

Chapter C8

RAIN LOADS

C8.1 SYMBOLS AND NOTATION

A = roof area serviced by a single drainage system, in ft^2 (m^2)

i = design rainfall intensity as specified by the code having jurisdiction, in $./\text{h}$ (mm/h)

Q = flow rate out of a single drainage system, in gal/min (m^3/s)

C8.2 ROOF DRAINAGE

Roof drainage systems are designed to handle all the flow associated with intense, short-duration rainfall events. For example, the 1993 BOCA National Plumbing Code [Ref. C8-1], and Factory Mutual Loss Prevention Data 1-54, "Roof Loads for New Construction" [Ref. C8-2] use a 1-h duration event with a 100-yr return period; the 1994 Standard Plumbing Code [Ref. C8-3] uses 1-h and 15-min duration events with 100-yr return periods for the primary and secondary drainage systems, respectively, and the 1990 National Building Code [Ref. C8-4] of Canada uses a 15-min event with a 10-yr return period. A very severe local storm or thunderstorm may produce a deluge of such intensity and duration that properly designed primary drainage systems are temporarily overloaded. Such temporary loads are adequately covered in design when blocked drains (see Section 8.3) and ponding instability (see Section 8.4) are considered.

Roof drainage is a structural, architectural and mechanical (plumbing) issue. The type and location of secondary drains and the hydraulic head above their inlets at the design flow must be known in order to determine rain loads. Design team coordination is particularly important when establishing rain loads.

C8.3 DESIGN RAIN LOADS

The amount of water that could accumulate on a roof from blockage of the primary drainage system is determined and the roof is designed to withstand the load created by that water plus the uniform load caused by water that rises above the inlet of the secondary drainage systems at its design flow. If parapet walls, cant strips, expansion joints, and other features create the potential for deep water in an area, it may be advisable to install in that area secondary (overflow) drains with separate drain lines rather than overflow scuppers to reduce the magnitude of the design rain load. Where geometry permits, free discharge is the preferred form of emergency drainage.

When determining these water loads, it is assumed that the roof does not deflect. This eliminates complexities associated with determining the distribution of water loads within deflection depressions. However, it is quite important to consider this water when assessing ponding instability in Section 8.4.

The depth of water, d_h , above the inlet of the secondary drainage system (i.e., the hydraulic head) is a function of the rainfall intensity at the site, the area of roof serviced by that drainage system, and the size of the drainage system.

The flow rate through a single drainage system is as follows:

$$Q = 0.0104A_i \quad (\text{C8-1})$$

$$(\text{in SI: } Q = 0.278 \times 10^{-6} A_i)$$

The hydraulic head, d_h , is related to flow rate, Q , for various drainage systems in Table C8-1. That table indicates that d_h can vary considerably depending on the type and size of each drainage system and the flow rate it must handle. For this reason the single value of 1 in. (25 mm) (i.e., 5 lb/ft^2 (0.24 kN/m^2)) used in ASCE 7-93 has been eliminated.

The hydraulic head, d_h , is zero when the secondary drainage system is simply overflow all along a roof edge.

C8.4 PONDING INSTABILITY

Water may accumulate as ponds on relatively flat roofs. As additional water flows to such areas, the roof tends to deflect more, allowing a deeper pond to form there. If the structure does not possess enough stiffness to resist this progression, failure by localized overloading may result. References [C8-1 through C8-16] contain information on ponding and its importance in the design of flexible roofs. Rational design methods to preclude instability from ponding are presented in Refs. [C8-5 and C8-6].

By providing roofs with a slope of 1/4 in./ft (1.19°) or more, ponding instability can be avoided. If the slope is less than 1/4 in./ft (1.19°), the roof structure must be checked for ponding instability because construction tolerances and long-term deflections under dead load can result in flat portions susceptible to ponding.

C8.5 CONTROLLED DRAINAGE

In some areas of the country, ordinances are in effect that limit the rate of rainwater flow from roofs into storm drains. Controlled-flow drains are often used on such roofs. Those roofs must be capable of sustaining the storm water temporarily stored on them. Many roofs designed with controlled-flow drains have a design rain load of 30 lb/ft^2 (1.44 kN/m^2) and are equipped with a secondary drainage system (for example, scuppers) that prevents water depths ($d_s + d_h$) greater than 5.75 (145 mm) in. on the roof.

Examples

The following two examples illustrate the method used to establish design rain loads based on Chapter 8 of this standard.

Example 1: Determine the design rain load, R , at the secondary drainage for the roof plan shown in Fig. C8-1, located at a site in Birmingham, AL. The design rainfall intensity, i , specified by the plumbing code for a 100-yr, 1-h rainfall is 3.75 in./h (95 mm/h). The inlet of the 4 in. diameter (102 mm) secondary roof drains are set 2 in. (51 mm) above the roof surface.

Flow rate, Q , for the secondary drainage 4 in. diameter (102 mm) roof drain:

$$Q = 0.0104A_i \quad (\text{C8-1})$$

$$Q = 0.0104(2500)(3.75) = 97.5 \text{ gal/min (0.0062 m}^3/\text{s)}$$

Hydraulic head, d_h :

Using Table C8-1, for a 4 in. diameter (102 mm) roof drain with a flow rate of 97.5 gal/min (0.0062 m³/s) interpolate between a hydraulic head of 1 and 2 in. (25 mm and 51 mm) as follows:

$$d_h = 1 + [(97.5 - 80) \div (170 - 80)] = 1.19 \text{ in. 30.2 mm}$$

Static head $d_s = 2$ in. (51 mm); the water depth from drain inlet to the roof surface.

Design rain load, R , adjacent to the drains:

$$R = 5.2(d_s + d_h) \quad (\text{8-1})$$

$$R = 5.2(2 + 1.19) = 16.6 \text{ psf (0.80 kN/m}^2\text{)}$$

Example 2: Determine the design rain load, R , at the secondary drainage for the roof plan shown in Fig. C8-2, located at a site in Los Angeles, CA. The design rainfall intensity, i , specified by the plumbing code for a 100-yr, 1-h rainfall is 1.5 in./h (38 mm/h). The inlet of the 12 in. (305 mm) secondary roof scuppers are set 2 in. (51 mm) above the roof surface.

Flow rate, Q , for the secondary drainage, 12 in. (305 mm) wide channel scupper:

$$Q = 0.0104A_i \quad (\text{C8-1})$$

$$Q = 0.0104(11,500)(1.5) = 179 \text{ gal/min (0.0113 m}^3/\text{s)}$$

Hydraulic head, d_h :

Using Table C8-1, by interpolation, the flow rate for a 12 in. (305 mm) wide channel scupper is twice that of a 6 in. (152 mm) wide channel scupper. Using Table C8-1, the hydraulic head, d_h , for one-half the flow rate, Q , or 90 gal/min (0.0057 m³/s), through a 6 in. (152 mm) wide channel scupper is 3 in. (76 mm).

$d_h = 3$ in. (76 mm) for a 12 in. wide (305 mm) channel scupper with a flow rate, Q , of 179 gal/min (0.0113 m³/s).

Static head, $d_s = 2$ in. (51 mm); depth of water from the scupper inlet to the roof surface.

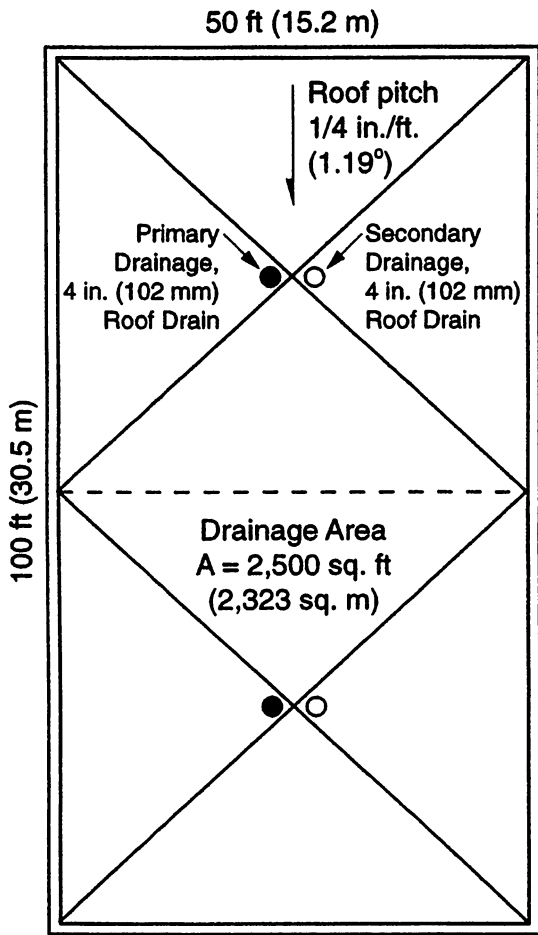
Design rain load, R , adjacent to the scuppers:

$$R = 5.2(d_h + d_s)$$

$$R = 5.2(2 + 3) = 26 \text{ psf (1.2 kN/m}^2\text{)}$$

REFERENCES

- [Ref. C8-1] Building Officials and Code Administrators International. (Jan. 1993). The BOCA National Plumbing Code/1993. BOCA Inc., Country Club Hills, IL.
- [Ref. C8-2] Factory Mutual Engineering Corp. (Aug. 1991). "Loss Prevention Data 1-54, Roof Loads for New Construction." Norwood, MA.
- [Ref. C8-3] Southern Building Code Congress International. (1991). Standard Plumbing Code, 1991 Ed. SBCCI Inc., Birmingham, AL.
- [Ref. C8-4] Associate Committee on the National Building Code. (Jan. 1990). National Building Code of Canada 1990, National Research Council of Canada, Ottawa, Ontario.
- [Ref. C8-5] American Institute of Steel Construction. (June 1989). "Specification for structural steel for buildings, allowable stress design and plastic design." AISC, New York.
- [Ref. C8-6] American Institute of Steel Construction. (Sept. 1986). "Load and resistance factor design specification for structural steel buildings." AISC, New York.
- [Ref. C8-7] American Institute of Timber Construction. (Dec. 1978). "Roof slope and drainage for flat or nearly flat roofs." *AITC Tech. Note No. 5*, Englewood, CO.
- [Ref. C8-8] Burgett, L.B. (First quarter, 1973). "Fast check for ponding." *Eng. J. Am. Inst. Steel Construction*, 10(1), 26-28.
- [Ref. C8-9] Chinn, J., Mansouri, A.H., and Adams, S.F. (May 1969). "Ponding of liquids on flat roofs." *J. Struct. Div. (ASCE)*, 95(ST5), 797-808.
- [Ref. C8-10] Chinn, J. (April 1965). "Failure of simply supported flat roofs by ponding of rain." *Eng. J. Am. Inst. Steel Construction*, 3(2), 38-41.
- [Ref. C8-11] Haussler, R.W. (Oct. 1962). "Roof deflection caused by rainwater pools." *Civil Eng.*, 32, 58-59.
- [Ref. C8-12] Heinzerling, J.E. (May 1971). "Structural design of steel joist roofs to resist ponding loads." Tech. Dig. No. 3. Steel Joist Institute, Arlington, VA.
- [Ref. C8-13] Marino, F.J. (July 1966). "Ponding of two-way roof systems." *Eng. J. Am. Inst. Steel Construction*, 3(3), 93-100.
- [Ref. C8-14] Salama, A.E., and Moody, M.L. (Feb. 1967). "Analysis of beams and plates for ponding loads." *J. Struct. Div. (ASCE)*, 93(ST1), 109-126.
- [Ref. C8-15] Sawyer, D.A. (Feb. 1967). "Ponding of rainwater on flexible roof systems." *J. Struct. Div. (ASCE)*, 93(ST1), 127-148.
- [Ref. C8-16] Sawyer, D.A. (Jan. 1969). "Roof-structural roof-drainage interactions." *J. Struct. Div. (ASCE)*, 94(ST1), 175-198.



* Dashed lines indicate the boundary between separate drainage areas.

FIGURE C8-1 EXAMPLE 1 ROOF PLAN

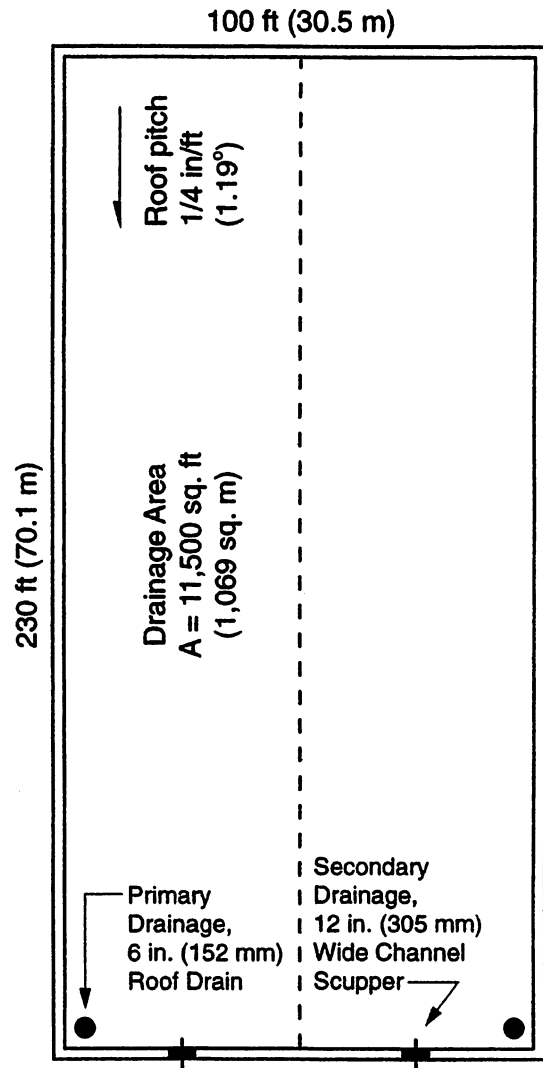


FIGURE C8-2 EXAMPLE 2 ROOF PLAN

TABLE C8-1 FLOW RATE, Q, IN GALLONS PER MINUTE OF VARIOUS DRAINAGE SYSTEMS AT VARIOUS HYDRAULIC HEADS, d_h , IN INCHES [REF. C8-2]

| Drainage System | Hydraulic Head d_h , in. | | | | | | | | | |
|---|----------------------------|-----|----------|-----|----------|-------|----------|-----|-------|-------|
| | 1 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 | 7 | 8 |
| 4 in. diameter drain | 80 | 170 | 180 | | | | | | | |
| 6 in. diameter drain | 100 | 190 | 270 | 380 | 540 | | | | | |
| 8 in. diameter drain | 125 | 230 | 340 | 560 | 850 | 1,100 | 1,170 | | | |
| 6 in. wide, channel scupper ^b | 18 | 50 | <i>a</i> | 90 | <i>a</i> | 140 | <i>a</i> | 194 | 321 | 393 |
| 24 in. wide, channel scupper | 72 | 200 | <i>a</i> | 360 | <i>a</i> | 560 | <i>a</i> | 776 | 1,284 | 1,572 |
| 6 in. wide, 4 in. high, closed scupper ^b | 18 | 50 | <i>a</i> | 90 | <i>a</i> | 140 | <i>a</i> | 177 | 231 | 253 |
| 24 in. wide, 4 in. high, closed scupper | 72 | 200 | <i>a</i> | 360 | <i>a</i> | 560 | <i>a</i> | 708 | 924 | 1,012 |
| 6 in. wide, 6 in. high, closed scupper | 18 | 50 | <i>a</i> | 90 | <i>a</i> | 140 | <i>a</i> | 194 | 303 | 343 |
| 24 in. wide, 6 in. high, closed scupper | 72 | 200 | <i>a</i> | 360 | <i>a</i> | 560 | <i>a</i> | 776 | 1,212 | 1,372 |

^aInterpolation is appropriate, including between widths of each scupper.

^bChannel scuppers are open-topped (i.e., 3-sided). Closed scuppers are 4-sided.

TABLE C8-2 IN SI, FLOW RATE, Q, IN CUBIC METERS PER SECOND OF VARIOUS DRAINAGE SYSTEMS AT VARIOUS HYDRAULIC HEADS, d_h , IN MILLIMETERS

| Drainage System | Hydraulic Head d_h , mm | | | | | | | | | |
|---|---------------------------|-------|----------|-------|----------|-------|----------|-------|-------|-------|
| | 25 | 51 | 64 | 76 | 89 | 102 | 114 | 127 | 178 | 203 |
| 102 mm diameter drain | .0051 | .0107 | .0114 | | | | | | | |
| 152 mm diameter drain | .0063 | .0120 | .0170 | .0240 | .0341 | | | | | |
| 203 mm diameter drain | .0079 | .0145 | .0214 | .0353 | .0536 | .0694 | .0738 | | | |
| 152 mm wide, channel scupper ^b | .0011 | .0032 | <i>a</i> | .0057 | <i>a</i> | .0088 | <i>a</i> | .0122 | .0202 | .0248 |
| 610 mm wide, channel scupper | .0045 | .0126 | <i>a</i> | .0227 | <i>a</i> | .0353 | <i>a</i> | .0490 | .0810 | .0992 |
| 152 mm wide, 102 mm high, closed scupper ^b | .0011 | .0032 | <i>a</i> | .0057 | <i>a</i> | .0088 | <i>a</i> | .0112 | .0146 | .0160 |
| 610 mm wide, 102 mm high, closed scupper | .0045 | .0126 | <i>a</i> | .0227 | <i>a</i> | .0353 | <i>a</i> | .0447 | .0583 | .0638 |
| 152 mm wide, 152 mm high, closed scupper | .0011 | .0032 | <i>a</i> | .0057 | <i>a</i> | .0088 | <i>a</i> | .0122 | .0191 | .0216 |
| 610 mm wide, 152 mm high, closed scupper | .0045 | .0126 | <i>a</i> | .0227 | <i>a</i> | .0353 | <i>a</i> | .0490 | .0765 | .0866 |

^aInterpolation is appropriate, including between widths of each scupper.

^bChannel scuppers are open-topped (i.e., 3-sided). Closed scuppers are 4-sided.

Chapter C9—This Section intentionally left blank.

