer to ASCE 7-02 Table C8-1.

- Hydraulic head for a 4” drain, that must drain 130 gal/min., falls between a 1” and 2” hydraulic head.

- Interpolation is necessary to establish an exact hydraulic head.
### FLOW RATES IN GPM VERSUS RESULTING HYDRAULIC HEAD

<table>
<thead>
<tr>
<th>Drainage</th>
<th>1</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>4” dia. drain</td>
<td>80</td>
<td>170</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6” dia. drain</td>
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<td>190</td>
<td>270</td>
<td>380</td>
<td>540</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8” dia. drain</td>
<td>125</td>
<td>230</td>
<td>340</td>
<td>560</td>
<td>850</td>
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<td></td>
<td></td>
<td></td>
</tr>
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<td>90</td>
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<td>140</td>
<td>167</td>
<td>194</td>
<td>321</td>
<td>393</td>
</tr>
<tr>
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<td>72</td>
<td>200</td>
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<td>1,572</td>
</tr>
<tr>
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<td>18</td>
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<td>90</td>
<td>115</td>
<td>140</td>
<td>167</td>
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<td>1,212</td>
<td>1,372</td>
</tr>
</tbody>
</table>
Interpolation to establish the hydraulic head at the primary drain

1 + (130-80/170-80) = 1.55”

In order for the 4” drain to handle the necessary flow, there will be a depth of 1.55” of water above the primary drain at its peak design flow.

The secondary system is typically placed about 1/2” above the depth of water above the primary at its design flow.

In this case, set the secondary invert at 2.5”.

In this way, the secondary does not activate under peak design flow.
Sizing the secondary scuppers

- Use Table 1106.7.
- Each secondary scupper must drain 2500 SF.
- Ensure that the hydraulic head will allow compliance with the maximum 5” depth allowable.
### TABLE 1106.7
SIZING SCUPPERS FOR A 5-INCH PER HOUR RATE OF RAINFALL

<table>
<thead>
<tr>
<th>HEAD IN INCHES</th>
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</tr>
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<tr>
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<td></td>
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</tr>
<tr>
<td>1</td>
<td></td>
<td>230</td>
</tr>
<tr>
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<td></td>
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<tr>
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</tbody>
</table>

For SI: 1 inch = 25.4 mm.

Note: To adjust this table for other than a 5-inch design rain fall rate multiply the square footage on the table by 5 then divide by the local design rain fall rate.

Example: For 4 inches of design rainfall rate, a 4-inch long scupper with a 1- inch head would accommodate 287 square feet. (230 * 5) / 4 = 287.
Sizing the secondary scupper

With the invert of the secondary scupper set at 2.5”, an additional 2” of head at the secondary keeps us within the 5” maximum depth (4.5”) of water accumulation should the primary system become obstructed.

A 16” wide scupper would comply.

Would a 12” wide scupper work if the total 5” depth of accumulation were designed for?

Interpolation between depths of hydraulic heads.

A 2.5” head falls mid-way between 1923 and 3461 SF or 2692 SF.
### TABLE 1106.7
SIZING SCUPPERS FOR A 5-INCH PER HOUR RATE OF RAINFALL

<table>
<thead>
<tr>
<th>HEAD IN INCHES</th>
<th>HORIZONTALLY PROJECTED ROOF AREA (SQUARE FEET)</th>
<th>LENGTH OF WEIR IN INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>230</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>641</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>1153</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>1794</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4 mm.

Note: To adjust this table for other than a 5-inch design rain fall rate multiply the square footage on the table by 5 then divide by the local design rain fall rate.

Example: For 4 inches of design rainfall rate, a 4-inch long scupper with a 1-inch head would accommodate 287 square feet. \((230 \times 5) / 4 = 287\).
How was Table P1106.7 Developed?

- Table C8-1 from ASCE 7 was used to establish Table P1106.7.

\[ Q = 0.0104 A_i \]

\[ A = \frac{Q}{i} \]

0.0104
<table>
<thead>
<tr>
<th>Drainage</th>
<th>1</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>4” dia. drain</td>
<td>80</td>
<td>170</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6” dia. drain</td>
<td>100</td>
<td>190</td>
<td>270</td>
<td>380</td>
<td>540</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8” dia. drain</td>
<td>125</td>
<td>230</td>
<td>340</td>
<td>560</td>
<td>850</td>
<td>1,100</td>
<td>1,170</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6’ wide channel scupper</td>
<td>18</td>
<td>50</td>
<td>70</td>
<td>90</td>
<td>115</td>
<td>140</td>
<td>167</td>
<td>194</td>
<td>321</td>
<td>393</td>
</tr>
<tr>
<td>24’ wide channel scupper</td>
<td>72</td>
<td>200</td>
<td>280</td>
<td>360</td>
<td>460</td>
<td>560</td>
<td>668</td>
<td>776</td>
<td>1,284</td>
<td>1,572</td>
</tr>
<tr>
<td>6”x 4” closed scupper</td>
<td>18</td>
<td>50</td>
<td>70</td>
<td>90</td>
<td>115</td>
<td>140</td>
<td>167</td>
<td>177</td>
<td>231</td>
<td>253</td>
</tr>
<tr>
<td>24”x 4” closed scupper</td>
<td>72</td>
<td>200</td>
<td>280</td>
<td>360</td>
<td>460</td>
<td>560</td>
<td>668</td>
<td>708</td>
<td>924</td>
<td>1,012</td>
</tr>
<tr>
<td>6”x 6” closed scupper</td>
<td>18</td>
<td>50</td>
<td>70</td>
<td>90</td>
<td>115</td>
<td>140</td>
<td>167</td>
<td>194</td>
<td>303</td>
<td>343</td>
</tr>
<tr>
<td>24”x 6” closed scupper</td>
<td>72</td>
<td>200</td>
<td>280</td>
<td>360</td>
<td>460</td>
<td>560</td>
<td>668</td>
<td>776</td>
<td>1,212</td>
<td>1,372</td>
</tr>
</tbody>
</table>
Some issues the code doesn’t address

- Number of drains or maximum area that can be served by one drain.
- Distance between drains.
- Minimum size of drains/conductors.
- Separation distance between the hydraulic head at the primary and the invert of the secondary drainage system.
- Height of the closed scupper above the estimated hydraulic head.
Summary

Roof drainage is a life safety concern.
As a design issue it is complex and the interaction of hydraulics and roof drainage are not well understood.
Nonetheless, it is one of the most important structural elements of building design.
Less restrictive Code revisions have occurred.
More than one construction discipline is involved, leading to lack of clear responsibility.
Roof collapses still occur at an alarming rate, even in new buildings.