EXPLORING the Sustainably Built Environment

The Effects of Debris on the Flow Rates of Roof Drains and Scuppers

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ABSTRACT

Roof collapses after significant rain events are becoming widely reported with a catastrophic loss of property, and in some cases, lives. Debris-blocked drains can be the culprit. To date, the effect of debris accumulation on flow rates of drainage systems has not been studied. This presentation describes a laboratory simulation of debris-blocked drains and the effects of inadequate drainage on roof assemblies.

SPEAKER

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The Effects of Debris on the Flow Rates of Roof Drains and Scuppers

Drainage of rainwater has long been considered an essential attribute for the proper performance of any roof system. Long-term and excessive accumulation of water will contribute to the deterioration of most roofing systems and, in worst-case scenarios, has been responsible for excessive live loads that can lead to structural collapse.

Roofing systems commonly rely upon roof drains and through-wall scuppers for drainage. The effects of debris on the flow-rate characteristics of roof drains and scuppers has not been well understood or studied.

Routine maintenance, which should include intermittent cleaning of debris from roof surfaces, has always been recommended within the roofing industry. An article by Eddie Garcia in *Western Roofing* in August 2009 discusses the importance of roof maintenance, and specifically, the importance of keeping a roof free of debris.[1] Numerous other authors, including Griffin and Fricklas,[2] also address the importance of roof drainage and maintenance.

The reality, however, is that roof maintenance usually occurs only after a leak or roof problem develops. The failure to routinely clean a roof can and has led to serious roof problems. Proper roof maintenance is the ultimate responsibility of the building owner.

This article reviews the effects of roof type and debris on the flow-rate characteristics of roof drains and scuppers. This study was limited to debris accumulation on roof surfaces and does not consider the effects of debris within drainpipe leader systems. The data generated assume that drain leaders are clear and free to flow.

Background

Drainage of roofing systems has typically been accomplished by a combination of slope, perimeter gutters, internal roof drains, and/or through-wall scuppers. Proper roof drainage has long been required by national building codes. Within the roofing industry, organizations such as the National Roofing Contractors Association (NRCA) and manufacturers have had longstanding recommendations and requirements for proper roof drainage.

Most roofing material manufacturers require a positive slope and that a new roof will drain and be free of ponding water within 48 hours after a rainfall event. A few single-ply and old coal tar manufacturers have permitted accumulation of water on their roofing systems.

International Building/Plumbing Code

By law, roof construction has to be in compliance with local adopted building codes. The International Building Code (IBC)[3] is currently the most uniformly accepted code within the United States. The IBC requires positive slope for new construction and incorporates the International Plumbing Code (IPC),[4] which addresses requirements for roof drainage.

The required minimum size for roof drains and/or scuppers for a given roof area is dependent upon a number of factors, including:

- Geographical location
- 100-year, one-hour rainfall rate
- Below-deck drainpipe system (vertical or sloped)

Primary Drain Example

Orlando, Florida, falls within an area of the IPC (per Figure 1106.1) that indicates the maximum anticipated 100-year rainfall event could be up to 4.5 inches of rain per hour. The determination of the size of a roof drain for a given roof area is dependent on the orientation of the below-deck drain piping. Assuming horizontal leader piping at ¼ in per ft of slope (Table 1106.3), the maximum area of drainage for a 6-in diameter drain would be 6,795 sq ft. This square footage is based upon extrapolating between the 4-in and 5-in rainfall rate. The properties of water are included in *Table A*.

Properties of Water
1 cubic ft of water = 62.42 pounds
1 cubic foot of water = 7.48 gallons
1 gallon of water = 8.34 pounds

Table A

The IPC also requires the installation of independent, separate-but-equal, primary, and secondary drainage systems. The primary and secondary systems are to be equal in cross-sectional drainage capacity and have independent discharge piping or leaders. The theory is that if the primary drain/scupper becomes blocked, for whatever reason, the secondary independent drain/scupper system can accommodate the anticipated rainfall event.

The flow rate for a given condition in gallons per minute (gpm) can be calculated. For the Orlando roof with 6,795 sq ft that experiences a 4.5-in rainfall in one hour, the roof drain system should be capable of with-

6,795 sq ft of roof * 4.5-in rainfall per hour = 2,548 cubic ft of water per hour
2,548 cubic ft * 7.48 gallons per cubic ft = 19,059 gallons per hour
19,059 gallons per hour = 317 gallons per minute

Table B

standing flow rates of up to 317 gallons per minute during a maximum rainfall event (*Table B*).

Roof Drain Strainer

The IPC also requires that roof drains have strainers with inlet openings equal to 150% of the cross-sectional area for a given drain pipe (Section 1105.1, Strainers). As an example, for a 6-in roof drain, the given cross-sectional area is approximately 28.3 sq in. The strainer for a 6-in roof drain would be required to have an inlet opening of at least 42.4 sq in. The IPC does not distinguish between the vertical inlet open areas or horizontal sections on the top of the strainer.

Secondary Drainage

Under Section 1107 of the IPC, secondary roof drains are required in addition to the primary drainage system. Secondary drainage systems are required for emergency purposes in the event the primary drain systems become blocked. The IPC requires that the secondary drainage system have separate points of discharge that are to be sized based on the same rainfall rates as that of the primary drainage system.

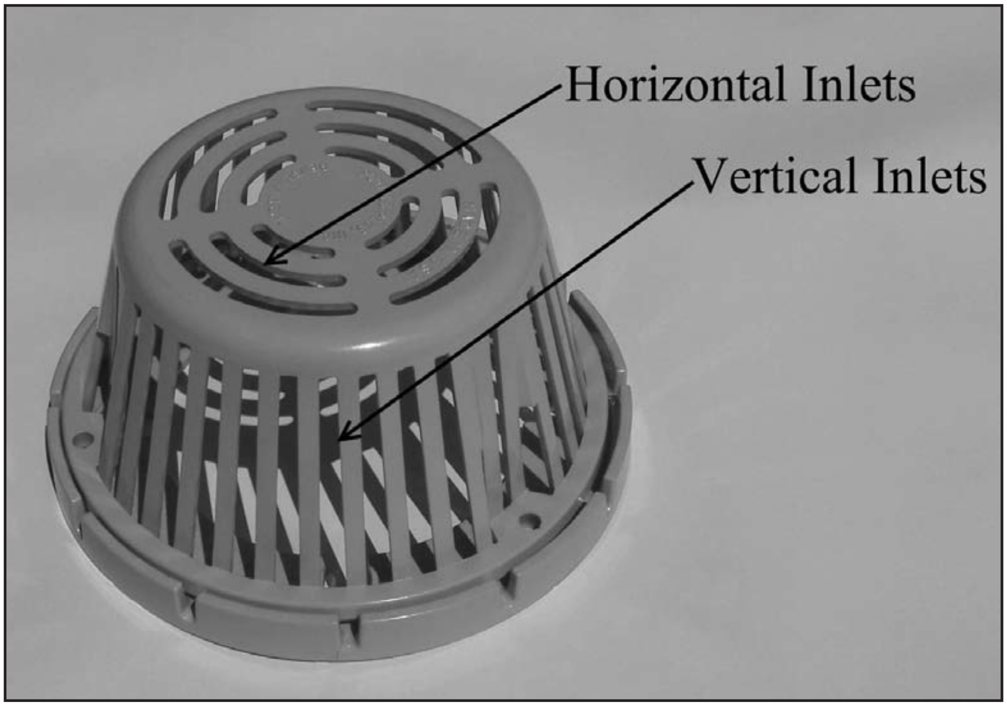
If scuppers are utilized, the size shall be sufficient to prevent ponding to a depth that exceeds the design limits of the roof. The exact methodology for determining the sizing of scuppers used as the secondary drainage system is not specified under current requirements of the IPC.

Debris

The type of debris found on a roof surface varies widely. Typical debris includes vegetation, leaves, trash, cans, bottles, plastic bags, dirt, etc.Field experience has shown that debris will accumulate starting at the roof surface and extend upwards along the sides of strainers or scuppers. Debris generated by some of the new "breen" roofs may also be problematic.

Laboratory Testing

In order to evaluate the effects of debris on the performance of roof drains and scuppers, an elevated steel tank was constructed and con-



Roof drain strainer

Debris at roof drain

Simulated debris

Drain Flow Research

Laboratory Roof Drain Flow Testing, Water Level, inch height

8" Drain, 14" Strainer Dome, 15 ft. 6 in. of 8" Drain / PVC Pipe - Horizontal Configuration

Condition - Approx. Flow Rate, gpm	*Open Area, in²*	*100*	*200*	*300*	*400*	*500*	*600*	*700*	*800*
w/o Strainer	48.7	**1.7**	**2.3**	**2.5**	**2.7**	**2.8**	**3.1**	**3.4**	**3.5**
w/ Clear Strainer	97.0	**2.6**	**2.8**	**3.4**	**3.9**	**4.3**	**4.7**	**5.0**	**5.3**
Debris, 25% of side opening	78.8	**3.6**	**3.8**	**4.4**	**4.8**	**5.2**	**5.5**	**6.0**	**6.4**
Debris, 50% of side opening	60.6	**4.6**	**4.8**	**5.2**	**5.6**	**6.3**	**6.6**	**6.9**	**7.1**
Debris, 75% of side opening	42.4	**5.3**	**5.4**	**6.0**	**6.4**	**6.9**	**7.3**	**7.8**	**7.8**

6" Drain, 9½" Strainer Dome, 15 ft. 6 in. of 6" Drain / PVC Pipe - Horizontal Configuration

Condition - Approx. Flow Rate, gpm	*Open Area, in²*	*100*	*200*	*300*	*400*	*500*	*600*	*700*	*800*
w/o Strainer	28.3	**2.6**	**3.3**	**4.4**	**5.9**	**7.5**	**9.5**	**12.0**	**14.8**
w/ Clear Strainer	51.0	**2.6**	**3.3**	**4.4**	**5.9**	**7.5**	**9.7**	**12.8**	**16.8**
Debris, 25% of side opening	40.3	**4.9**	**4.9**	**5.4**	**6.3**	**7.7**	**9.8**	**12.4**	**>18**
Debris, 50% of side opening	29.5	**5.7**	**6.0**	**6.3**	**7.0**	**9.3**	**13.9**	**>18**	**>18**

Table C

nected to pumps and a water reservoir. Different types of drain devices were flooded at incremental flow rates of 200, 400, 600, and 800 gallons per minute. As water was pumped at different flow rates, the depth of water accumulation was measured.

Six-inch and 8-inch diameter roof drains and four through-wall scupper assemblies were tested under varying conditions.

Simulated Debris

Simulated debris was placed over the vertical inlets of roof strainers. The vertical inlet strainer openings were restricted at rates of 25%, 50%, and 75%. The resultant accumulation of water, depth, and flow rate was measured. Data generated from this testing are included in *Table C*.

Testing verified that a relatively small amount of debris would substantially reduce the flow-rate capabilities of a primary drain assembly. As a result, water will accumulate and lead to increased structural loading.

As an example, if the 6-in roof drain installed in Orlando without a secondary drainage system is partially obscured by 25%, 50%, or 75%, water depth at the drain will increase by 4.4 inches to 5.4, 6.3, and 9.8 inches respectively. As the depth of water increases, the secondary roof drainage system will engage to prevent excessive structural loading and potential collapse.

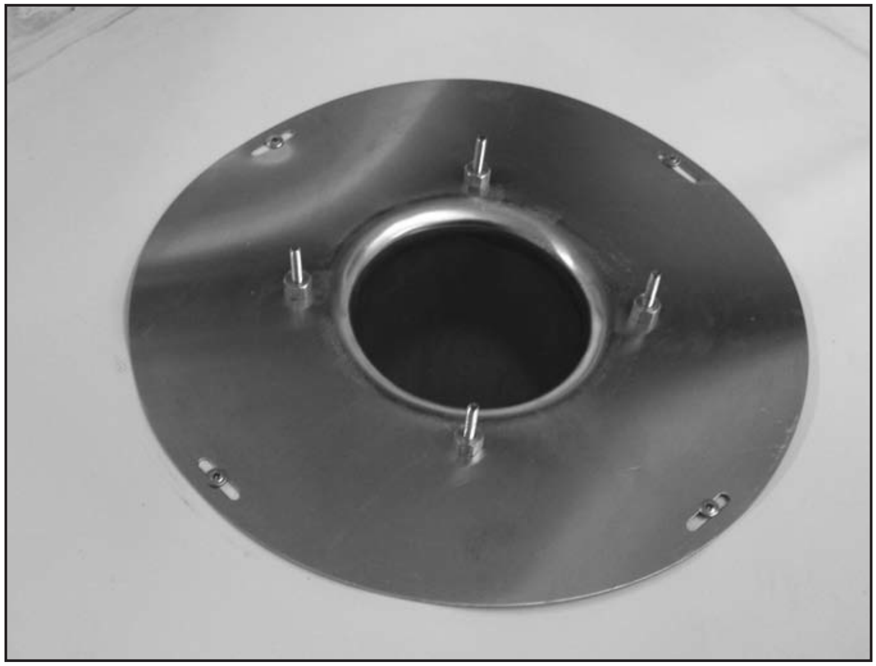
Retrofit Roof Drains

Within the single-ply community, a common method of re-roofing involves the use of "retrofit roof drains." The new retrofit roof drains are inserted within existing roof drains. The insert consists of a metal tube or drain stem with a horizontal flange that is welded to the single-ply membrane.

A gasket or backflow seal device placed within the vertical section of the stem expands, forcing the retrofit roof drain and the existing drainpipe to form a watertight seal. A performance standard to test this seal has been developed by the American National Standard Institute (ANSI) and Single-Ply Roofing Institute (SPRI).[5]

The net result of installing a retrofit roof drain is that the cross-sectional diameter or area of the existing drainpipe is reduced. Manufacturers have not analyzed the effect these drains have on the reduction of flow rates and/or increased water accumulation.

A 6-in roof drain was retrofitted with a typical drain insert. The new assembly was then flooded with water. Data generated from the testing of the retrofit roof drain is included in *Table D*. A comparison of the 60-in drain with and without the insert is shown in *Chart A*.



Retrofit roof drain

Drain Flow Research

Laboratory Roof Drain Flow Testing, Water Level, inch height

6" Retrofit Drain, 9-1/2" Plastic Strainer Dome, 15 ft. 6 in. of 6" Drain / PVC Pipe - Horizontal Configuration

Condition - Approx. Flow Rate, gpm	*Open Area, in²*	*100*	*200*	*300*	*400*	*500*	*600*	*700*	*800*
w/o Strainer	19.6	**5.2**	**5.3**	**5.8**	**7.3**	**8.2**	**9.8**	**12.7**	**16.0**
w/ Clear Strainer	48.4	**5.2**	**5.3**	**5.6**	**7.3**	**8.2**	**9.8**	**13.7**	**>18**
Debris, 25% of side opening	35.1	**5.5**	**5.8**	**5.8**	**6.8**	**7.8**	**10.0**	**14.7**	**>18**
Debris, 50% of side opening	24.3	**5.6**	**6.5**	**7.6**	**8.8**	**12.4**	**16.5**	**>18**	**>18**
Debris, 75% of side opening	15.0	**7.2**	**8.3**	**10.3**	**13.3**	**17.1**	**>18**	**>18**	**>18**

Table D

Ice Debris

Common debris that accumulates on a roof can be addressed by roof maintenance. In some instances, a hail or snow event can create an accumulation of ice at a roof drain and/or scupper. The accumulation of hail, ice, or snow in effect becomes meteorologically supplied debris.

During some hail events, a roof drain/scupper can rapidly become obscured, resulting in an ice dam at the drain/scupper assembly. Water accumulates, backs up, and can produce leakage at roof defects. In worst-case scenarios, water accumulation can result in roof collapse.

Testing the 6-in roof drain, 240 pounds of ice was deposited in the test-

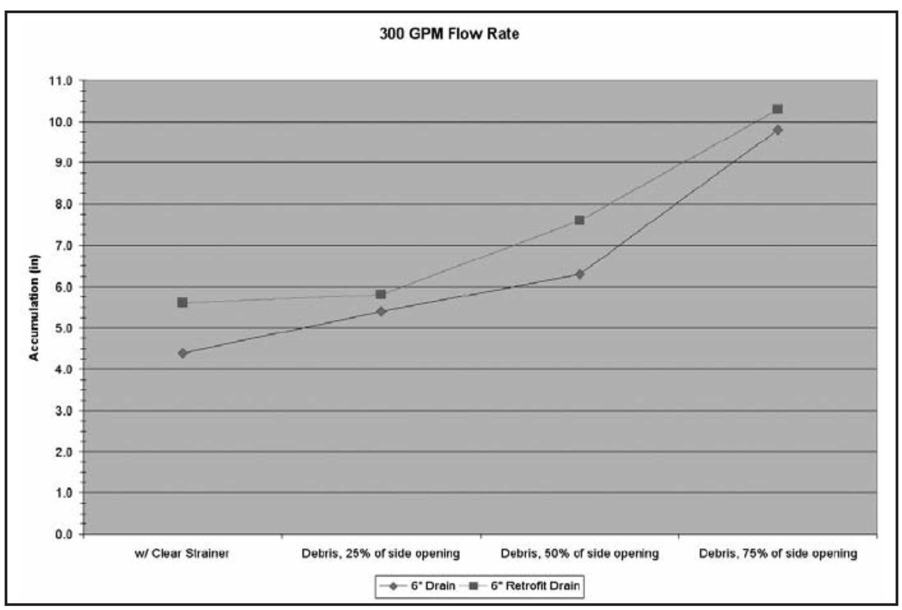


Chart A

ing device in order to observe this phenomenon. At 200 gallons-per-minute of flow, the water level quickly rose from 3.25 to 6 inches. In real-world situations, the amount of ice accumulation as a result of hail or snow can be significantly greater than the amounts used in testing.

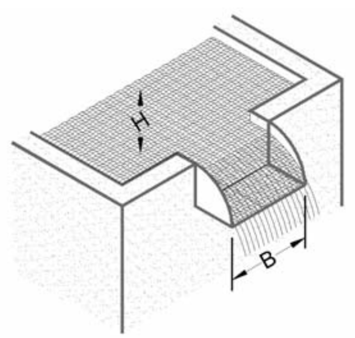
Scuppers

The study of flow rates through rectangular perimeter openings, scuppers or weirs, is a common subject in the study of fluid dynamics.[6] Scuppers can be constructed with either an open top (a channel) or a closed top with four sides. The theoretical flow of water through channels has been reported by Griffin and Fricklas (*Diagram A*).

Other groups have reviewed the properties of flow-through scuppers, including the American Society of Civil Engineers (ASCE)[7] and RCI, Inc.[8] Theoretical flow rates have been published for various channel/scupper configurations.

Four different sizes of through-wall scuppers were utilized for this study:

- 6 in x 6 in
- 6 in x 9 in
- 6 in x 12 in
- 6 in x 24 in



$$Q = 3.33(b - 0.2H)H^{1.5}$$

Q = scupper capacity (ft³/s)
b = scupper width (ft)
H = hydraulic head (ft) (assumed equal to scupper height)

Diagram A

Laboratory Roof Scupper Flow Testing, Water Level, inch height									
Scupper Opening Dimensions: 24" Wide X 6" Height									
Condition - Approx. Flow Rate, gpm	*Open Area, in²*	*100*	*200*	*300*	*400*	*500*	*600*	*700*	*800*
Clear Open	144	**2.5**	**3.0**	**3.5**	**3.9**	**4.4**	**4.8**	**5.2**	**5.8**
Debris, 25% of opening height	108	**3.9**	**4.3**	**4.7**	**5.3**	**5.6**	**6.0**	**6.5**	**6.9**
Debris, 50% of opening height	72	**5.6**	**5.8**	**6.0**	**6.5**	**6.8**	**7.3**	**8.2**	**9.3**
Debris, 75% of opening height	36	**5.7**	**6.9**	**8.7**	**11.4**	**12.7**	**13.8**	**>17**	**>17**
Scupper Opening Dimensions: 12" Wide X 6" Height									
Condition - Approx. Flow Rate, gpm	*Open Area, in²*	*100*	*200*	*300*	*400*	*500*	*600*	*700*	*800*
Clear Open	72	**3.3**	**4.0**	**4.8**	**5.9**	**6.5**	**7.1**	**8.2**	**9.1**
Debris, 25% of opening height	54	**4.5**	**5.3**	**5.9**	**6.8**	**7.9**	**8.9**	**10.7**	**12.8**
Debris, 50% of opening height	36	**6.0**	**6.8**	**7.7**	**9.4**	**11.9**	**15.0**	**<17**	**<17**
Debris, 75% of opening height	18	**10.3**	**12.4**	**16.8**	**<17**	**<17**	**<17**	**<17**	**<17**
Scupper Opening Dimensions: 9" Wide X 6" Height									
Condition - Approx. Flow Rate, gpm	*Open Area, in²*	*100*	*200*	*300*	*400*	*500*	*600*	*700*	*800*
Clear Open	54	**4.0**	**4.8**	**5.6**	**6.8**	**7.9**	**8.9**	**11.6**	**13.2**
Debris, 25% of opening height	40.5	**5.1**	**6.0**	**7.4**	**9.0**	**10.4**	**11.9**	**15.0**	**<17**
Debris, 50% of opening height	27	**6.9**	**7.8**	**10.7**	**14.0**	**15.8**	**<17**	**<17**	**<17**
Debris, 75% of opening height	13.5	**12.3**	**16.1**	**<17**	**<17**	**<17**	**<17**	**<17**	**<17**
Scupper Opening Dimensions: 6" Wide X 6" Height									
Condition - Approx. Flow Rate, gpm	*Open Area, in²*	*100*	*200*	*300*	*400*	*500*	*600*	*700*	*800*
Clear Open	36	**5.0**	**6.3**	**7.7**	**9.5**	**11.5**	**13.8**	**>17**	**>17**
Debris, 25% of opening height	27	**5.8**	**7.0**	**9.6**	**12.5**	**13.6**	**14.3**	**>17**	**>17**
Debris, 50% of opening height	18	**8.7**	**10.9**	**15.8**	**>17**	**>17**	**>17**	**>17**	**>17**
Debris, 75% of opening height	9	**>17**	**>17**	**>17**	**>17**	**>17**	**>17**	**>17**	**>17**

Table E

The scuppers were initially flooded with water at rates of 100 to 800 gallons per minute until steady-state conditions were reached. Each configuration was tested with a clear opening and then partially obscured at rates of 25%, 50%, and 75%. The height of water accumulation for each combination of factors was measured. Data generated from the testing of the scuppers is included in *Table E.*

From a fluid dynamics standpoint, the flow-rate characteristics change as the depth or accumulation of water increases. As the scupper is flooded, the water depth is less than the vertical element of the scupper. Water flows as in an open-sided channel. Once the scupper becomes submerged, the flow-rate characteristics change as a result of the increased hydraulic head and the friction with all four sides of the scupper.

Scupper flow-rate characteristics are not included within the building codes. In order to design a scupper with sufficient capability to match the drainage requirements of the primary roof drainage system, reverse engineering may be required using either actual testing or available theoretical flow-rate data.

Primary – Secondary Drain Model

One scenario was studied based on test data: a 6-in primary drain with ¼-in horizontal leaders located in Orlando, Florida. Prior data show one drain for 6,795 sq ft of roof. In this situation, 317 gallons of water per minute would be generated during a 4.5-in-per-hour rainfall event. If the secondary drainage system consists of 6-in by 6-in through-wall scuppers, 1 inch higher than the primary drain, then the accumulation shown in *Table F* would develop, depending upon the percentage of debris present at the primary roof drain.

Percentage of Primary Drain Blockage	Percentage of Secondary Drain Blockage	Approximate Discharge at Roof Drain (gpm)	Approximate Discharge at Scupper (gpm)	Approximate Accumulation at Roof Drain, Hydraulic Head (in)
0	0	269	48	3.9
25%	0	264	53	5.1
50%	0	211	106	6.1
75%	0	151	166	7.1
100%	0	0	317	9.0
100%	25%	0	317	11.0
100%	50%	0	317	17.2
100%	75%	0	317	>18

Table F

Based upon test data, a 6-in by 6-in through-wall scupper may not be sufficient, dependent upon the live-load capability of the structural deck. When the primary roof drain is blocked, water accumulates up to 9.0 inches. This amount of water would create a live load that could not be supported by most structural decks.

CONCLUSIONS

Several conclusions can be reached as a result of this study:

- Compliance with code requirements for drainage in new roofing and reroofing is critical for proper roof performance.
- In geographical areas prone to hurricane events, designers should consider increasing the capacity of the drainage system due to potential blockage as a result of airborne debris.
- Periodic roof maintenance, including debris removal, is necessary for proper roof drain and scupper performance. Removal of debris from the roof surface is the responsibility of the owner.
- The new "green" roof assemblies most likely will require increased debris removal to assure proper and consistent drainage.
- Width is the dominant factor in flow-rate performance of roof scuppers.
- The use of roof scuppers as the primary and secondary drainage system may require reverse engineering to determine the proper height and size. Flow rates through scuppers obviously are dependent upon the height of the water accumulation. The depth of water and subsequent loading of the roof structure should be taken into consideration by the building designer.

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