

PROPER GUTTER AND DOWNSPOUT SIZING

DESIGN OF ROOF DRAINAGE SYSTEMS ROOF DRAINAGE

The roof is one of the most essential parts of a building as it protects occupants, contents, and interior of the structure from the elements. Once an architect has determined the kind of roof he intends to use, he must give equal attention to the design of the roof drainage system.

Factors to be considered in the design of roof drainage systems are the area to be drained, size of gutters, downspouts, outlets, slope of roof, type of building, and appearance.

ROOF AREA TO BE CONSIDERED

The design capacity for a roof drainage system depends on the quantity of water to be handled. The quantity of water in turn depends on the roof area, slope, and rainfall intensity.

In considering the roof area, it must be remembered that rain does not necessarily fall vertically and that maximum conditions exist only when rain falls perpendicular to a surface. Since the roof area would increase as its pitch increases, then it would not be advisable to use the plan area of a pitched roof in the calculation of a drainage system.

Experience has taught that use of the true area of a pitched roof often leads to oversizing of gutters, downspouts, and drains. To determine the design area for a pitched roof, Table 1-1 is used.

**TABLE 1-1
DESIGN AREAS FOR PITCHED ROOFS**

PITCH		*B
in./ft.	mm/mm	
Level to 3	76/305	1.00
4 to 5	102-127/305	1.05
6 to 8	152-203/305	1.10
9 to 11	229-279/305	1.20
12	305/305	1.30

* To determine the design area multiply the plan area by the factor in B column

These areas are then divided by the proper factor given in Table 1-2, thus obtaining the required area in square inches (square mm) for each downspout. From Table 1-3 select the downspout.

RAINFALL INTENSITY - DOWNSPOUT CAPACITY

Rainfall intensity is usually given in inches per hour for a five minute duration or one hour duration based on U.S. Weather Bureau records. Table 1-2 based on records through 1978, gives five minute intensities for selected cities. New Orleans, Los Angeles, for example, may have 8 in./hr.(203 mm/hr) for a five minute duration yet record only 4.8 in. (121 mm) in an hour over a 100 year period. These rates correspond to 0.133 in./min.(3.4 mm/min.) and 0.08 in./min.(2 mm/min.). Local codes may require that drainage systems only be designed for the latter. It takes 96.15 square feet(8.93 square meters) of surface with 1 inch per hour(25 mm/hr) of water to correspond with 1 gpm (0.063 l/s) flow rate. Downspouts and gutters are sized in relation to rainfall on this basis.

Plumbing codes typically use the vertically projected roof area for drainage design and they often use a square foot allowance per square inch of downspout for 1 in./hr.(25 mm/hr) rainfall that varies with diameter, for example, 3 in.(76 mm): 911(85); 4 in.(102 mm): 1100 (102); 5 in.(127 mm): 1280 (119); 6 in.(152 mm): 1400 (130) and 8 in.(203 mm): 1750 (163) sq. ft.(sq. m). Net drainage capacity from using Table 1-1 and 1-2 should be compared with local code requirements.

DOWNSPOUT SIZING

In sizing downspouts, the following considerations apply:

1. Downspouts of less than 7.00 sq.in.(4515 sq mm) cross section should not be used except for small areas such as porches and canopies.
2. The size of the downspout should be constant throughout its length.
3. Downspouts should be constructed with conductor heads every 40 ft(12.2 m) to admit air and prevent vacuum.
4. Offset of more than 10 ft(3.0 m) can affect drainage capacity.
5. The gutter outlet capacity should suit the downspout capacity.
6. The downspout size must suit the bottom width of the gutter.

PROPER GUTTER AND DOWNSPOUT SIZING

**TABLE 1-3
DIMENSIONS OF STANDARD DOWNSPOUTS**

TYPE	AREA		"A" Size		Nominal Size		Actual	
	sq.in.	sq.mm.	sq.in.	sq.mm.	in.	mm.	in.	mm.
Plain Round	7.07	4560	5.94	3831	3	76	3	76
	12.57	810	11.04	7120	4	102	4	102
	19.63	12661	17.71	11422	5	127	5	127
	28.27	18234	25.95	16737	6	152	6	152
	50.24	32404	47.15	30411	8	203	8	203
Corrugated Round	5.94	3831			3	76	3	76
	11.04	7120			4	102	4	102
	17.72	11429			5	127	5	127
	25.97	16750			6	152	6	152
Plain Rectangular	3.94	2541	3.00	1935	2	51	1.75x2.25	44x57
	6.00	3870	4.80	3096	3	76	2x3	51x76
	12.00	7740	10.31	6649	4	102	3x4	76x102
	20.00	12900	15.75	10158	5	127	3.75x4.75	95x121
	24.00	15480	21.56	13906	6	152	4x6	102x152
Rectangular Corrugated	3.80	2451	3.00	1935	2	51	1.75x2.25	44x57
	7.73	4985	6.38	4155	3	76	2.37x3.25	60x83
	11.70	7621	10.00	6513	4	102	2.75x4.25	70x108
	18.75	12213	16.63	10832	5	127	3.75x5	95x127

"A" = area of 1/4 in.(6.4 mm) undersized inlet See Figures 1-31 and 1-32 for gage

7. Assuming that using the fewest number of downspouts is desirable, their locations will be affected by

a. gutter capacity and length. To limit the effects of thermal expansion in gutters 50 ft(15.3 m) is a practical maximum length of gutter to be served by a downspout. Unless special provisions are made for flexibility in downspouts, gutters and their support systems, gutters should expand away from downspouts and downspouts should not be located near gutter expansion joints. See expansion coefficients in Appendix A-1 and expansion allowances in Figures 1-5 to 1-10.

b. the capacity of the inlet tube. See Table 1-3 and Figure 1-33. Also, a sharp bend at the inlet may clog.

c. potential for water freezing in downspouts and gutters. Open, partially open or corrugated styles downspouts are suggested for areas subject to icing. Locating downspouts on the north side of buildings is not recommended for such areas.

d. the appearance of the downspout system and a potential need for concealment. See Figures 1-31 and 1-32.

e. the greater capacity of a pitched gutter.

f. the downspout discharge location. Water disposal at this location should be acceptable. See Figures 1-31 and 1-36.

g. the risk of gutter overflow from insufficient drainage capacity. See Figures 1-4, 1-21, and 1-23.

h. a scupper serving a designated roof area. See Figures 1-26 to 1-30.

After the number and location of downspouts have been determined, the areas to be drained by each downspout

should be figured. In making this calculation for a pitched roof, the plan area should be adjusted according to recommendations given on Table 1-1.

SAMPLE PROBLEM: Select downspouts for a building in Boston, Mass. The building is 100 x 85 ft.(30.5 x 26 m) with a double pitched roof having a slope of 6 in./ft.(152 mm/m). The slope is toward the 100 ft.(30.5 m) side. Maximum rainfall conditions will be used to determine downspout size.

It is decided to drain the building with 4 downspouts located at each corner of the building. An expansion joint will be installed in each gutter between the downspouts.

The plan area of this building is 8500 sq ft.(790 sq m). Since the slope is 6 in./ft.(152 mm/m), factor 1.10 is used (Table 1-1), making the design area 9350 sq ft.(868 sq m). Thus each of the four downspouts will serve a 2338 sq ft.(217 sq m) area. From column B, Table 1-2, opposite Boston, it is found that 1 sq in.(645 sq mm) of downspout will drain 170 sq ft.(16 sq m) of roof area. Divide 2338(217) by 170(16) to determine that each downspout should have a minimum area of 13.56 sq in.(8746 sq mm).

From Table 1-3, it is found that there is a choice of; a 5 in.(127 mm) Plain Round, a 5 in.(127 mm) Corrugated Round, a 5 in.(127 mm) Rectangular Corrugated, or 5 in.(127 mm) Plain Rectangular downspout.

PROPER GUTTER AND DOWNSPOUT SIZING

GUTTER SIZING

In sizing gutters, the following considerations apply for typical section lengths of 8 to 10 feet(2.41 to 3.0 m):

1. Spacing and size of outlet openings. (The gutter can never be any more effective than the outlet and downspout selected to drain it. Downspout sizes must not exceed the bottom width of the gutter.)
2. Slope of the roof. (The gutter must be of such a design and location that water from a steep pitched roof will not by its own velocity tend to overrun the front edge.)
3. Style of gutters to be used. (All gutters are not effective for their full depth and width, see Figures 1-1 and 1-4 for design data.)
4. Maximum length of gutter. (50 ft.(15.2 m) between ends or expansion joints is the limit unless the system is especially designed to accommodate the greater expansion, the larger flow and the need for special supports.)
5. Gutter support capability. (Supports should be based on full capacity of the gutter. Ice load capacity also affect the size and strength of the system.)

Level gutters may be sized by Charts 1-1, 1-2, or 1-3. Sloped gutters may be sized by Chart 1-3. Formulae for flow in gutters with different pitch are not available. The capacity of a gutter with 1/16 in./ft.(5.21 mm/m) or less pitch is taken as that of a level gutter even though it is somewhat greater.

RECTANGULAR GUTTER SIZING

The size of rectangular gutters depends upon these factors:

1. Area to be drained. (A, Chart 1-1)
2. Rainfall intensity per hour. (I, Chart 1-1)
3. Length of gutter in ft.(m) (L, Chart 1-1)
4. Ratio of depth to width of gutter. (M, Chart 1-1)

Chart 1-1 is based on level gutter capacity as experimentally determined by the National Institute of Standards and Technology (NIST) formerly National Bureau of Standards. It is plotted from $W = 0.0106 M^{-4/7} L^{3/28}(1A)^{5/14}$ with W in feet(m).

IRREGULAR CROSS SECTION GUTTER SIZING

The required sizes of gutters other than rectangular or round can be determined by finding the semicircle or rectangular area that most closely fits the irregular cross section.

HALF ROUND GUTTER SIZING

Chart 1-2 is based on level gutter capacity as determined by NIST. It is based on $W = 0.0182 (IA)^{2/5}$. W is the width in in.(mm). I denotes rainfall intensity (Table 1-2) and A is the roof area in square feet(sq m) (Table 1-1).

SAMPLE PROBLEM: To size rectangular gutter for a building 120 x 30 ft.(35.6 x 9.1 m) located in Buffalo, NY. This building has a flat roof with a raised roof edge on three sides. A gutter is to be located on one of the 120 ft.(35.6 m) sides. So that each section of gutter will not exceed 50 ft.(15.2 m), three downspouts will be used with 2 gutter expansion joints. The area to be drained by each section of gutter will be 1200 sq ft.(111.5 sq m), the rainfall intensity from Table 1-2, col A is 6 in/hr(152 mm/hr), the length of each gutter section is 40 ft.(12.2 m), and the ratio of gutter depth to width is 0.75. On Chart 1-1 find the vertical line representing L = 40(12.2 m). Proceed vertically along this line to its intersection with the oblique line representing M = 0.75. Pass to B vertically to the intersect the horizontal line representing IA = 7200(16948). The point of intersection occurs between the oblique line representing gutter widths of 5 and 6 in.(127 and 152 mm). The required width of gutter is, therefore, 6 in.(152 mm) and its depth need be only 4.5 in.(114 mm).in.

SAMPLE PROBLEM: To size a half round gutter for a building, located in Kansas City, Mo., with a flat roof 80 x 40 ft.(24.4 x 12.2 m). This building has a parapet wall on three sides and a gutter to be located on an 80 ft.(24.4 m) side. Column A, Table 1-2, was used to determine rainfall conditions. Since the gutter run will exceed 50 ft.(15.2 m), two downspouts will be used with an expansion joint between.

The area of the building is 3200 sq ft.(297 sq m). Thus each of the downspouts will serve an area of 1600 sq ft. (149 sq m). From column A, Table 1-2, opposite Kansas City, Mo., it is found that 1 sq in.(100 sq mm) of downspout will drain 160 sq ft.(2.3 sq m/100 sq mm) of roof area. Divide 1600 sq ft.(149 sq m) by 160 sq ft/sq in.(2.3 sq m/100 sq mm) to determine that each downspout should have a minimum area of 10 sq in.(6470 sq mm). From Table 1-3 it is found that a 4 in.(102 mm) downspout is required. From Chart 1-2 it is determined that a 9.5 in.(241 mm) half round gutter should be used. Area and flow in Table 1-4 are based on 1 in.(25 mm) of rainfall per hour; divide these areas by the local rainfall rate in inches per hour to determine the actual roof area to be served by the gutter diameter. "The capacity of a sloped rectangular gutter may be approximated by using a gutter cross section area not less than that of a semicircular gutter and a depth to width ratio of at least 0.75.