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4.3.3.1 Gabion Check Dams



GABION CHECK DAM

Source: Environmental Geological Agency

Definition and Purpose

Gabion check dams are check dams constructed from gabion baskets and placed across a swale, drainage ditch, or other concentrated flow areas, excluding streams. These check dams consist of two rows; one placed on top of the other, with the upper center basket removed to act as the weir. Their primary purpose is to reduce the velocity of stormwater by flattening the slope of the channel, thereby reducing erosion.

Appropriate Applications

Gabion check dams are generally applicable where traditional check dams are used (Section 4.3.3). However, gabion check dams may be preferable over traditional check dams where dam stability is of concern. These scenarios may include where (TDOT):

- Channel drainage areas exceed 10 acres;
- Channel slopes exceed 4%;
- Site conditions restrict or limit equipment access, which impose challenges of creating check dams through dumping rocks or other materials; and
- Permanent runoff velocity control is desired.

Limitations and Maintenance

All types of check dams are not to be used in streams. The construction of gabion check dams requires more time and will likely be more costly than traditional check dams and other potential EPSC measures. Furthermore, if gabion check dams are used as a temporary measure, the removal of such structures results in more disruption to the channel slopes



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and stability. This is because excavation will be required to remove riprap wedges, coarse aggregate used to fill void spaces between the gabions and natural ground, and gabions built into the channel sidewalls. Gabion check dams are less functional when (TDOT):

- Channel drainage areas exceed 35 acres;
- Channels are not properly stabilized, are subjected to larger shear forces and velocities, and drain highly erodible watersheds;
- Channel slope exceeds 10%;
- Channel side slopes are steeper than 2H:1V;
- Channels require vegetation establishment; and
- Other scenarios are present that may indicate excessive sediment yields.

In addition to inspection points for traditional check dams, the wire baskets must be inspected on gabion check dams. Inspect the wire baskets for signs of abrasion and wear.

Planning and Design Considerations

Similar to traditional check dams, a Type III geotextile fabric is to be installed between the base of the gabion structure and the channel bed and extend three feet beyond the toe of the riprap slope. Because gabion baskets are pre-fabricated at standard sizes, the remaining planning and design considerations differ from traditional check dam design. Nonetheless, formal design is only required when gabion check dams are implemented as permanent EPSC measures. Each gabion check dam used should be labeled on the EPSC plans as permanent or temporary (or both) with corresponding information such as the required weir width, the size and length of gabion for the lower row, and the size and length of gabion for the upper row.

A variety of gabion check dam weir sizes and configurations may be applicable to convey the peak flow rate from the design storm (Table 4.3.3.1-A). These provided flow rates were calculated to provide ample protection before channel stability or lining measures have been implemented, and are much lower than the necessary flow rates to overtop the structure. Thus, when left in place as permanent structures, gabion check dams sized in accordance with Table 4.3.3.1-A will be able to convey peak flow rates from larger storms such that the channel stability measures were implemented with good practices (Section 4.2.6).



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Table 4.3.3.1-A: Flow rate capacities for various gabion configurations, Source: TDOT.

18-inch Upper Gabion Row													
Bottom Width of Channel (ft)	12-inch Lower Gabion						18-inch Lower Gabion						
	Weir Length (ft)			Allowable Flow Rate (cfs)			Weir Length (ft)			Allowable Flow Rate (cfs)			
	Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			
	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	
3	2.6	3.3	7.6	13.4	18.8	13.4	8.6	12.3	19.6	23.1	31	35.6	
4	3.6	4.3	8.6	13.2	17.7	14.7	9.6	13.3	20.6	25.9	33.8	38.5	
5	4.6	5.3	9.6	13.9	17.9	16	10.6	14.3	21.6	28.8	36.7	41.4	
6	5.6	6.3	10.6	15	18.7	17.4	11.6	15.3	22.6	31.7	39.6	44.4	
7	6.6	7.3	11.6	16.1	19.9	18.7	12.6	16.3	23.6	34.7	42.6	47.2	
8	7.6	8.3	12.6	17.5	20.9	20.1	13.6	17.3	24.6	37.7	45.7	50	
9	8.6	9.3	13.6	18.8	22.2	21.5	14.6	18.3	25.6	40.7	48.4	53.2	
10	9.6	10.3	14.6	20.3	23.4	23	15.6	19.3	26.6	43.8	51.6	56.2	
12	11.6	12.3	16.6	23.2	26.1	26	17.6	21.3	28.6	49.8	57.7	62.3	
15	14.6	15.3	19.6	27.8	30.5	30.5	20.6	24.3	31.6	59.2	66.9	71.4	

12-inch Upper Gabion Row																			
Bottom Width of Channel (ft)	12-inch Lower Gabion						18-inch Lower Gabion						36-inch Lower Gabion						
	Weir Length (ft)			Allowable Flow Rate (cfs)			Weir Length (ft)			Allowable Flow Rate (cfs)			Weir Length (ft)			Allowable Flow Rate (cfs)			
	Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			
	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	
3	4.2	4.5	6	4.7	6.3	6.9	6.2	7.5	10	7.6	9.9	11.4	12.2	16.5	22	20.4	27.8	34.3	
4	5.2	5.5	7	5.6	7.1	7.7	7.2	8.5	11	9	11.3	12.8	13.2	17.5	23	23.2	30.6	37.1	
5	6.2	6.5	8	6.5	7.9	8.6	8.2	9.5	12	10.4	12.7	14.3	14.2	18.5	24	26.1	33.6	40	
6	7.2	7.5	9	7.5	8.8	9.5	9.2	10.5	13	11.9	14.2	15.7	15.2	19.5	25	29	36.5	42.9	
7	8.2	8.5	10	8.4	9.8	10.4	10.2	11.5	14	13.4	15.7	17.2	16.2	20.5	26	31.9	39.5	45.9	
8	9.2	9.5	11	9.4	10.7	11.4	11.2	12.5	15	14.9	17.1	18.6	17.2	21.5	27	24.9	42.5	48.8	
9	10.2	10.5	12	10.4	11.7	12.3	12.2	13.5	16	16.4	18.6	20.1	18.2	22.5	28	37.9	45.3	51.8	
10	11.2	11.5	13	11.4	12.6	13.3	13.2	14.5	17	18	20.1	21.6	19.2	23.5	29	41	48.3	54.8	
12	13.2	13.5	15	13.4	14.6	15.2	15.2	16.5	19	21	23.2	24.6	21.2	25.5	31	47.1	54.4	60.9	
15	16.2	16.5	18	16.5	17.6	18.2	18.2	19.5	22	25.6	27.8	29.2	24.2	28.5	34	56.4	63.6	70.1	



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When gabion check dams are intended to be permanent structures, two checks are required:

1. Engineering computations to ensure that the gabion structure will not be overtopped; and
2. Engineering computations to ensure that the gabion structure can withstand the shear forces it is subject to.

The depth of flow over the weir can be computed utilizing standard weir equations (Eqn 17 or Eqn 18 from Section 4.3.3) and solving for height.

Because the wire mesh of gabion structures allows the structure to act as a single unit (Section 3.3.2.1), the gradation of stone used is less critical for shear stress calculations. However, the gradation is important so that void spaces in the gabion structure are minimized, such that runoff cannot easily flow through the dam. TDOT suggests a gradation of stone smaller than Class A-1. Thus, the allowable shear stress is more dependent on the wire. A typical allowable shear stress is that of 5.3 pounds per square foot, although it is more ideal to check manufacturer specifications, if such a threshold is provided.

By definition, the critical depth is the depth of flow over the weir that maximizes the discharge at a given specific energy or minimizes the specific energy for a given discharge. Although the water surface would be at the depth, H, by Eqn 17 (rectangular weir), as it flows onto the weir, it will pass through critical depth, d_c , as it flows across the downstream side of the weir. Since this is the minimum depth which will occur on the weir, this also represents the point of greatest velocity and shear stress. The equation for calculating shear stress at critical depth is similar to Eqn 12 expressed in Section 3.3.2.1:

$$\tau_c = \gamma \times d_c \times S_c \quad (\text{Eqn 19})$$

where γ is the unit weight of water (62.4 pounds per cubic foot), d_c is the critical depth of flow in feet, and S_c is the critical slope (the slope at which normal depth and critical depth are equivalent) expressed in feet per foot. Because gabion baskets are rectangular prisms, only rectangular weirs can be constructed and the critical depth for rectangular cross-section weirs is calculated by:

$$d_c = \left(\frac{Q^2}{g \times L^2} \right)^{1/3} \quad (\text{Eqn 20})$$

where Q is discharge in cubic feet per second, L is the length of the weir in feet, and g is the acceleration due to gravity (32.2 feet per square second). Critical slope for rectangular weirs can be calculated by rearranging Manning's Equation:

$$S_c = \left(\frac{Q \times n \times (L + 2 \times d_c)^{2/3}}{1.486 \times (L \times d_c)^{5/3}} \right)^2 \quad (\text{Eqn 21})$$

where n is Manning's roughness coefficient, which is typically 0.069 for gabion stone filler. Be sure to check the roughness coefficient from the supplier or Table 4.2.6.4-A.



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Similar to weir sizing, a variety of gabion sizes may be applicable for the dam and are to be spaced apart according to Table 4.3.3.1-B. Selecting the sizes of the lower and upper gabion rows is to be in accordance with Tables 4.3.3.1-C and 4.3.3.1-D, respectively. When multiple sizing options are available for the lower gabion row, selecting the taller configuration is generally recommended. For instance, if a channel with 3H:1V side slopes is designed to convey a flow of 13 cubic feet per second, the lower gabion row could be either 12 or 18 inches tall (Table 4.3.3.1-B). In this scenario, an 18-inch height is preferred, as long as it does not cause the overall structure to extend above the channel banks. That is, the sizing of the upper gabion following guidance in Table 4.3.3.1-C but must not exceed the height of the channel banks once stacked on the bottom row. Lastly, refer to Table 4.3.3.1-D for the spacing of multiple gabion check dams within a channel.

Table 4.3.3.1-B: Maximum spacing for gabion check dams. Source: TDOT.

Ground Slope (ft/ft)	Maximum Spacing (ft)		
	12-inch Basket	18-inch Basket	36-inch Basket
0.01	72	122	272
0.015	47	81	181
0.02	35	60	135
0.03	22	39	89
0.04	16	29	66
0.05	12	22	52
0.06	10	18	43
0.07	-	15	37
0.08	-	13	32
0.09	-	11	28
0.1	-	10	25
0.11	-	-	22
0.12	-	-	20
0.13	-	-	19
0.14	-	-	17
0.15	-	-	16
0.2	-	-	11



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Table 4.3.3.1-C: Design dimensions for lower gabion rows. Source: TDOT.

Bottom Width of Channel (ft)	12-inch Lower Gabion									18-inch Lower Gabion									36-inch Lower Gabion											
	Min. Gabion Length (ft)			Lower Embedment Length (ft)			Upper Embedment Length* (ft)			Min. Gabion Length (ft)			Lower Embedment Length (ft)			Upper Embedment Length* (ft)			Min. Gabion Length (ft)			Lower Embedment Length (ft)			Upper Embedment Length* (ft)					
	Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)					
	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1
3	9	9	12	3	3	4.5	1.5	0.75	1.5	9	12	15	3	4.5	6	0.5	0.75	1	15	21	27	6	9	12	0.5	0.75	1			
4	9	9	12	2.5	2.5	4	1	0.25	1	12	15	15	4	5.5	5.5	1.5	1.75	0.5	18	21	27	7	8.5	11.5	1.5	0.25	0.5			
5	9	12	12	2	3.5	3.5	0.5	1.25	0.5	12	15	18	3.5	5	6.5	1	1.25	1.5	18	24	30	6.5	9.5	12.5	1	1.25	1.5			
6	12	12	15	3	3	4.5	1.5	0.75	1.5	12	15	18	3	4.5	6	0.5	0.75	1	18	24	30	6	9	12	0.5	0.75	1			
7	12	15	15	2.5	4	4	1	1.75	1	15	15	18	4	4	5.5	1.5	0.25	0.5	21	24	30	7	8.5	11.5	1.5	0.25	0.5			
8	12	15	15	2	3.5	3.5	0.5	1.25	0.5	15	18	21	3.5	5	6.5	1	1.25	1.5	21	27	33	6.5	9.5	12.5	1	1.25	1.5			
9	15	15	18	3	3	4.5	1.5	0.75	1.5	15	18	21	3	4.5	6	0.5	0.75	1	21	27	33	6	9	12	0.5	0.75	1			
10	15	15	18	2.5	2.5	4	1	0.25	1	18	18	21	4	4	5.5	1.5	0.25	0.5	24	27	33	7	8.5	11.5	1.5	0.25	0.5			
12	18	18	21	3	3	4.5	1.5	0.75	1.5	18	21	24	3	4.5	6	0.5	0.75	1	24	30	36	6	9	12	0.5	0.75	1			
15	21	21	24	3	3	4.5	1.5	0.75	1.5	21	24	27	3	4.5	6	0.5	0.75	1	27	33	39	6	9	12	0.5	0.75	1			

*Assuming 3-inch embedment depth at base of gabion



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Table 4.3.3.1-D: Design dimensions for upper gabion rows. Source: TDOT.

Bottom Width of Channel (ft)	12-inch Upper Gabion									18-inch Upper Gabion								
	Min. Gabion Length (ft)			Lower Embedment Length (ft)			Upper Embedment Length* (ft)			Min. Gabion Length (ft)			Lower Embedment Length (ft)			Upper Embedment Length* (ft)		
	Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)			Side Slope (H:V)		
	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1	2:1	3:1	4:1
3	3	6	6	2.1	4.5	4.5	0.1	1.5	0.5	6	9	9	3.3	5.4	6.3	0.3	0.9	0.3
4	3	6	6	2.1	4.5	4.5	0.1	1.5	0.5	6	9	9	3.3	5.4	6.3	0.3	0.9	0.3
5	3	6	6	2.1	4.5	4.5	0.1	1.5	0.5	6	9	9	3.3	5.4	6.3	0.3	0.9	0.3
6	3	6	6	2.1	4.5	4.5	0.1	1.5	0.5	6	9	9	3.3	5.4	6.3	0.3	0.9	0.3
7	3	6	6	2.1	4.5	4.5	0.1	1.5	0.5	6	9	9	3.3	5.4	6.3	0.3	0.9	0.3
8	3	6	6	2.1	4.5	4.5	0.1	1.5	0.5	6	9	9	3.3	5.4	6.3	0.3	0.9	0.3
9	3	6	6	2.1	4.5	4.5	0.1	1.5	0.5	6	9	9	3.3	5.4	6.3	0.3	0.9	0.3
10	3	6	6	2.1	4.5	4.5	0.1	1.5	0.5	6	9	9	3.3	5.4	6.3	0.3	0.9	0.3
12	3	6	6	2.1	4.5	4.5	0.1	1.5	0.5	6	9	9	3.3	5.4	6.3	0.3	0.9	0.3
15	3	6	6	2.1	4.5	4.5	0.1	1.5	0.5	6	9	9	3.3	5.4	6.3	0.3	0.9	0.3

Example Application

-Example Courtesy of TDOT-

Given:

A roadway side ditch for a pavement replacement project on a freeway will direct the runoff from approximately 5 acres into a proposed swale, which will carry flows to a river that runs parallel to the roadway. The roadway is situated at the top of a hill that slopes steeply down to the river, which has been listed as an ETW. The proposed swale will have a planimetric length of 170 feet and will be at a slope of 8.0%. It is proposed to have a 4-foot bottom width with 3H:1V side slopes. The height of this swale, from the flow line to the top of the bank, is 4 feet. Due to the environmentally sensitive nature of the receiving waters, it is desired to provide a vegetated lining for the swale, if possible. Rational Method computations have determined that the 5-year peak discharge will be 22.2 cfs while the 50-year peak discharge will be 29.2 cfs.

Determine:

The required gabion check dam configurations (weir length, gabion sizing, and dam spacing).

Solution:



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Step 1 - Determine the required gabion check dam configuration: Since this site drains to an ETW, the flow rates provided in Table 4.3.3.1-A will be compared with the 5-year peak flow rate at the site in order to select a suitable gabion check dam configuration. This table contains one row, which corresponds to a channel bottom width of 4 feet; and on that row, there are five possible configurations that correspond to 3H:1V channel side slopes. However, the allowable flow rates for three of these configurations are less than the 5-year flow rate at the site; thus, there are two possible configurations:

- Option 1 consists of a 36-inch lower gabion row, with a 12-inch upper gabion row, a weir width of 17.5 feet, and an allowable flow rate of 30.6 cfs; and
- Option 2 consists of an 18-inch lower gabion row, with an 18-inch upper gabion row, a weir width of 12.3 feet, and an allowable flow rate of 33.8 cfs.

It is decided to use Option 1 as it will fit within the proposed 4-foot depth of the swale, and the lower gabion is larger, which is preferred.

Tables 4.3.3.1-C and 4.3.3.1-D specify the required lengths of gabion in each row and the lengths of embedment into the sides of the channel for the ends of the two rows of gabions. Based on the table for the lower row, the lower row will have a total length of 21 feet, with an upper embedment length of 0.25 feet and a lower embedment length of 8.5 feet. Based on the table for the upper row, the upper row will require a gabion length of 6 feet on each side of the structure, as well as an upper embedment length of 1.5 feet and a lower embedment length of 4.5 feet (Table 4.3.3.1-D).

It is also useful to determine the depth of embedment of the lower gabion row into the channel bottom. The downstream face of the lower row should be embedded 3 inches. Since the proposed swale will have a slope of 8.0%, the depth of embedment on the upstream side of the lower gabion row may be computed as:

$$\text{Depth of Embedment} = 3\text{in} + (36\text{in} \times 0.08) = 5.9 \text{ inches}$$

The planimetric length of the riprap wedge should also be determined. The 2H:1V slope of the wedge corresponds to a 50% slope. Since the ditch will be at an 8.0% slope, the difference between these corresponds to a slope of 42%. The height of the upstream end of the riprap wedge will correspond to the height of the lower gabion row, which, accounting for the 3-inch embedment depth, is 35 inches or 2.92 feet. Thus, the length of the wedge will be:

$$\text{Length of wedge} = 2.92 \text{ ft} / 0.42 = 6.95 \text{ ft}$$



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Step 2 - Check the weir width for the 50-year discharge: Since the gabion check dams are to be left in place as permanent structures, the adequacy of the proposed weir width should be checked for the 50-year peak discharge. As discussed in the Planning and Design Criteria, this involves checking both the depth of flow over the weir (Eqn 17) as well as the shear stress at critical depth (Eqn 19).

$$Q = C \times L \times H^{1.5}$$

$$29.2 = 3.09 \times 17.5 \times H^{1.5}$$

$$H = \left(\frac{29.2}{3.09 \times 17.5}\right)^{2/3} = 0.66 \text{ ft}$$

Since the computed depth of flow is less than the 1-foot upper gabion height, the proposed weir passes the first check. The second check involves determining the shear stress at critical depth. To determine the shear stress, the critical depth and critical slope must first be computed.

$$d_c = \left(\frac{Q^2}{g \times L^2}\right)^{1/3} = \left(\frac{29.2^2}{32.2 \times 17.5^2}\right)^{1/3} = 0.44 \text{ ft}$$

$$S_c = \left(\frac{Q \times n \times (L + 2 \times d_c)^{2/3}}{1.486 \times (L \times d_c)^{5/3}}\right)^2 = \left(\frac{29.2 \times 0.069 \times (17.5 + 2 \times 0.44)^{2/3}}{1.486 \times (17.5 \times 0.44)^{5/3}}\right)^2 = 0.1 \text{ ft/ft}$$

Finally, the shear stress may be computed from Eqn 19:

$$\tau_c = \gamma \times d_c \times S_c = 62.4 \times 0.44 \times 0.1 = 2.75 \text{ lb/ft}^2$$

Since the computed shear is less than the allowable shear of 5.3 lb/ft², the proposed weir passes both tests for the 50-year peak discharge.

Step 3 - Determine the check dam spacing: Since the slope of the proposed swale is 8.0%, the check dam spacing may be determined directly from Table 4.3.3.1-B. Once the spacing has been determined, it is possible to determine the number of check dams required for the 170-foot length of the proposed swale. However, two aspects of this computation should be noted first. One is that the spacing provided on the table does not represent the length of the gabion basket. Thus, the total spacing used to compute the number of dams should therefore be based on the distance provided from the table (32 feet) plus the width of the lower gabion row (36 inches), or 35 feet total. The second aspect is that the most downstream check dam will be located at the end of the proposed swale. Given the lengths of the riprap wedge and lower gabion row, the upstream face of this check dam will be 9.5 feet upstream of the swale outfall. Since the remaining balance of the swale length is 160.5 feet, the number of check dams should be computed as:

$$\text{Number of dams} = 160.5 / 35 = 4.6 = 5 \text{ dams}$$

As determined above, the total length of each check dam, including the riprap wedge, will be 9.5 feet. Thus, for 5 dams, the total length of hard revetment will be 47.5 feet, which is between one-fourth and one-third of the total swale length of 170 feet. This runs somewhat counter to the initially stated goal of providing a grassed swale for



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flows to the receiving stream. Thus, using procedures described in Section 4.2.6.1, the possibility of using turf reinforcement mats to provide a permanent lining for the swale can be investigated. Although the design computations are not presented here, it is found that a Class II TRM would provide an adequate lining for the 50-year event. Further, the shear stress on the unvegetated liner for the peak 5-year discharge would be 2.98 lb/ft², so that an additional riprap lining on the bottom of the swale would not be required to provide erosion protection before the establishment of vegetation in the lining. In the final analysis, the selection of erosion prevention measures for this site should be based on economic considerations.

References

TDOT. *Drainage Manual Ch10*.