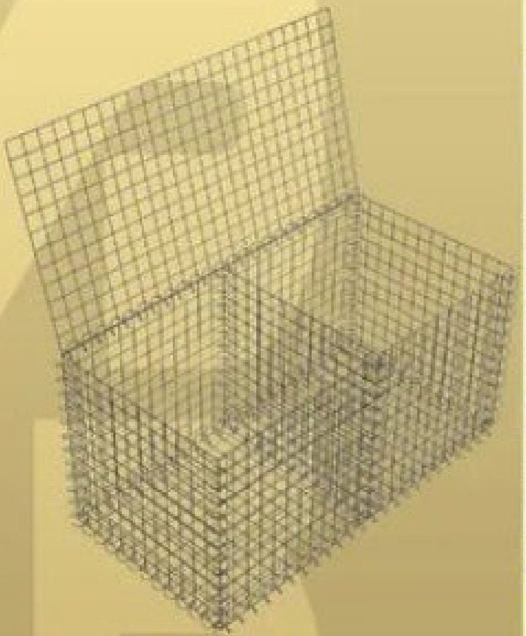
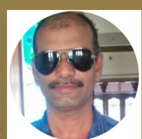
GABION WALLS DESIGN



Gabion Gravity Wall

Mechanically Stabilized Earth (MSE)
Gabion Wall
[Reinforced Soil Wall]



AP Engineers Hub

Gabion Walls Installation Guide

Foundation

Foundation Requirements, which must be established by the engineer, will vary with site conditions, height of gabion structure, etc. Generally, the top layer of soil is stripped until a layer of the required bearing soil strength is reached. In some cases, the foundation may consist of suitable fill material compacted to a minimum of 95 percent of Proctor density.

Assembly

To assemble each gabion, fold out the four sides and the ends; fold adjacent sides up and join edges with spiral binders; insert diaphragms at 3-foot centers and fasten them to the base panel with spiral binders. Place the empty gabions in the designed pattern on the foundation. When the entire first course is in position, permanently secure adjacent gabions by installing vertical spiral binders running full height at all corners. Similarly secure both edges of all diaphragms with spiral binders. Crimp ends of all spiral binders. Corner stiffeners are then installed diagonally across the corners on 1-foot centers (not used for gabions less than 3-feet high). The stiffeners must be hooked over crossing wires and crimped closed at both ends. Final gabion alignment must be checked before filling begins.

Filling

Fill material must be as specified by the engineer. It must have suitable compressive strength and durability to resist the loading, as well as the effects of water and weathering. Usually, 3 to 8-inch clean, hard stone is specified. A well graded stone-fill increases density. Place the stone in 12-inch lifts with power equipment, but distribute evenly by hand to minimize voids and ensure a pleasing appearance along the exposed faces. Keep baskets square and diaphragms straight. The fill in adjoining cells should not vary in height by more than 1-foot. Level the final stone layer allowing the diaphragms' tops to be visible. Lower lids and bind along all gabions' edges and at diaphragms' tops with spiral binders. Alternatively, tie or lacing wire can be utilized for this operation.

Successive Courses

Place the next course of assembled empty gabions on top of the filled course. Stagger the joints so that the vertical connections are offset from one another. Bind the empty baskets to the filled ones below the spirals or tie wire at all external bottom edges. Bind vertical edges together with spiral binders and continue with the same steps as for the first layer. Successive courses are placed in like manner until the structure is complete.

Gabion Walls Design Guide

Gravity Wall Design

Gabion Walls are generally analyzed as gravity retaining walls, that is, walls which use their own weight to resist the lateral earth pressures. The use of horizontal layers of welded wire mesh (Anchor Mesh) as horizontal tie-backs for soil reinforcement (MSE Walls) is discussed separately. This material is presented for the use of a qualified engineer familiar with traditional procedures for retaining wall design.

Gabion walls may be stepped on either the front or the back (soil side) face as illustrated in Figure 1. The design of both types is based on the same principles.

Design begins with the selection of trail dimensions for a typical vertical cross section through the wall. Four main steps must then be followed:

1. Determine the forces acting on the wall.
2. Check that resisting moment exceeds the overturning moment by a suitable safety factor.
3. Check that sliding resistance exceeds the active horizontal force by a suitable safety factor.
4. Check that the resultant force falls within the middle third of the wall's base, and that the maximum bearing pressure is within the allowable limit.

These steps are repeated iteratively until a suitable design that meets all criteria is achieved. The wall stability must be checked at the base and at each course. Pertinent equations are given below, and an application is illustrated in Example 1.

Mechanically Stabilized Earth (MSE) Walls Soil Reinforcement

When required, flat layers of welded wire mesh (Anchor Mesh) are specified as soil reinforcement to secure the gabion wall into the backfill. In such cases, the Anchor Mesh must be joined securely to the gabion wall facing with spirals or tie wire at the specified elevations as layers of backfill are placed and compacted.

Forces Acting on the Wall

As shown in Figure 1, the main forces acting on gabion walls are the vertical forces from the weight of the gabions and the lateral earth pressure acting on the back face. These forces are used herein to illustrate the main design principles. If other forces are encountered, such as vehicular loads or seismic loads, they must also be included in the analysis.

The weight of a unit length (one foot) of wall is simply the product of the wall cross section and the density of the gabion fill. The latter value may be conservatively taken as 100 lb/ft^3 for typical material (W_g).

The lateral earth pressure is usually calculated by the Coulomb equation. Although based on granular material, it is conservative for cohesive material. According to Coulomb theory, the total active force of the triangular pressure distribution acting on the wall is:

$$P_a = K_a w_s H^2 / 2$$

Equation 1

Where w_s is the soil density, H is the wall height, and K_a is the coefficient of active soil pressure. The soil density is often taken as 120 lb/ft^3 where a specific value is not available.

If a uniformly distributed surcharge pressure (q) is present on top of the backfill surface, it may be treated as an equivalent layer of soil that creates a uniform pressure over the entire height of the wall. Equation 1 is modified to:

$$P_a = K_a(w_s H^2 / 2 + qH)$$

Equation 1A

The pressure coefficient is K_a is given by:

$$K_a = \frac{\cos^2(\boldsymbol{f} - \boldsymbol{b})}{\cos^2 \boldsymbol{b} \cos(\boldsymbol{d} + \boldsymbol{b}) \left[1 + \sqrt{\frac{\sin(\boldsymbol{f} + \boldsymbol{d})\sin(\boldsymbol{f} - \boldsymbol{a})}{\cos(\boldsymbol{d} + \boldsymbol{b})\cos(\boldsymbol{a} - \boldsymbol{b})}}\right]^2}$$

Equation 2

Where:

- ***a*** = slope angle of backfill surface
- ***b*** = acute angle of back face slope with vertical (-value where as in Fig 1A; + value when as in Fig 1B)
- ***d*** = angle of wall friction
- ***f*** = angle of internal friction of soil

P_a is inclined to a line normal to the slope of the back face by the angle ***d***. However, because the effect of wall friction is small, ***d*** is usually taken as zero. Typical values of ***f*** for various soils are given in Table I. Values of K_a for various combinations of ß, ***d***, and ***a*** are given in Table II.

The horizontal component of P_a is:

$$P_h = P_a \cos \boldsymbol{b}$$

Equation 3

The vertical component of P_a is usually neglected in design because it reduces the overturning moment and increases the sliding resistance.

Overturning Moment Check

The active soil pressure forces tend to overturn the wall, and this must be properly balanced by the resisting moment developed from the weight of the wall and other forces. Using basic principles of statics, moments are taken about the toe of the wall to check overturning.

This check may be expressed as

$$M_r \geq SF_o M_o$$

Equation 4

Where M_r is the resisting moment, M_o is the overturning moment, and SF_o is the safety factor against overturning (typically 2.0). Each moment is obtained by summing the products of each appropriate force times its perpendicular distance the toe of the wall.

Neglecting wall friction, the active earth force acts normal to the slope of the back face at a distance H/3 above the base. When a surcharge is present, the distance of the total active force above the toe becomes

$$d_a = \frac{H(H + 3q / w_s)}{3(H + 2q / w_s)} + B \sin \boldsymbol{b}$$

Equation 5

The overturning moment is

$$M_o = d_a P_h$$

Equation 6

The weight of the gabion wall (W_g) acts vertically through the centroid of its cross section area. The horizontal distance to this point from the toe of the wall (d_g) may be obtained from the statical moment of wall areas. That is, moments of areas about the toe are taken, then divided by the total area, as shown in Example 1.

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Equation 2

Where:

a	=	slope angle of backfill surface
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The resisting moment is the sum of the products of vertical forces or weights per unit length (W) and their distance (d) from the toe of the wall:

$$M_r = \sum dW$$

Equation 7

For the simple gravity wall, the resisting moment is provided entirely by the weight of the wall and

$$M_r = d_g W_g$$

Equation 7A

Sliding Resistance Check

The tendency of the active earth pressure to cause the wall to slide horizontally must be opposed by the frictional resistance at the base of the wall. This may be expressed as

$$mW_v \geq SF_s P_h$$

Equation 8

Where m is the coefficient of the sliding friction (tan of angle of friction of soil), W_v is the sum of the vertical forces (W_g in this case), and SF_s is the safety factor against sliding (typically 1.5).

Check Bearing Pressure

First check to determine if the resultant vertical force lies within the middle third of the base. If B denotes the width of the base, the eccentricity, e, of the vertical force from the midwidth of the base is

$$e = B/2 - (M_r - M_o)/W_v$$

Equation 9

For the resultant force to lie in the middle third:

$$-B/6 \leq e \leq B/6$$

Equation 10

The maximum pressure under the base, P, is then

$$P = (W_v/B)(1 + 6e/B)$$

Equation 11

The maximum pressure must not exceed the allowable soil bearing pressure, P_b:

$$P \leq P_b$$

Equation 12

The safety factor must be included in P_b.

Example 1:

Given Data (Refer to Cross Section, page 5)

Wall Height..............................	H	=	9 ft
Surcharge.................................	q	=	300 psf
Backfill slope angle..................	*a*	=	0 deg
Back Face slope angle................	*b*	=	-6 deg
Soil friction angle......................	*f*	=	35 deg
Soil density..............................	w_s	=	120 pcf
Gabion fill density......................	w_g	=	100 pcf
Soil bearing pressure..................	P_b	=	4000 psf

Determine if safety factors are within limits:

Pressure coefficient from Equation 2 is K_a=0.23

Active earth force, P_a, from Equation 1A is

$$P_a = 0.23(120 x 9^2 + 300 x 9)$$
$$= 1{,}739\ lb/ft$$

Horizontal component from Equation 3 is

$$P_h = 1739 \cos 6$$
$$= 1{,}730\ lb/ft$$

Vertical distance to P_h from Equation 5 is

$$d_a = \frac{9(9 + 3 \times 300/120)}{3(9 + 2 \times 300/120)} + 6\sin(-6)$$
$$= 2.91\ ft$$

Overturning moment from Equation 6 is

$$M_o = 2.91 \times 1730$$
$$= 5034\ ft-lb/ft$$

Weight of gabions for a 1-ft unit length is

$$W_g = (18 + 13.5 + 9)100$$
$$= 40.5 \times 100$$
$$= 4050\ lb/ft$$

Horizontal distance to W_g is

$$dg = \Sigma Ax / \Sigma A$$
$$= \frac{18(3\cos 6 + 1.5\sin 6) + 13.5(3.75\cos 6 + 4.5\sin 6) + 9(4.5\cos 6 + 7.5\sin 6)}{} / 40.5$$
$$= 3.96\ ft$$

Resisting moment from Equation 7 is

$$M_r = 3.96x4050$$
$$= 16{,}038\ ft - lb / ft$$

Safety factor against overturning from Equation 4 is

$$SF_O = M_r / M_O$$
$$= 16.038 / 5034$$
$$= 3.19 > 2.00$$

OK

Safety factor against sliding from Equation 8 is

$$SF_s = mW_g / P_h$$
$$= \tan 35x4050 / 1730$$
$$= 1.64 > 1.50$$

OK

Reaction eccentricity from Equation 9 is

$$e = 6/2 - (16038 - 5034)/4050$$
$$= 0.283\ ft$$

Limit of eccentricity from Equation 10 is

$$-1 \le e \le 1\ ft$$

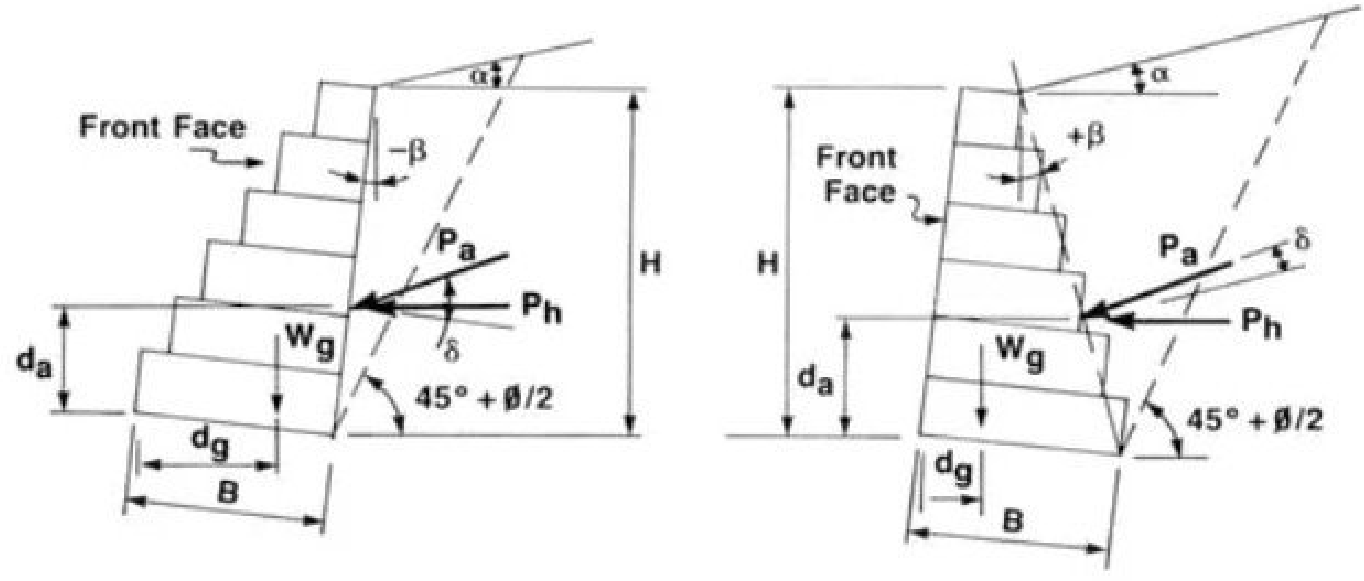
OK

Maximum base pressure from Equation 11 is

$$p = (4050/6)(1 + 6x.283/6)$$
$$= 866\ psf < 4000\ psf$$

OK

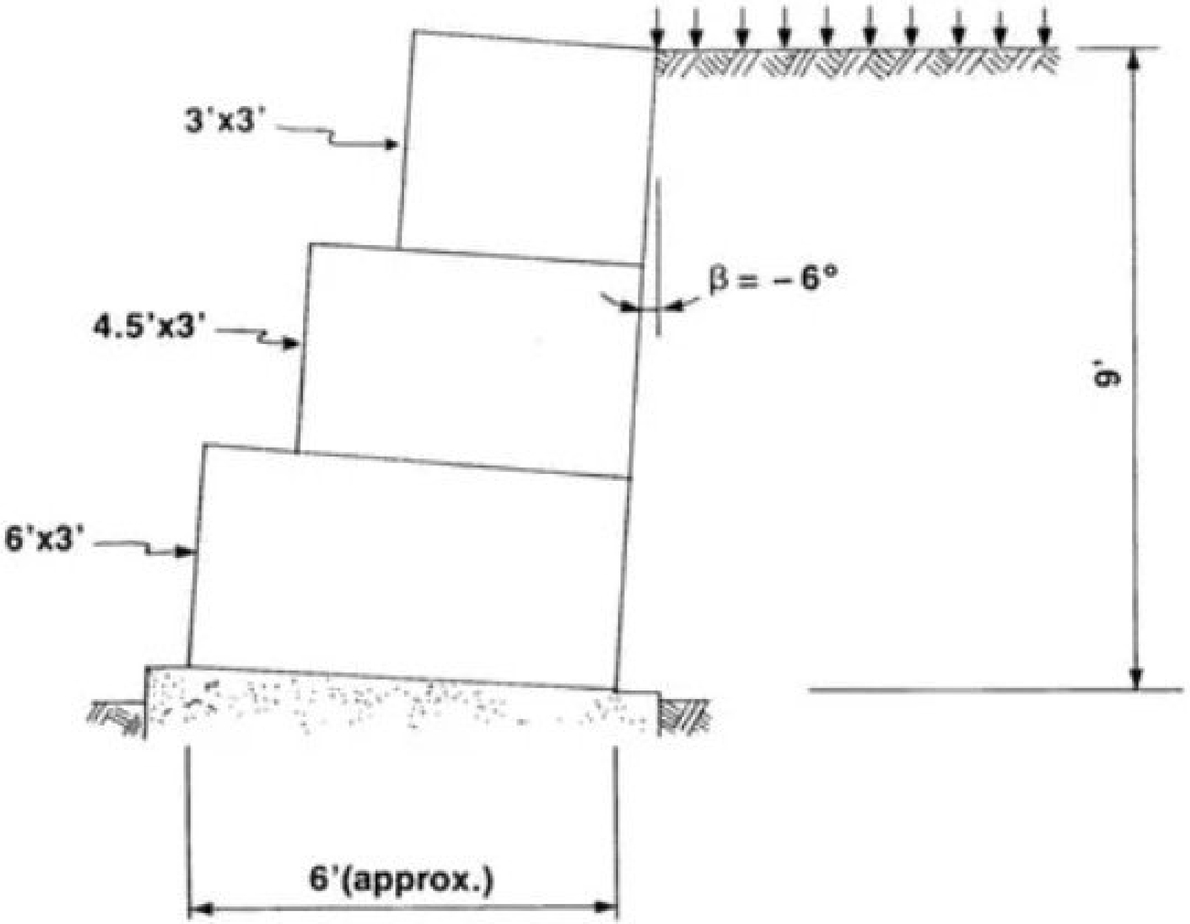
All safety factors are within limits. Stability checks at intermediate levels in the walls show similar results.



A. Stepped Front Face B. Stepped Back Face

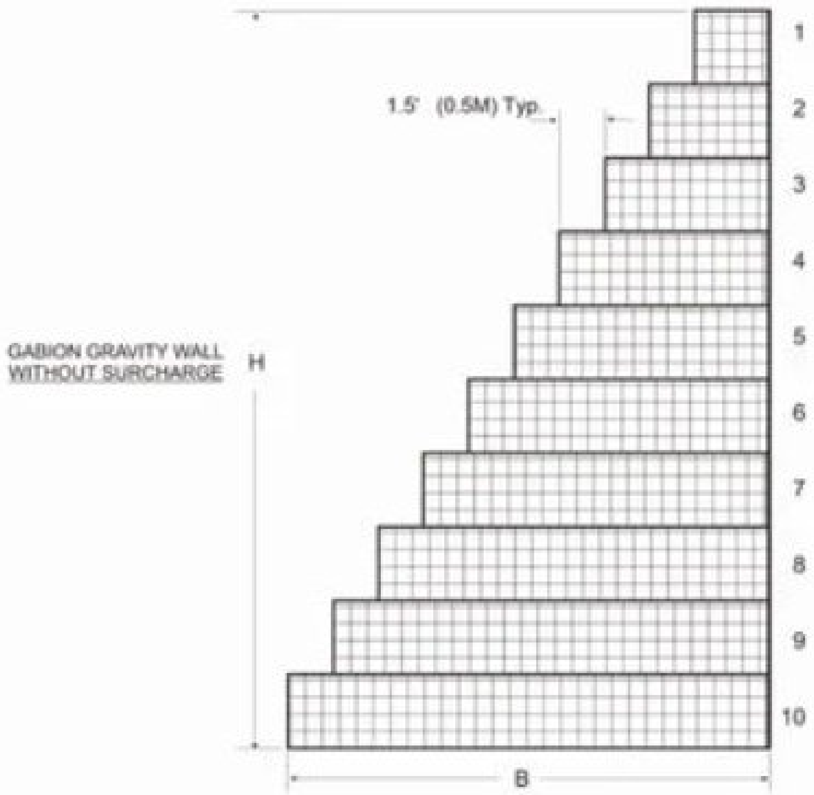
Gravity Wall Design

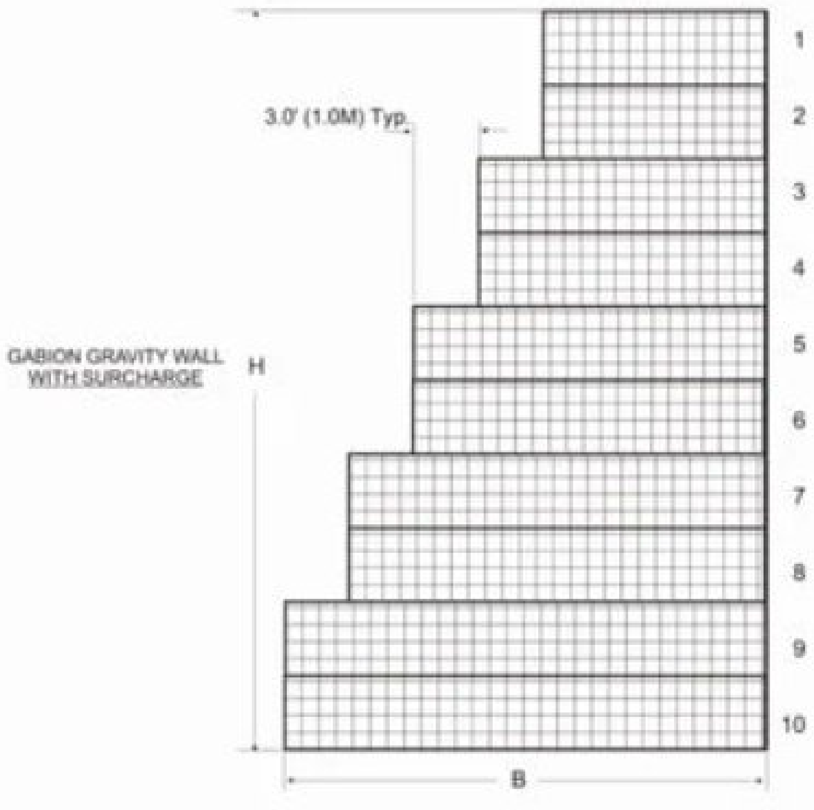
Figure 1



Cross Section for Example 1

GABION GRAVITY WALLS QUICK CROSS SECTION DESIGN GUIDE





NO. OF COURSES	ENGLISH FEET		METRIC METERS	
	H	B	H	B
1	3.0	3.0	1.0	1.0
2	6.0	4.5	2.0	1.5
3	9.0	6.0	3.0	2.0
4	12.0	7.5	4.0	2.5
5	15.0	9.0	5.0	3.0
6	18.0	10.5	6.0	3.5
7	21.0	12.0	7.0	4.0
8	24.0	13.5	8.0	4.5
9	27.0	15.0	9.0	5.0
10	30.0	16.5	10.0	5.5
	H	B	H	B
1	3.0	6.0	1.0	2.0
2	6.0	6.0	2.0	2.0
3	9.0	9.0	3.0	3.0
4	12.0	9.0	4.0	3.0
5	15.0	12.0	5.0	4.0
6	18.0	12.0	6.0	4.0
7	21.0	15.0	7.0	5.0
8	24.0	15.0	8.0	5.0
9	27.0	18.0	9.0	6.0
10	30.0	18.0	10.0	6.0

To increase the efficiency of MSE gabion walls, layers of wire mesh (Anchor Mesh) may be attached to the back face and embedded in the backfill. The Anchor Mesh layers in this reinforced soil wall will resist the active soil force, by a combination of friction on the wire surface and mechanical interlock with the soil. Reinforced soil walls generally use a single thickness of gabions. Design consists of (1) walls stability checks similar to that for gravity walls, assuming the gabions and the reinforced soil act together as one unit, and (2) checks for strength and pullout resistance of the reinforcement layers, to ensure such action. The considerations that differ from gravity wall design are discussed below.

Walls will typically be 6 degrees from vertical. To simplify calculations, assume wall is vertical for certain calculations as indicated in Example 2.

In checking overturning, sliding and bearing, the weight of the soil in the reinforced zone is included with the weight of the wall.

The tensile force in each layer of reinforcement is assumed to resist the active earth force over an incremental height of wall. Its calculated value must be limited to the tensile strength of the mesh divided by the safety factor (typically 1.85). Therefore: 3000/1.85=1620 lb/ft.

As in gravity wall design, the wall is designed to resist the force generated by a sliding wedge of soil as defined by Coulomb. The reinforcement at each layer must ext end past the wedge by at least 3-feet, and by a distance sufficient to provide anchorage in the adjacent soil. Generally, this results in a B distance 0.5 to 0.7 times the height of the wall.

Additional equations used in the design of MSE walls, derived from statics are given in Example 2.

Example 2:

Given Data (See Cross Section, page 10)

Wall Height...............	H =	24 ft (21 ft+3 ft embedment)
Wall Thickness............	T =	3 ft
Surcharge..................	Q =	300 psf
Backfill slope angle......	a =	0 deg
Back Face slope angle...	b =	-6 deg
Soil friction angle.........	f =	35 deg
Soil density...............	Ws =	120 pcf
Gabion fill density......	Wg =	100 pcf
Soil bearing pressure...	Pb =	4000 psf

(1) Determine if safety factors are within limits:

The trial value for dimension B was selected as 16.5 approximately 0.7H. Also see note near the end of part 2 below on trial selection of B to provide adequate embedment length. In these calculations, positive values are used for the sin and tan of b and the sign in the equation changed as necessary.

Pressure coefficient from Equation 2 is K_a=0.23

Active earth force, P_a, from Equation 1A is

$$P_a = 0.23(120 \times 24^2 / 2 + 300 \times 24)$$
$$= 9605\, lb/ft$$

Vertical distance to P_a from Equation 5 is

$$d_a = \frac{24(24 + 3 \times 300 / 120)}{3(24 + 2 \times 300 / 120)}$$
$$= 9.22\, ft$$

Overturning moment from Equation 6 is

$$M_o = 9.22 \times 9605$$
$$= 88{,}600\, ft - lb/ft$$

Weight of gabions is

$$W_g = (3 \times 24 \times 100$$
$$= 7200\, lb/ft$$

Horizontal distance to Wg is

$$d_g = t/2 + (H/2)\tan \mathbf{b}$$
$$= 3/2 + (24/2)\tan 6$$
$$= 2.76\, ft$$

Weight of surcharge is

$$W_g = qb$$
$$= q(B - t - H \tan \mathbf{b})$$
$$= 300(1.65 - 3 - 24 \tan 6)$$
$$= 300(10.98)$$
$$= 3290\, lb/ft$$

Horizontal distance to W_q is

$$d_q = b/2 + H \tan \mathbf{b} + t$$
$$= 10.98/2 + 24 \tan 6 + 3$$
$$= 11.01\, ft$$

Weight of soil wedge is

$$W_s = (H \tan \mathbf{b}/2 + b)Hw_s$$
$$= (24 \tan 6/2 + 10.98)24x120$$
$$= 35{,}250\, lb/ft$$

Horizontal distance to W_S is

$$d_s = \frac{(H^2 \tan \mathbf{b})(H \tan \mathbf{b}/3 + t) + (Hb)}{(b/2 + H \tan \mathbf{b} + t)} \; w_s / W_s$$

$$= \frac{(24^2 \tan 6)(24 \tan 6/3 + 3) + (24x10.98)}{(10.98/2 + 24 \tan 6 + 3)} \; \frac{120}{35250}$$

$$= 10.67 \; ft$$

Resisting moment from Equation 7 is

$$M_r = W_s d_s + W_g d_g + W_q d_q$$
$$= 35{,}250 \times 10.67 + 7200 \times 2.76 + 3290 \times 11.01$$
$$= 432{,}200 \; ft - lb / ft$$

Safety factor against overturning from Equation 4 is

$$SF_O = M_r / M_O$$
$$= 432{,}200 / 88{,}600$$
$$= 4.88 > 2.00$$

OK

Total vertical weight is

$$W_V = W_s + W_g + W_q$$
$$= 35{,}250 + 7200 + 3290$$
$$= 45{,}740 \, lb / ft$$

Safety factor against sliding from Equation 8 is

$$SF_s = \mathbf{m} W_V / P_h$$
$$= \tan 35 \times 45{,}740 / 9605$$
$$= 3.33 > 1.50$$

OK

Reaction eccentricity from Equation 9 is

$$e = 16.5/2 - (432{,}200 - 88{,}600)45{,}740$$
$$= 0.738 \; ft$$

Limit of eccentricity from Equation 10 is

$$-2.75 \le e \le 2.75 \; ft$$

OK

Maximum base pressure from Equation 11 is

$$p = (45{,}740/16.5)(1 + 6 \times 0.738/16.5)$$
$$= 3520 \; psf < 4000 \; psf$$

OK

All safety factors are within limits. Stability checks at intermediate levels in the walls show similar results.

(2) Determine if reinforcement mesh is satisfactory

The pressure on any layer a distance z (ft) below the surface is

$$f_V = w_s z + q$$
$$= 120z + 300 \; psf$$

The tensile strength on any layer of reinforcement in a vertical segment of soil of thickness S_V (ft), centered about the reinforcement layer, is

$$T = S_V K_a f_V$$
$$= 0.23 S_V f_V$$

Calculate T for each layer as follows

z (ft)	S_V (ft)	F_V (psf)	T (lb/ft)	T<1620 lb/ft?
3	4.5	660	683	Y
6	3.0	1020	704	Y
9	3.0	1380	952	Y
12	3.0	1740	1200	Y
15	3.0	2100	1449	Y
18	3.0	2460	1697	N
21	3.0	2820	1946	N
24	1.5	3180	1097	Y

The tensile force at 18 and 21 ft exceeded the limit. Therefore, insert an intermediate layer at 19.5 and 22.5 ft.

Recalculate the following revised table:

z (ft)	S_V (ft)	F_V (psf)	T (lb/ft)	T<1620 lb/ft?
3	4.5	660	683	Y
6	3.0	1020	704	Y
9	3.0	1380	952	Y
12	3.0	1740	1200	Y
15	3.0	2100	1449	Y
18	2.25	2460	1273	Y
19.5	1.5	2640	911	Y
21	1.5	2820	973	Y
22.5	1.5	3000	1035	Y
24	0.75	3180	549	Y

The tensile force is now within allowable limits at all layers.

The minimum embedment length past the wedge to provide a safety factor of 1.5 against pullout in any layer is

$$L_{em} = 1.5T/(2\Gamma f_v \tan \mathbf{f})$$

Where Γ is a "scale correction factor" assumed as 0.65.

$$L_{em} = 1.5T/(2x0.65\, f_v \tan 35)$$
$$= 1.65T/f_v$$

At the top of the wall, the distance, X, to the wedge failure plane from the back of the wall is

$$X = H \tan(45 - \mathbf{f}/2) - H \tan \mathbf{b}$$
$$= 24 \tan(27.5) - 24 \tan(6)$$
$$= 11.54\, ft$$

At any layer, the length of embedment past the wedge is

$$L_e = B - t - X(H - z)/H$$
$$= 16.5 - 3 - 11.54(24 - z)/24$$
$$= 1.956 + 0.481z$$

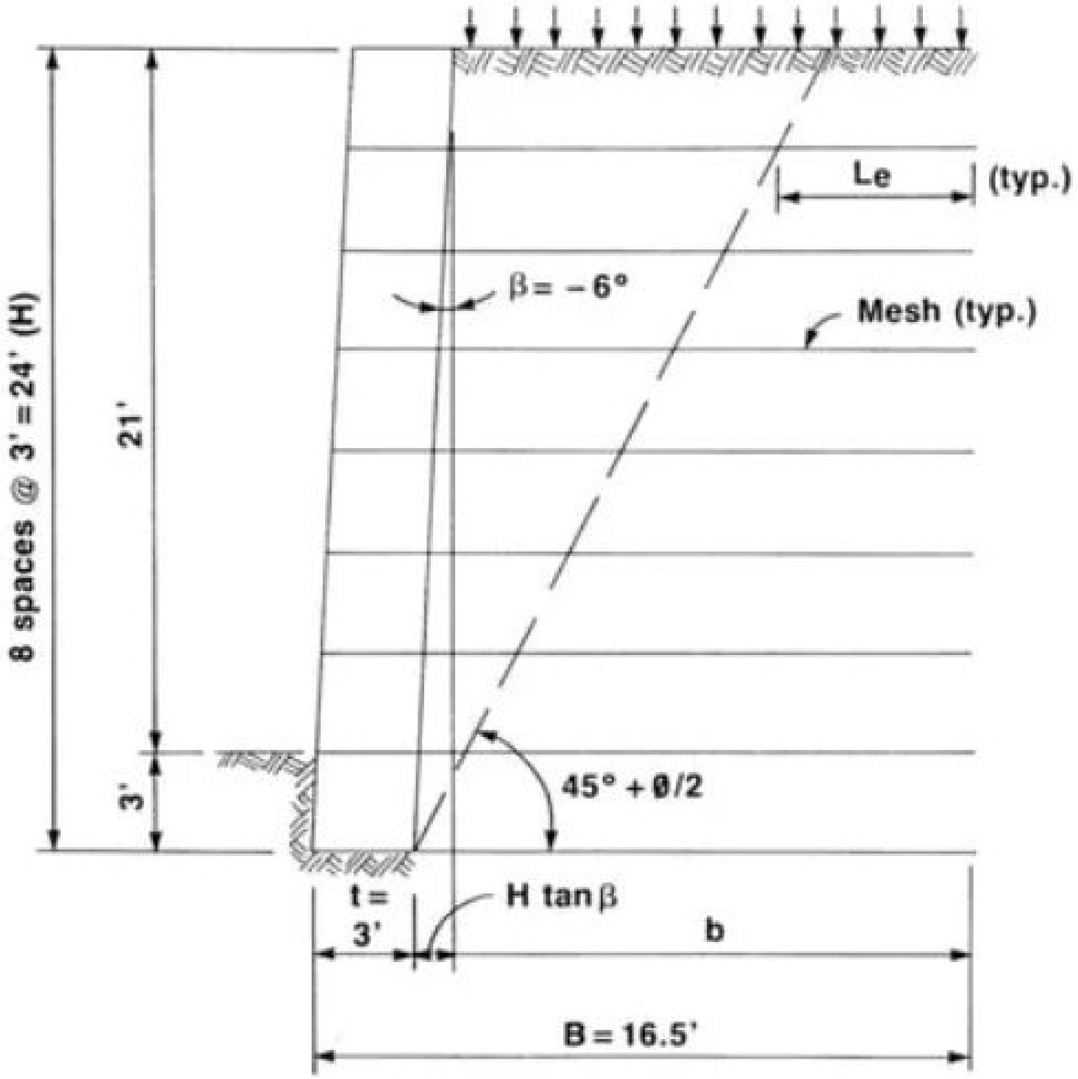
[Note: L_e can be calculated for the top layer of reinforcement initially, when selecting B, to make sure it is at least 3-feet. If not, increase B for the trial design.]

Calculate L_e and L_{em} for each layer as follows:

z (ft)	F_v (psf)	T (lb/ft)	L_e (ft)	L_{em} (ft)	L_e>L_{em}?
3	660	683	3.40	1.71	Y
6	1020	704	4.84	1.14	Y
9	1380	952	6.29	1.14	Y
12	1740	1200	7.73	1.14	Y
15	2100	1449	9.17	1.14	Y
18	2460	1273	10.62	0.85	Y
19.5	2640	911	11.34	0.59	Y
21	2820	973	12.06	0.59	Y
22.5	3000	1035	12.78	0.59	Y
24	3180	549	13.50	0.28	Y

The embedded length of reinforcement in each layer is greater than the minimum required for pullout and is also at least 3-feet. Reinforcement design is satisfactory with mesh added at the 19.5 and 22.5-foot levels.

General Note: Every effort has been made to ensure the accuracy and reliability of the information presented herein. Nevertheless, the user of this brochure is responsible for checking and verifying the data by independent means. Application of the information must be based on responsible professional judgment. No express warranties of merchantability or fitness are created or intended by this document. Specification data referring to mechanical and physical properties and chemical analyses related solely to test performed at the time of manufacture in specimens obtained from specific locations of the product in accordance with prescribed sampling procedures.



Cross Section for Example 2

Table I

Angles of Internal Friction and Unit Weights of Soil*

Soil Type	Soil Condition	Angle of Internal Friction f(deg)	Soil Density, w (lb/ft^3)
Course sand, sand & gravel	Compact soil	40	140
	Loose	35	90
Medium sand	Compact soil	40	130
	Loose	30	90
Fine silty sand, sandy silt	Compact soil	30	130
	Loose	25	85
Uniform silt	Compact soil	30	135
	Loose	25	85
Clay-silt	Soft/medium	20	90/120
Silty clay	Soft/medium	15	90/120
Clay	Soft/medium	0/10	90/120

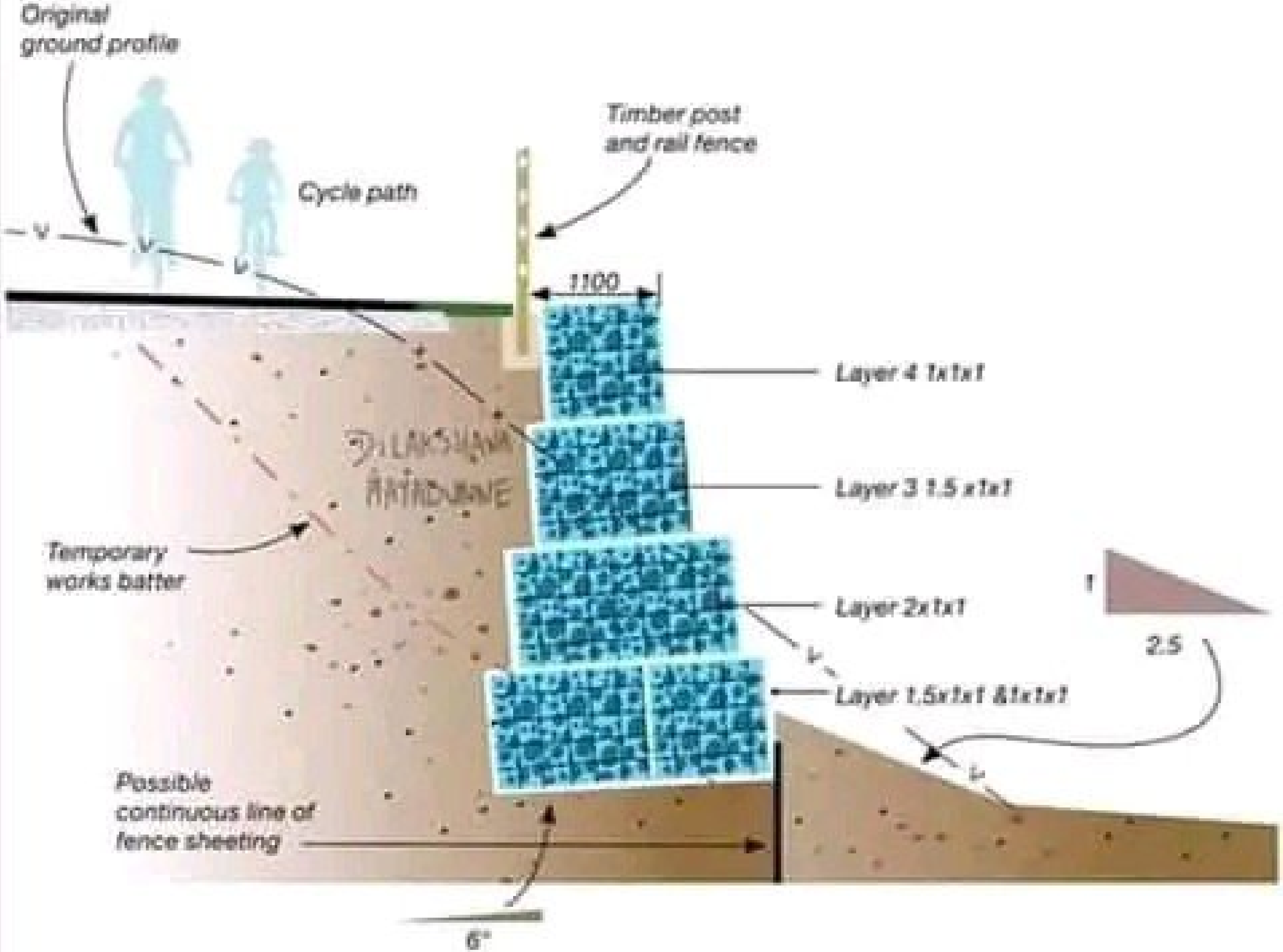
*F.S. Merritt, Ed., "Standard Handbook for Civil Engineers" McGraw-Hill, 1983

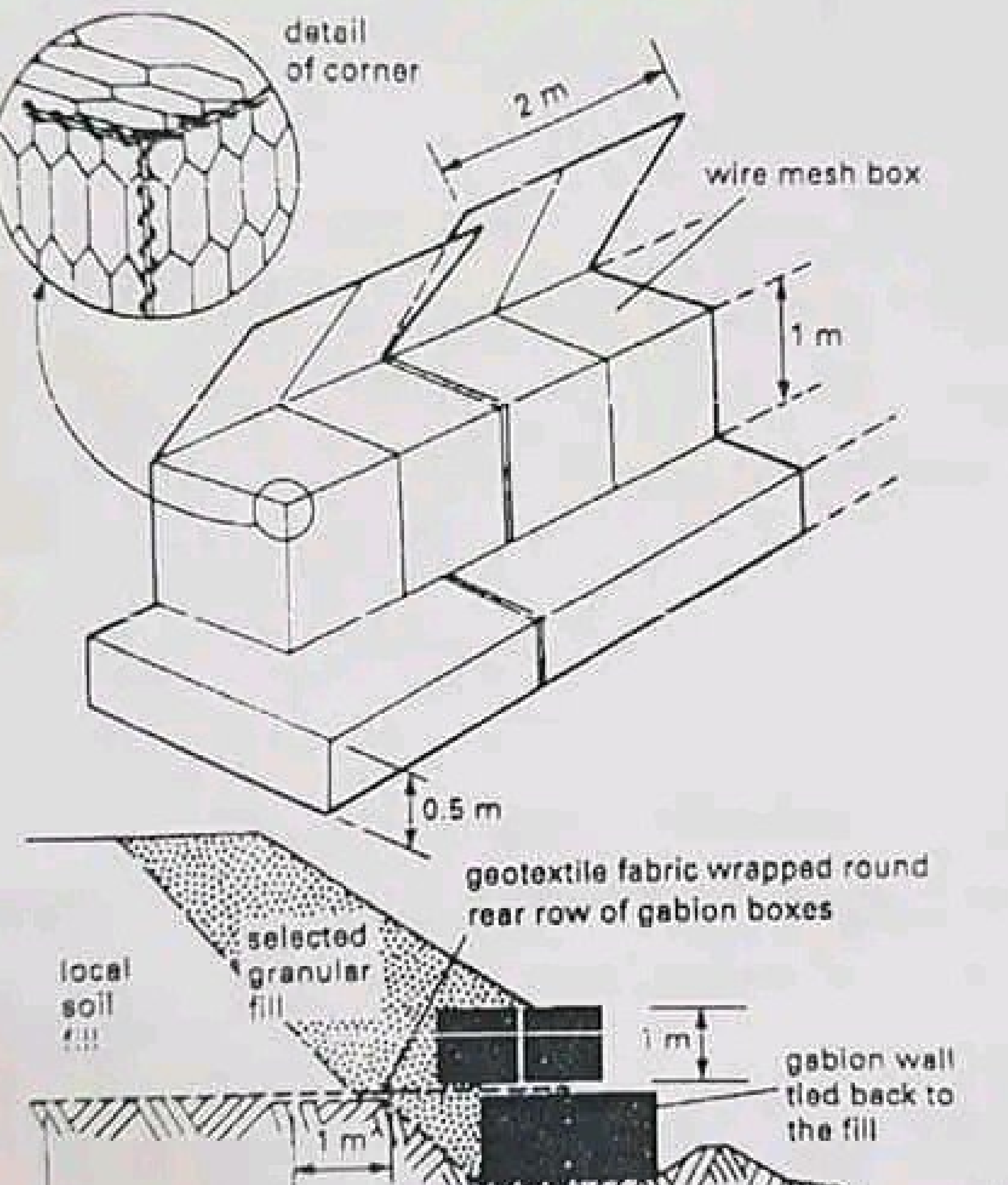
Table II

Active Pressure Coefficient, K_a

b	*a*	*f* = 10	*f* = 15	*f* = 20	*f* = 25	*f* = 30	*f* = 35	*f* = 40
-6	0	0.68	0.56	0.45	0.37	0.29	0.23	0.18
-6	5	0.74	0.6	0.49	0.39	0.31	0.24	0.19
-6	10	0.94	0.67	0.53	0.42	0.33	0.26	0.2
-6	15		0.89	0.59	0.46	0.35	0.27	0.21
-6	20			0.82	0.52	0.39	0.29	0.22
-6	25				0.75	0.44	0.32	0.24
-6	30					0.67	0.37	0.26
-6	35						0.58	0.3
-6	40							0.49
0	0	0.7	0.59	0.49	0.41	0.33	0.27	0.22
0	5	0.77	0.63	0.52	0.43	0.35	0.28	0.23
0	10	0.97	0.7	0.57	0.46	0.37	0.3	0.24
0	15		0.93	0.64	0.5	0.4	0.32	0.25
0	20			0.88	0.57	0.44	0.34	0.27
0	25				0.82	0.5	0.38	0.29
0	30					0.75	0.44	0.32
0	35						0.67	0.37
0	40							0.59
5	0	0.73	0.62	0.52	0.44	0.37	0.31	0.25
5	5	0.8	0.67	0.56	0.47	0.39	0.32	0.26
5	10	1	0.74	0.61	0.5	0.41	0.34	0.28
5	15		0.98	0.68	0.55	0.45	0.36	0.29
5	20			0.94	0.62	0.49	0.39	0.31
5	25				0.89	0.56	0.43	0.34
5	30					0.83	0.5	0.37
5	35						0.76	0.43
5	40							0.68
10	0	0.76	0.65	0.56	0.48	0.41	0.34	0.29
10	5	0.83	0.7	0.6	0.51	0.43	0.36	0.3
10	10	1.05	0.78	0.65	0.55	0.46	0.38	0.32
10	15		1.04	0.74	0.6	0.5	0.41	0.34
10	20			1.02	0.68	0.55	0.44	0.36
10	25				0.98	0.63	0.49	0.39
10	30					0.92	0.57	0.43
10	35						0.86	0.5
10	40							0.79
15	0	0.79	0.69	0.6	0.52	0.45	0.39	0.33
15	5	0.87	0.75	0.65	0.56	0.48	0.41	0.35
15	10	1.1	0.83	0.71	0.6	0.51	0.43	0.37
15	15		1.11	0.8	0.66	0.55	0.47	0.39
15	20			1.1	0.75	0.61	0.51	0.42
15	25				1.08	0.7	0.56	0.45
15	30					1.04	0.65	0.5
15	35						0.98	0.58
15	40							0.91

Gabion wall construction





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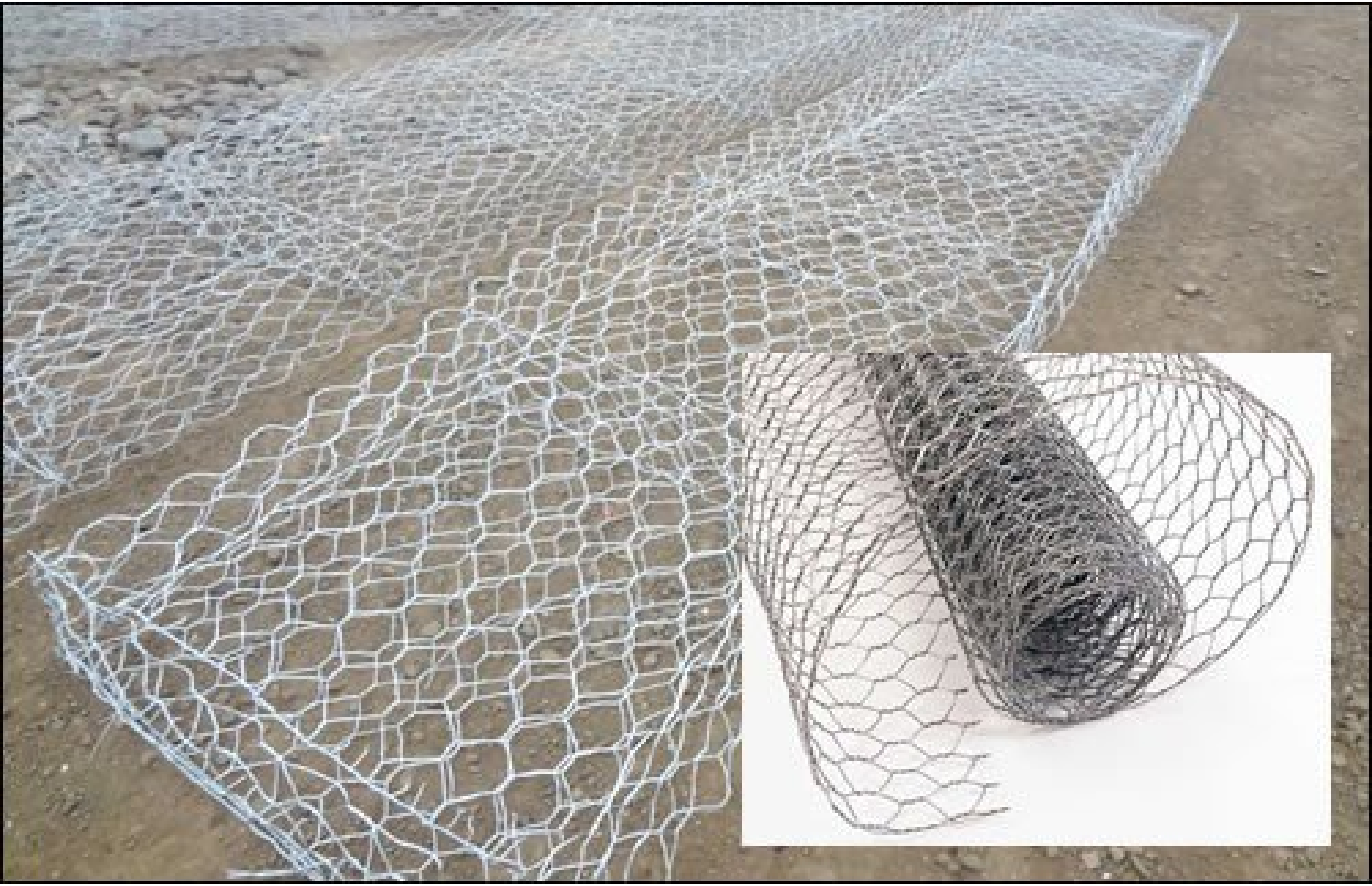
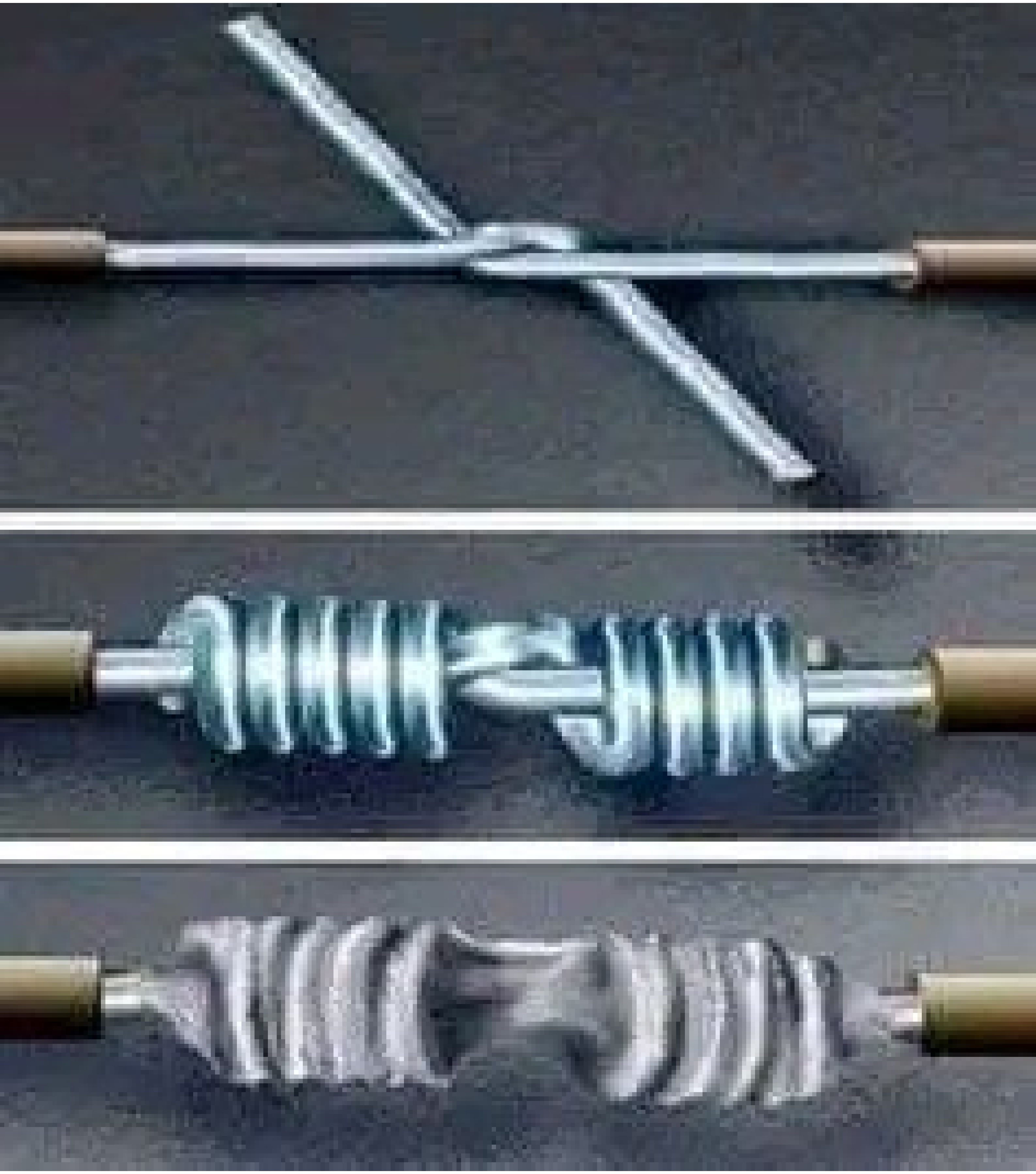
GABION MESHES

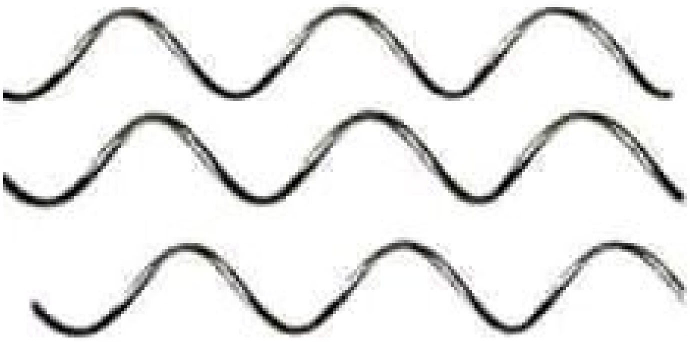
- This type of soil strengthening, often also used without an outside wall, consists of wire mesh "boxes, which are filled with roughly cut stone or other material.
- The mesh cages reduce some internal movement and forces, and also reduce erosive forces.
- Gabion walls are free-draining retaining structures and as such are often built in locations where ground water is present.









Spiral wire

Spiral wire connection

U clip

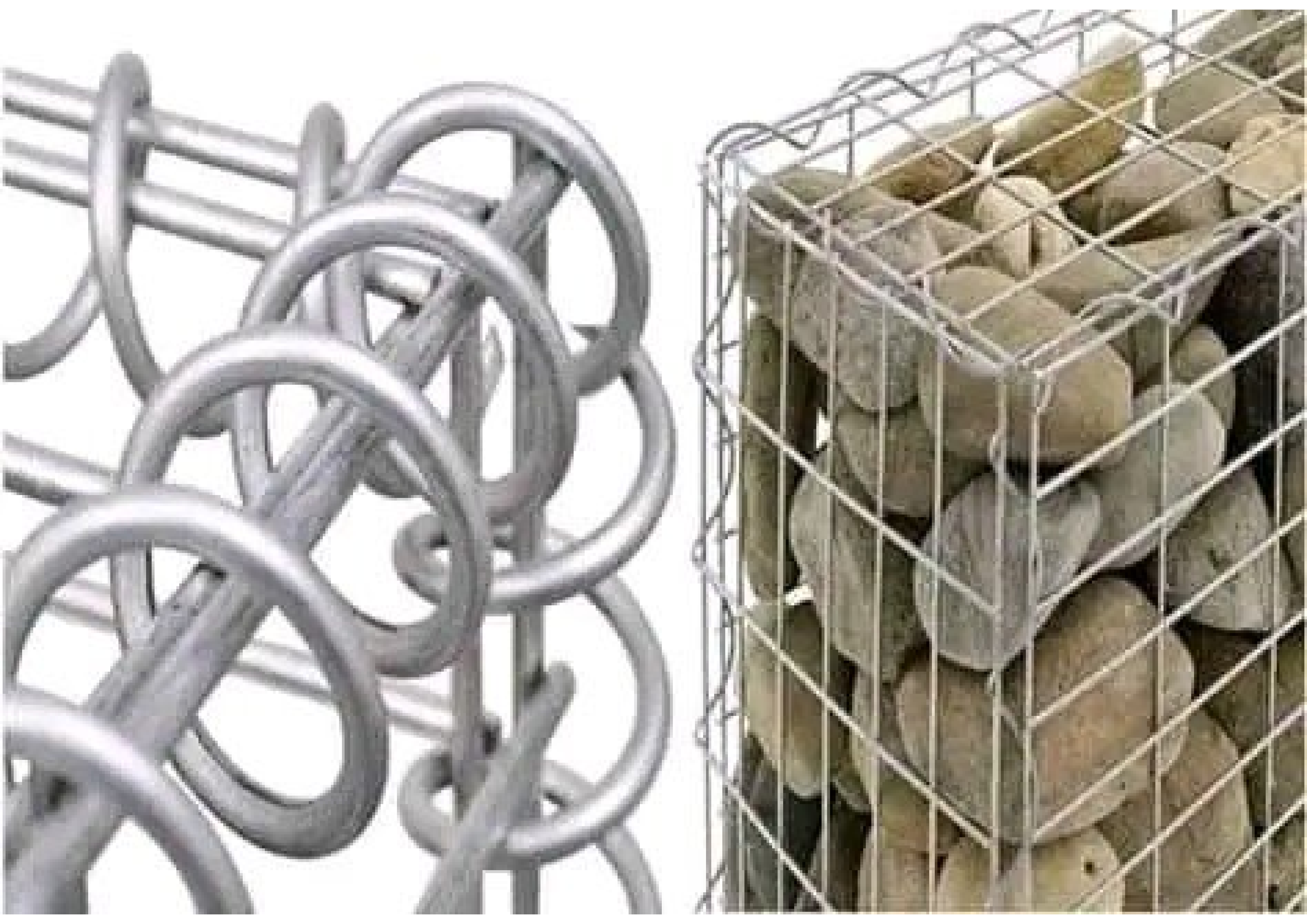
U clip connection

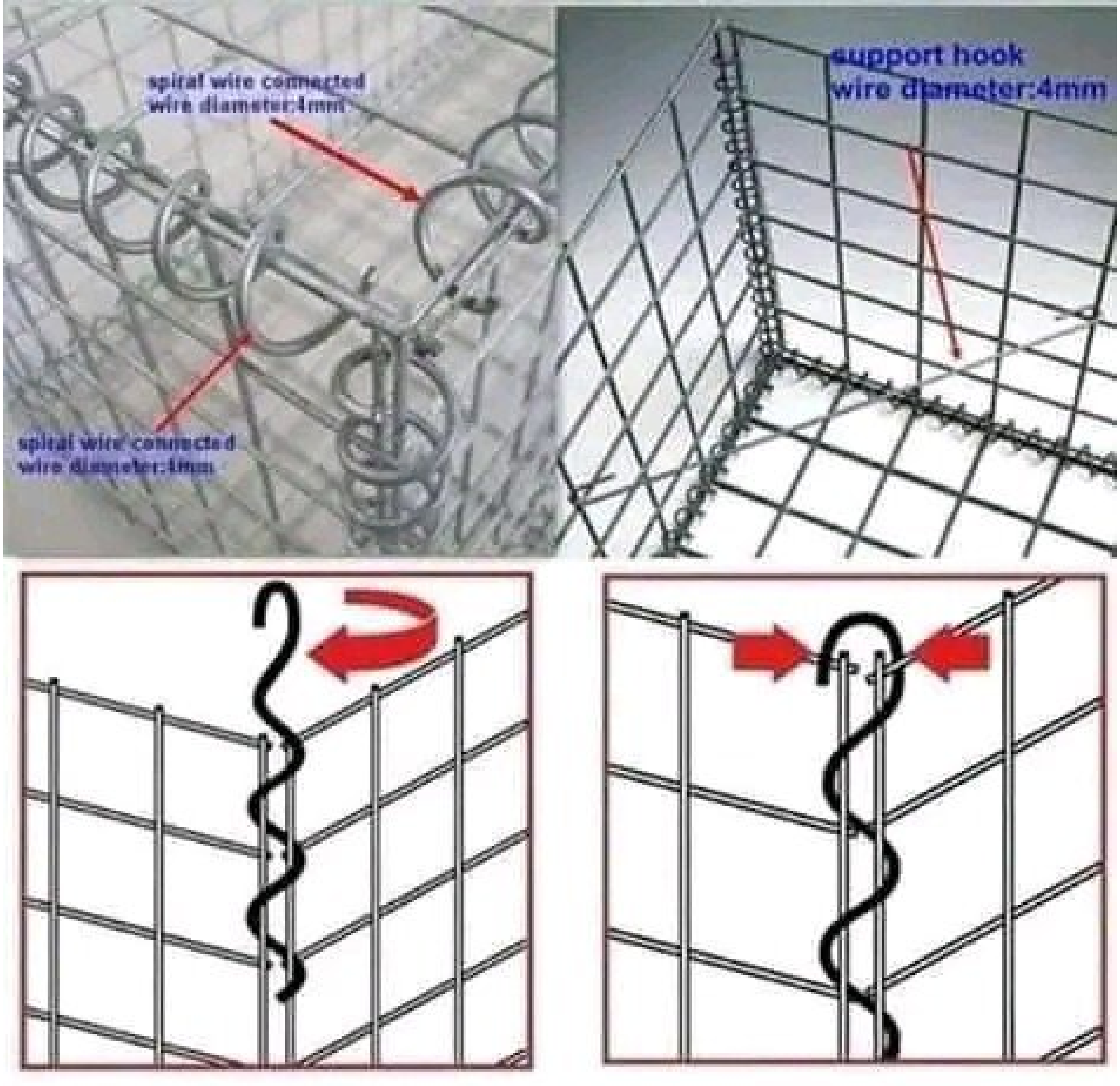
C ring

C ring connection

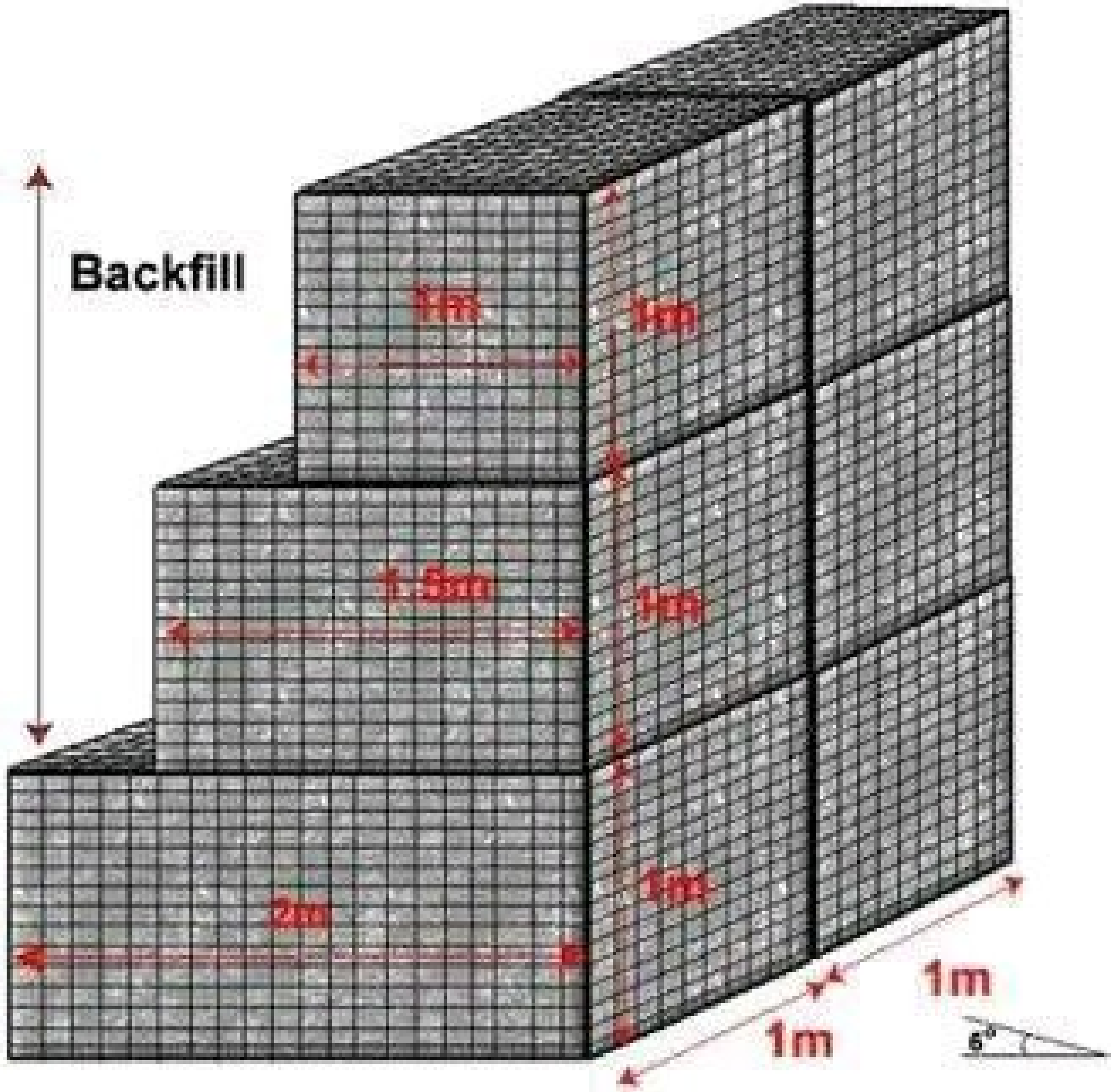
Lacing wire connection

Hook connection




spiral wire connected
wire diameter:4mm
spiral wire connected
wire diameter:4mm
support hook
wire diameter:4mm


NoaGarden
Design


Backfill
1.5m
2m
1m
1m


Gabion1

Techno-Economical Analysis of Gabion Retaining Wall Against Conventional Retaining Walls


Dr-Ganesh C. Chikute
AISSMS-All India Shri Shivaji Memorial Society


Ishwar Sonar
College of Engineering, Pune

Techno-Economical Analysis of Gabion Retaining Wall Against Conventional Retaining Walls

Ganesh C. Chikute[1], Ishwar P. Sonar[2]

[1]Ph.D. Student, Department of Civil Engineering, Government College of Engineering Pune COEP, India,
[2]Assistant professor, Department of Civil Engineering, Government College of Engineering Pune COEP, India,

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Abstract - *For a particular local condition selection of inappropriate conventional methods used in the construction of retaining wall proves not only time consuming but also costlier due to the transportation of required materials and its associated cost. Selecting most technically appropriate, safe and cost-effective system out of the various available types including rubble masonry gravity wall, RCC cantilever wall, RCC counterfort wall and gabion retaining wall is a rigorous task. Present work addresses a comparative techno-economical analysis of various conventional retaining walls with the Gabion wall. While performing the design procedure the input data including height, backfill, foundation strata and loading conditions are kept constant for all the four type of retaining walls. From the design output in the form of section and steel, it is observed that the retaining wall of Gabion type proves economical and effective compared to other wall considered for analysis. The locally available materials are the key elements which can be used in the construction of gabion walls makes the project time bound and cost effective.*

***Key Words*: Retaining wall, Gabion wall, Design of retaining wall, cost effectiveness.**

1. INTRODUCTION

Retaining wall is structure which restrain soil of unnatural slopes [4]. They are used to bound soils between two different elevations often in areas of terrain possessing undesirable slopes or in areas where the landscape needs to be shaped severely and engineered for more specific purposes like hillside farming or roadway overpasses [2].

Retaining walls are classified as follows of

Based on Material Used- Concrete, Brick/stone masonry, Clay/Soil Timber

Based on resisting the load-

Gravity Wall- A massive wall that resists, overturning by its own weight.

RCC Cantilever wall- Wall constructed in RCC having thin stem and base slab resist load by cantilever action. It is generally economical up to about 7m in height.

RCC Counterfort wall- When height of wall is more than 6-to 8 m Steam and base slab at regular interval tied with counterfort for economy

All the types of wall explain above have some disadvantages [14] i.e. require more cross section area, slow speed of construction work, Costly [1], may not suitable in water prone area[3] having weak foundation strata. A gabion wall is gravity wall having advantageous points as easy drainage [13], cheaper, flexible (differential settlement can be tolerate), speedy work, wastage materials can use and having no hydrostatic pressure, huge structure like landfills [12]. Above advantageous point attract the researchers to compare the Gabion wall with conventional retaining wall, to check feasibility and economy.

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2. MATERIAL AND METHOD

Gabion Wall is nothing but Boulder filled box type cage formed by Standard nets made of steel wire or polymer ropes. The netting is from mechanically double twisted hexagonal wire mesh made of Heavily Galvanized steel wire. The boxes are properly wired and laced together to form flexible, monolithic, confined building blocks, which are called as Gabion walls. Gabions in conjunction with boulders act as wall which retains water or soil as water front structures, as bridge abutment retaining structures and as slope stabilizing, erosion controlling systems, aprons and revetment construction etc. These walls are porous gravity walls, which stand by self-weight and it does not require any foundation or anchorage. Gabions can be used effectively and economically in its all applications. Gabions are classified in two categories as Metallic Gabion box & Polymer Gabion Box.

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2.1 Details of Gabion box

The steel wire gabion boxes and mattresses are factory-fabricated boxes manufactured using Mechanically Woven Double Twisted Hexagonal shaped wire meshes. Mechanically woven Double twisted wire meshes are non raveling; manufactured by twisting continuous pairs of wires through three one-half turns (commonly called double-twisted) to form hexagonal shaped mesh openings which are then interconnected to adjacent wires to form hexagonal meshes. The edges of the mesh are toughened with a thicker wire called the selvedge/edge wire.

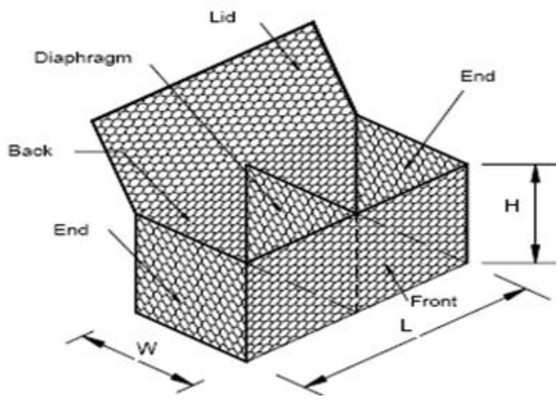

FIG 1-Metallic Gabion box [5]

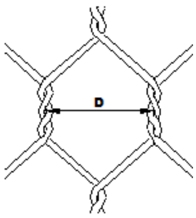

FIG 2- Double Twisted Hexagonal Wire Mesh

2.2 Specification of Metallic Gabion Box-

a) Wire Mesh- The wire used in the manufacture of mechanically woven, GI double twisted, hexagonal shaped mesh for use in gabions shall conform to the specifications shown next in Table No1.

b) Mesh Size- The mesh size is nothing but opening size of mesh is explained next in Table No 2.

c) Gabion Box sizes and Tolerances- Gabion box available in various sizes as shown in Table No 3.

d) Stone- Locally available stone are used to fill Gabion Box; its sizes are as shown in Table No 4.

Table 1- Specification for Wires for Gabion Box [6]

Parameter	Mesh wire	Selvedge / Edge wire	Lacing wire	Test Standard
Diameter (mm)	2.7	3.4	2.2	ASTM A 641 BS 1052 IS 4826 EN 10223-3 EN 10244-2
Tolerance (mm)	± 0.06	± 0.07	± 0.06	
Zinc coating (gms./sq.m)	245 Min.	265 Min.	230 Min.	
Diameter (mm)	3.0	3.9	2.2	
Tolerance (mm)	± 0.07	± 0.1	± 0.06	
Zinc coating (gms./sq.m)	270 Min.	275 Min.	230 Min.	
Diameter (mm)	3.4	4.4	2.2	
Tolerance (mm)	± 0.07	± 0.1	± 0.06	
Zinc coating (gms./sq.m)	265 Min.	290 Min.	230 Min.	
Zinc Adherence	Flaking or cracking should not be observed on rubbing with bare fingers.			EN 10244-2
Elongation (%)	10 Min			EN 10223-3

Table 2- Gabion Box Mesh Size [6]

Mesh Type	D (mm)	Tolerance for D	Mesh Wire Diameter (mm)
60 x 80	60	(+16%, -4%)	2.2, 2.7
80 x 100	80	(+16%, -4%)	2.7, 3.0
100 x 120	100	(+16%, -4%)	2.7, 3.0

Table 3- Gabion Box Sizes & Tolerance [6]

L(m)	W(m)	H(m)	Diaphragm Number	Tolerance	Test
2	1	1	1	+/- 5%	ASTM A975
3	1	1	2		
4	1	1	3		
2	1	0.5	1		
3	1	0.5	2		
4	1	0.5	3		
2	1	0.3	1		
3	1	0.3	2		
4	1	0.3	3		

Table 4- Specification for stone used in Gabion [6]

Gabion Basket or Mattress Height	Predominant Rock Size	Minimum Rock Dimension	Maximum Rock Dimension
300, 450,900 mm Basket	100 to 200 mm	100 mm	230 mm
150, 230, 300 mm mattress	75 to 150 mm	75 mm	175 mm

2.3 Tests Conducted on Gabion Box-

1) Tensile Strength- As per En 10223-3 or ASTM A641 a wire sample of sufficient length, approximately 1.2m shall be cut from either end of each coil selected for test the tensile strength. As per ASTM standards the tensile strength of the steel wire shall be in a range of 350-500 Mpa.

2) Zinc Coating- The minimum weight of the zinc coating and allowable tolerance shall meet the below mentioned requirements explain in Table No 1.

3) PVC Coating Thickness- The thickness of the PVC coating shall be determined on a randomly chosen individual piece of wire removed from the mesh. The thickness of the PVC coating is determined by stripping the PVC coating from the wire and measure the reduced diameter with a micrometer. The thickness of the coating is the difference between the diameter of steel wire before removing PVC coating and after removing PVC coating.

2.4 Construction Procedures-

Step 1: Geotechnical investigation.

Step 2: Design and Drawing.

Step 3: Foundation preparation

Step 4: Filter Cloth or Filter Stone.

Step 5: Gabion assembly

Step 6: Placing & Filling of Gabion

Step 7: Backfilling

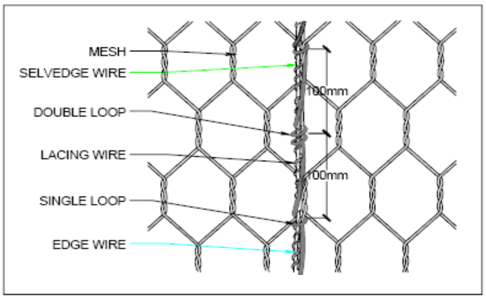

FIG 3- Gabion box connection details

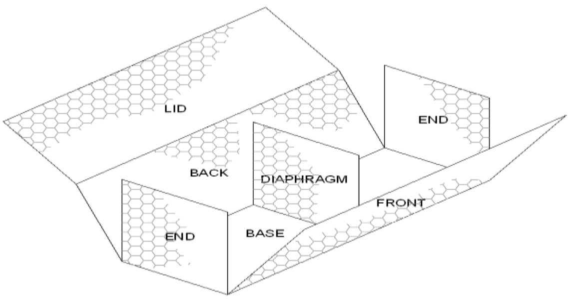

FIG 4- Gabion box assembly details

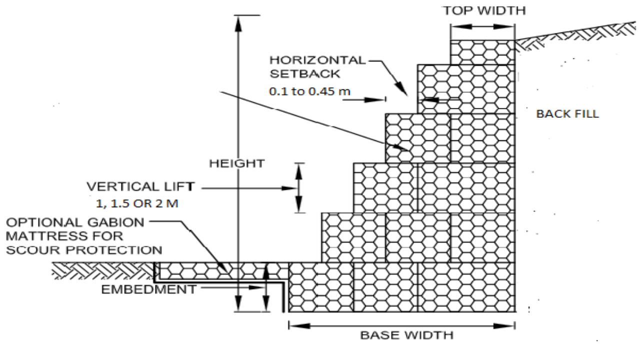

FIG 5- Typical Gabion wall cross section

FIG 6- Gabion retaining wall

FIG 7- River bank protection

3. CASE STUDY

For analysis and design of wall one site selected on bank of Mulla river (Pune ,India) near Ordinance factory at kirkee. There so much bank erosion near Compound walls between watchtowers no 16 & 17. The Erosion is so serious that started collapsing of Compound wall. Following data which is used in analysis and design are collected from site.

FIG 8- Bank erosion at Ordinance factory, Kirki, Pune

1. Length of Wall- 125 Rmt
2. Maximum RL- 99.800 (Bridge Bottom)
3. Minimum RL- 91.425
4. Maximum Height- 8.375 m
5. Detail Ground level of entire area
6. Back fill material- Black cotton Soil
7. Foundation Strata- Soft Rock

In this study most economical wall for above site is workout by comparing Gravity wall, RCC Cantilever wall ,RCC Counterfort wall and Gabion wall by analyzing and designing all above mentioned wall from data collected from site. No surcharge and horizontal backfill is considered for analysis.

3.1 Stability analyses and design method-

The design procedure of Gravity wall, RCC Cantilever wall and counterfort wall is very common and can be found in any text book [9]. Design is done as per IS Code 456-2000. Gabion wall is design similarly as Gravity wall. Stability analysis of walls includes check against sliding at the base, overturning about the toe, bearing failure of the foundation soil and overall stability failure. The notations related to Figures are described below.

γ = Unit weight of backfill, retained fill, foundation soil = 18 KN/M^3

γc = Unit weight of concrete = 25 KN/M^3

ϕ = Angle of internal friction of backfill = 30°

D = Depth of embedment of foundation = 0.90 M

H = Height of the wall from EGL to the foundation level = 9.30 M

SBC = Bearing capacity of foundation soil = 500 KN/M^2

Ka = Rankine's coefficient of active earth pressure = 1-sinϕ/1+sinϕ

Pa= Active force due to the retained fill = 0.5Ka γ

W1= Total weight of concrete (stem and base)

W2= Wt. of backfill B = Width of base of the retaining wall.

Check for overturning about toe

Overturning of the wall may occur about the toe, i.e. point A due to the lateral earth pressures shown in Figure. The Factor of Safety against such overturning can be expressed as [10]

FS (OT) = ΣMR/ΣMO>=1.55

Where, FS (OT) = Factor of Safety against overturning,

$\sum$MR = Summation of resisting moment about point A,

$\sum$MO = Summation of overturning moment about point A.

Check for sliding at the base

The Factor of Safety against sliding at the base may be expressed as [10]

FS (sliding) = $\sum$FR/$\sum$FD > = 1.5

Where, FS (sliding) = Factor of Safety against sliding at the base; $\sum$FR = Summation of resisting forces against sliding; $\sum$FD= Summation of forces causing sliding at the base

Check for bearing capacity failure

The vertical pressure as transmitted to the soil by the base slab of the wall should be checked against bearing capacity of the soil. It should be appreciated that due to the lateral earth pressure, the bearing pressure will be maximum at the toe and minimum at the heel. The Factor of Safety against bearing capacity is then defined as [10]

FS (bearing) = qu /qmax; = 3.0

Where, FS (bearing) = Factor of Safety against bearing capacity failure; qu= Ultimate bearing capacity of the foundation soil; q max = Maximum pressure at the base of the wall

e = Eccentricity of the resultant force at the base

= B/2 - $\sum$MR - $\sum$MO/ (W1 +W2); <= B/6, no tension case.

Passive forces are neglected for safer side in design as the soil in front of the toe may get eroded with time. However, in the situations where it may be estimated with certainty that the soil in front of the toe will never erode, the contribution from the passive force may be considered in calculating the factor of safety both against overturning and sliding.

3.2 Final cross sections from analysis

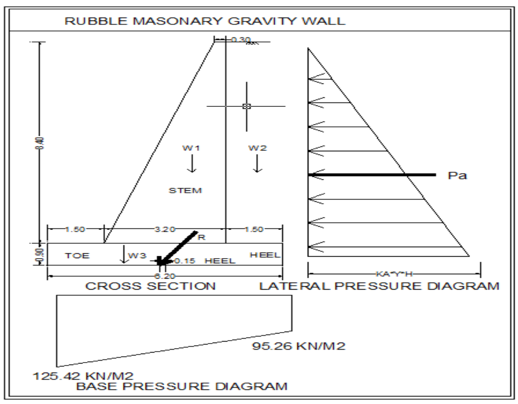

FIG 6 a- Final Cross Section of Gravity wall

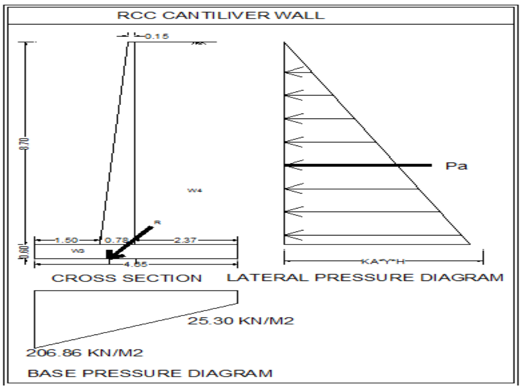

FIG 6 b- Final Cross Section of RCC Cantilever wall

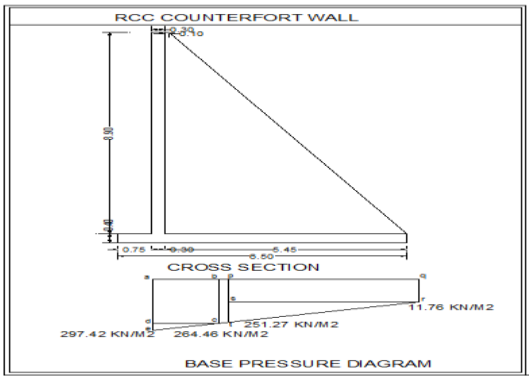

FIG 7 a- Final Cross Section of Counterfort wall

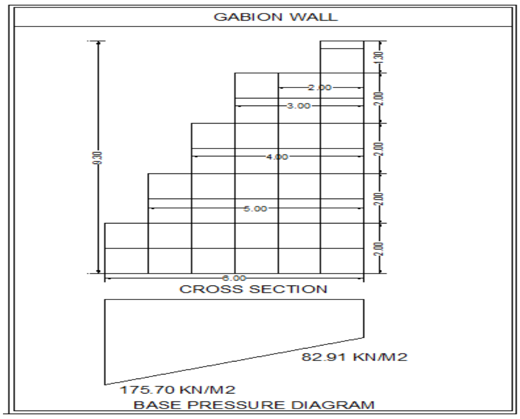

FIG 7 b- Final Cross Section of Gabion wall

4. COST COMPARISION

Estimation for various items shown table 6 are done from final sections (Fig-6,Fig-7) which are the results of analysis and design of all four walls. The rates are taken for costing are from District schedule rates, Government of India Central Public Work [8] Department. Price of Metallic box is based on its weight in Kg. Price of is about 85 Rs/Kg (7).Weight of Gabion is about 16.5 kg for box size 2X1X1 m and 24 kg for box size 3x1x1m.

Table 7- Cost per running meter length and % variation

	Stone Masonry	RCC Cantilever	RCC Counterfort	Gabion Wall
Cost per rmt	54,172	83,467	59,961	54,156
% variation	0.03	54.12	10.72	0

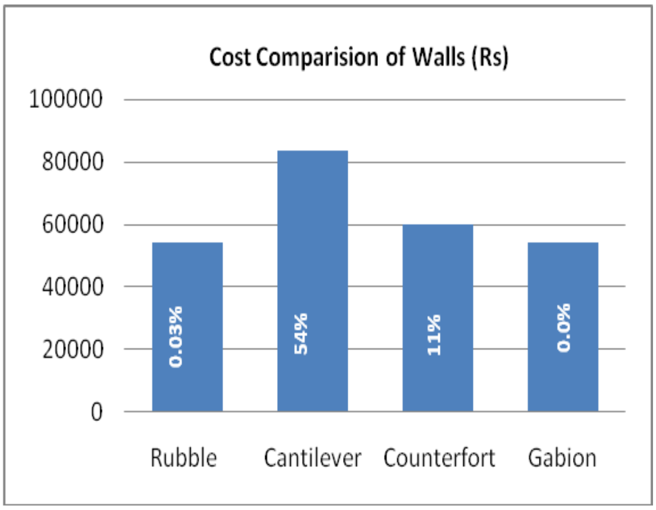

FIG 8- Histogram for cost all four walls

CONCLUSIONS-

From the entire study carried out following conclusion are drawn-

The construction cost of Gabion Wall as compare to Rubble Masonry, RCC Cantilever, RCC Counterfort, Graviloft retaining wall are 0.3%, 54.12%, 10.72% , 9.56% less respectively.

Though the construction cost variation between Rubble Masonry Gravity Wall and Gabion wall is very low (0.3%), Gabion Wall will be preferable on account of speedy (continues) work and use of locally available materials.

For speedy work Gabion Wall is best option as there is no curing period is required for it. Gabion Wall is better economical option against other conventional types of retaining wall. Gabion Wall is best suited for congested site, like Hilly area, River, nala Banks etc.

Gabion Wall is ideally suited for remote area where skill Labour, advance machinery, material is difficult to arrange.

Table 6- Estimation costing of all four walls-

Sr.No.	ITEM	UNIT	RATE	QUANTITY				AMONUT RS			
				Rubble Masonry	RCC Cantilever	RCC Counterfort	Gabion	Rubble Masonry	RCC Cantilever	RCC Counterfort	Gabion
1	Site Clearance	SQM	2.639	10,918.0	10,708.8	10,958.5	10,891.0	28,813	28,260	28,919	28,741
2	Excavation Soil	CUM	101.8	3,021.3	2,332.6	3,154.6	2,807.3	307,722	237,579	321,298	285,925
3	Excavation Soft Rock	CUM	152.6	765.0	590.6	798.8	838.0	116,739	90,129	121,889	127,872
4	Dewatreing	HP/ HR	26	738.0	198.0	324.0	198.0	19,188	5,148	8,424	5,148
5	PCC	CUM	2449	85.0	61.9	85.0	0.0	208,165	151,532	208,165	0
6	Stone Masonary-Above plinth	CUM	2384.2	1,837.5	0.0	0.0	0.0	4,380,968	0	0	0
	Stone Masonary-Below plinth		2022.7	697.5	0.0	0.0	0.0	1,410,833	0	0	0
7	Pointing	SQM	62.5	2,428.1	0.0	0.0	0.0	151,754	0	0	0
8	RCC- M20	CUM	4092.3	0.0	854.4	977.3	0.0	0	3,496,657	3,999,649	0
	M-15	CUM	3720	0.0	0.0	0.0	0.0	0	0	0	0
9	Form Work	SQM	180.4	0.0	2,325.0	4,529.0	0.0	0	419,430	817,024	0
10	Reinforcement	KG	42.7	0.0	138,164.7	41,685.0	0.0	0	5,899,634	1,779,948	0
11	Gabion box	KG	85	0.0	0.0	0.0	38,712.8	0	0	0	3,290,584
12	Gabion filling	CUM	650	0.0	0.0	0.0	4,663.4	0	0	0	3,031,210
13	Pipe-Wipe Hole	RMT	185	469.7	122.0	85.4	0.0	86,895	22,570	15,799	0
14	Refilling	CUM	32	1,890.0	2,577.4	6,063.1	0.0	60,480	82,476	194,020	0
	TOTAL COST (Rs)							6,771,556	10,433,416	7,495,136	6,769,479
	COST PER RMT (L=125M)							**54,172**	**83,467**	**59,961**	**54,156**
	% VARIATION IN COST							0.03%	54.12%	10.72%	0.00%

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Authors Profile

Ganesh C. Chikute completed his graduation and post graduation in Civil Engineering and currently pursing in PhD from College of Engineering (COEP) Pune under Pune University India.

Dr. Ishwar P. sonar is Assistant professor, Civil Engineering Department, College of Engineering (COEP) Pune India. His specialization is in structure Engineering. His research work is Bamboo reinforcement, advanced concrete, steel structure

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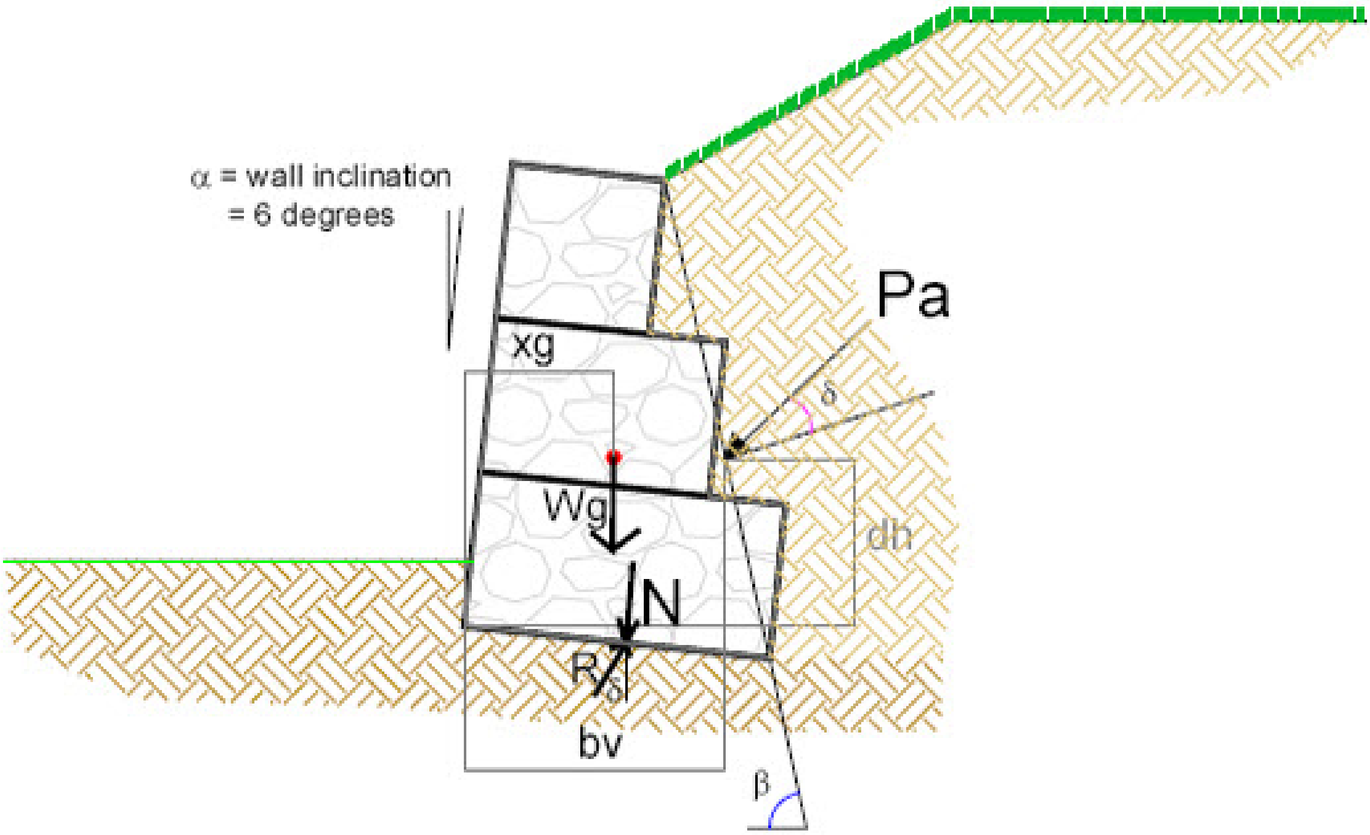
Designing with Gabions



Volume 1

A Reference Guide for the Designing of Mass Gravity Gabion Walls

Registered Office: Unit 5, The Cobden Centre, Folly Brook Road, Emerald Park, Emersons Green, Bristol BS16 7FQ

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Enviromesh

Garner Street Business Park
Etruria
Stoke-on-Trent
Staffordshire
ST4 7BH

Tel: **0044 (0) 845 136 0101**
Fax: **0044 (0) 845 136 0202**
Email: **roger.farmer@enviromeshgabions.com**
Web: **www.enviromeshgabions.com**

Introduction

Gabions have long become an established method of construction for retaining structures worldwide, providing economical and environmentally acceptable solutions.

These structures are generally designed as mass gravity walls with either stepped or flush faces depending upon the requirements of the engineer.

This design guide has been prepared to assist competent structural / civil engineers and architects in the best practice of designing gabion walls.

Alternatively, Enviromesh can provide a free desk top design feasibility service using dedicated in house software.

This technical service is to support our clients with a design facility aimed at providing the most economical system to meet the clients needs.

For advice or assistance with the design of a gabion wall, please call Enviromesh direct, on any of the contact details given at the end of this guide.

What are Gabions?

The term gabion refers to a modular containment system that enables rock, stone or other inert materials to be used as a construction material.

The modules or cages as they are known, are formed of wire mesh fabric panels, jointed to form square, rectangular or trapezoidal shaped units. These units are part pre-assembled in the factory to form a flat pack system.

These flat pack units are then supplied to the customer and formed into the final shaped module on site with the necessary lacing wire, helicals and / or rings as required. Each module has to be connected to adjacent modules to form a monolithic structure.

The types of mesh used, must be of a non ravelling type such as welded wire mesh or hexagonal woven wire mesh and provided with corrosion protection to suit the required exposure conditions.

The gabions are normally machined filled in layers with the contractor picking the stone over by hand to reduce excessive voids. The exposed faces are also systematically hand packed to provide an appearance of a dry stone wall.

Although some structures are only machine filled, this procedure is not normally recommended.

For gabion structures to perform correctly the quality of installation is of paramount important.

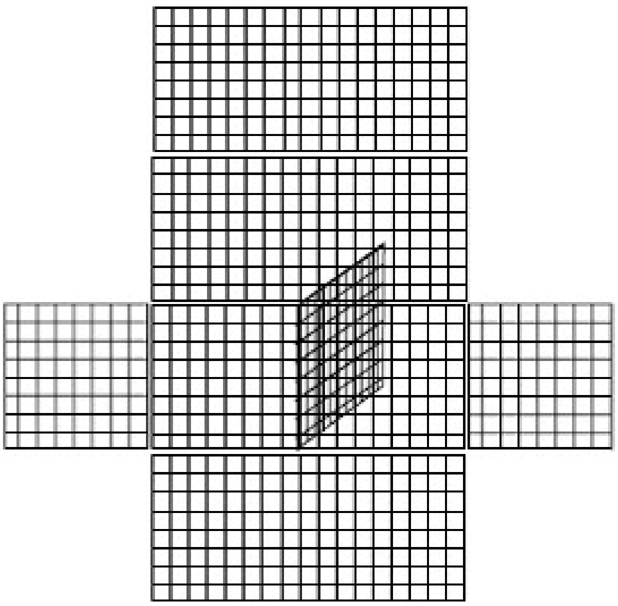
Welded Mesh Gabions

These gabions are manufactured from a square mesh, normally of opening size 76.2mm x 76.2mm where the longitudinal wires are welded to the cross wires at there intersection points. This type of fabric manufacture, produces a dimensionally stable mesh.

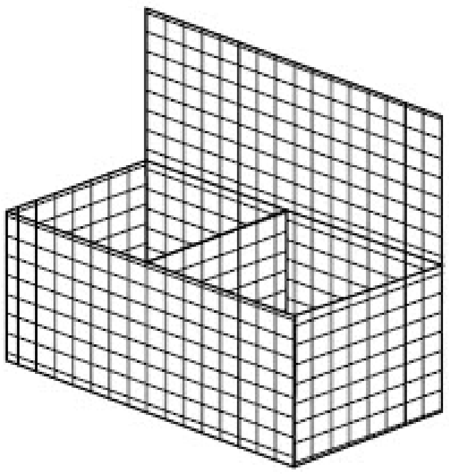
This mesh, produced in panels or rolls, is then cut into the required panel sizes to form the flat pack unit. This is done by clipping the face, rear, side and diaphragm panels (intermediate dividing panels) to the base panel so that they can rotate to be folded flat. The lid may be clipped to the front or back panel or left loose dependant upon the unit size.

Units can be manufactured in any multiple of the mesh size, but are normally supplied as standard sizes to the industry. Welded mesh gabions can be readily modified on site by cutting the mesh back to the next transverse mesh wire.

Welded mesh gabions are available in a number of wire diameters to suit the application or can be manufactured in a combination of mesh-wire specifications to provide economy in supply.



WELDED MESH GABION OPENED OUT FLAT PACK



GABION FORMED INTO BOX SHAPE ON SITE

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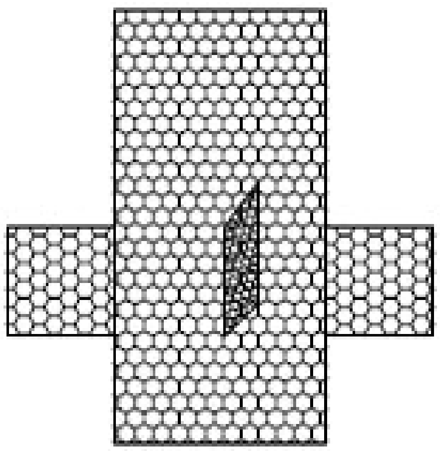
Woven Mesh Gabions

These gabions are manufactured from a mesh that has a hexagonal opening which is formed by twisting pairs of wire together with one and a half turns (sometimes referred to as triple or double twist).

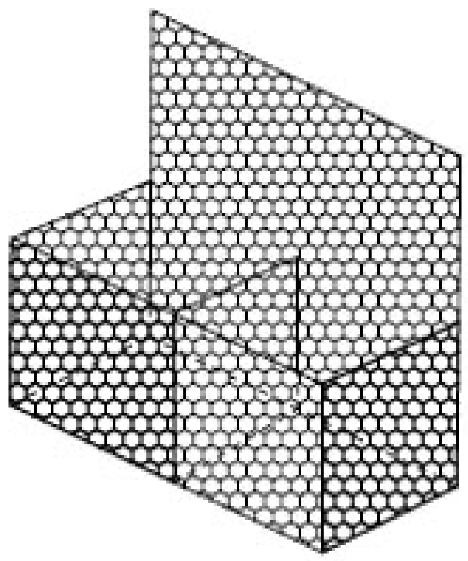
This type of mesh production is continuous. To form panels, the mesh is guillotined across the weave and the cut ends of the wire are wrapped around a heavier wire to form a selvedge end.

The unit is factory fabricated from one main panel which forms the front, base, rear and lid of the unit with additional panels connected to the base section of the main panel to form the diaphragm and end panels. Dependant upon the manufacturer, the mesh orientation is normally either with the weave horizontal or vertical on the face panel and the connection of the ends and diaphragm to the base is via a spiral wire or pairs of twisted wires, twisted together around the base mesh.

This type of mesh is a flexible mesh as it can articulate about the twists. It is normally manufactured from a 2.7mm wire diameter. The coatings are either galvanised only, galvanised and PVC coated or galvanised and HDPE coated. The dimension between the twists is a nominal 80mm.



HEXAGONAL MESH GABION
OPENED OUT FLAT PACK



GABION FORMED INTO BOX
SHAPE ON SITE

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Gabion Filling Materials

The design of gabion retaining walls is based on the mass of the contained stone or rock being able to resist the disturbing forces due to soil and external loadings. The design does not consider that the gabion mesh provides improvement to stability. The design code applicable to gabions is BS 8002 - The Code of Conduct for Earth Retaining Structures.

In the design of the retaining structure, the principles are the same for both woven and welded mesh gabions. Where walls are subject to possible settlement, woven mesh gabions have more flexibility and therefore may be best suited in these situations. Where a high quality of appearance is needed, welded gabions are superior providing that the correct selection of mesh wire combinations are chosen.

The selection of rock or stone fill is very important, as the performance of gabion structures is dependant upon the mass. Although the mass is the criteria for design, other factors to be considered are:-

Grading of fill

Gabion fill is normally a graded fill of between 100 to 200mm in diameter with a nominal 6% smaller or larger.
The grading can be tightened to 80 to 150mm providing the control of the grading is tight. Stones smaller than the mesh will not be contained by it.
The grading is important to ensure that voids within the unit are minimised otherwise settlements can occur.

Angularity of fill

The more angular the fill, the better interlock and the less deformation of the face occurs.

Rounded stone has little interlock and results in greater deformation of the face. To overcome the deformation, a heavier mesh wire should be used.
Welded mesh gabions are manufactured from 3, 4, or 5mm wire diameters and Woven gabions from a wire diameter of 2.7mm. Therefore for a rounded stone fill, welded wire mesh gabions should be specified, 4mm for gabion 27 system and 5mm for standard gabion 39 system.

Crushed concrete or gritstone, although angular, tend to become rounded. They do have greater interlock than rounded stones and therefore 4mm welded wire mesh should be specified

Quarried stone which is normally angular, is the preferable fill as the interlock is very good.

Blocky stone or flat stone when machined filled can result in large voids being present which can result in settlements. Care should be taken when machine filling to minimise large voids.

Ideally, all gabions should be fair faced (hand packed on the exposed faces). Where the cost of quarried rock fill is high, the gabions can be filled with 2 types of fill, a quarried rock or block stone for the exposed face with a cheaper stone fill behind. To assist in placing of differing fills, an additional cell can be incorporated normally set back 300mm from the face during gabion manufacture to assist in the construction.

Soil Characteristics

Before undertaking a gabion wall design, the types of soil being retained and the foundation soil type should be identified by a soil investigation survey to ascertain the correct parameters to use in design.

Gabion walls are designed with the drained soil parameters for the retained soils, but the un drained parameters can be considered for the computations for sliding (limitations on the cohesion values that can be taken for design will apply).

The design parameters for stability calculations are as follows :-

Granular materials :-	soil friction angle and density
Silty and Clayey materials:-	Plasticity index and density (correlations exist for assessing the drained soil friction angle with respect to the plasticity index)

Typical Soil friction Values

Soil Classification	Phi Value (degrees)		
	Loose	Compact	Dense
Sand and Gravel	29	34	41
Medium Sand	27	31	36
Fine Sand	25	27	31
Fine Sand Silty, Sandy Silty	25	27	29

Chalk	(re moulded)	30 to 34
	(intact)	32 to 37
Glacial Till		35 to 42
Oxford Clay	(peak strength)	28
	(residual strength)	13
Weald Clay	(peak strength)	22
	(residual strength)	9 to 15
Gault Clay	(peak strength)	22
	(residual strength)	26
London Clay	(residual strength)	10
Weathered Clay	(peak strength)	19 to 21
London Clay	(residual strength)	9 to 14

Soil Characteristics

Correlation of Plasticity Index and Soil Friction Angle:-

Plasticity Index %	Phi value (degrees)
15	30
30	25
50	20
80	15

Interpret linearly for intermediate values.

Correlation of Plasticity Index and CBR:-

Soil Type	Plasticity Index %	CBR %
Heavy Clay	>50	<2
	40 to 49	2
	30 to 39	2
Silty Clay	20 to 29	3
Sandy Clay	10 to 19	4
Silt	<10	1
Sand Poorly Graded	Non Plastic	20
Sand Well Graded	Non Plastic	40
Gravel Poorly Graded	Non Plastic	40
Sandy Gravel Well Graded	Non Plastic	60

Typical Densities of Soils

Soil Type	Moist Weight	
	Loose KN/cum	Dense KN/cum
Gravels	16	18
Well Graded Sand	19	21
Course or Medium Sand	16.5	18.5
Fine or Silty Sand	17	19
Soft Clay	17	
Firm Clay	18	
Stiff Clay	19	
Very Stiff Hard Clay	20	
Stiff Hard Glacial Clay	21	

The above soil information is a guide only and does not negate the need for a proper soil investigation survey to be carried out.

Design Methods

Design methods of analysis for determining the stability of gabion walls are based on The Code of Practice BS 8002 which superseded CP2. The two methods considered are:-

- Serviceability Limit State Design
- Ultimate Limit State Design

In the original code of practice, CP2, the analysis was based on Ultimate Limit State, where the structure had to meet certain factors of safety on sliding (1.5) and overturning (2.0). The soil forces being determined on the peak soil conditions.

BS 8002 recommends the Serviceability Limit State design where the factors of safety achieved must be greater than unity. The soil forces being determined on factored soil parameters.

At present, most design is still carried out on the Ultimate Limit State, but generally a Serviceability Limit State Design would give a similar section.

Gabion walls form typically a trapezoidal format, formed of a number of courses with the width of each course reducing as the wall height increases. The walls may be flush faced or stepped as required by design or visual requirements, and are normally inclined at 6 degrees to the vertical in the case of standard gabion 39 system and up to 10 degrees for the gabion 27 system.

To establish the initial cross section for evaluation, the base width considered is 0.7 x the wall height for standard gabion 39 system inclined at 6 degrees to the vertical and 0.55 x the height for gabion 27 system at an inclination of 10 degrees. The wall height for evaluation should allow for a minimum toe in of 0.3 to 0.5m dependant on soil type.

Based on a 3.0m high wall, the base widths would be:-

Standard Gabions	0.7 x 3.0	=	2.1m (nearest standard unit width is 2m)
Gabion 27 System	0.55 x 3.0	=	1.65m (nearest standard unit width is 1.7m, a design example is evaluated later)

The make up for the walls will then be:-

Course	**Standard Gabion 39 System** (width x height)	**Gabion 27 System** (width x height)
4		1.7 x 1.0
3	2.0 x 1.0	1.4 x 0.7
2	1.5 x 1.0	1.0 x 0.7
1	1.0 x 1.0	0.7 x 0.7
Total Volume	**4.5 cum**	**3.87cum**

Note:- Gabon 27 system at an inclination of 10 degrees from the vertical normally provides a more economical section.

Design Analysis

Once the initial section has been determined, stability checks can be carried out.

The provision for any superimposed surcharge loadings to the retained soil both in the construction stage and the permanent condition must be accounted for. Normally, a typical construction loading is taken as 10kN/sqm for retained soils with nominal inclinations. If unusual construction plant is to be used in the vicinity of the wall, then the superimposed loading should be increased accordingly.
Where the retaining wall height is large or is built within a slope or in clayey material, it may be necessary to carry out an overall slope stability check in case a circular failure plane exists which passes beneath the structure in the soil strata.

Two methods of computing the soil forces on the retaining wall can be used,:-

Coulomb's Analysis:-
This is a mathematical analysis based on considering a coefficient of active thrust for the soil. The method considers the soil parameters and the friction developed at the back of the wall. The analysis is limited to retained soil profiles which have a single grade, but more complex slopes can be considered by rationalising the complex surface to a single grade and applying a continuous surcharge to approximate the profile. It can only consider a continuous single surcharge, but methods are available to deal with line or point loadings on the retained soil.

Wedge Analysis:-
This is a graphical solution that considers the forces acting on the soil wedge behind the wall to maintain it in equilibrium. The method considers various failure planes. For each plane, a force vector diagram is plotted and the maximum thrust can be determined from the locus of the active thrust vector on the diagram. This method is the preferred method of analysis as it can accommodate variations in the profile of the retained ground along with multiple surcharge loading conditions. However the analysis can be lengthy as it has to be carried out at each course and therefore is best managed by computer programs.

The software used by ENVIROMESH, computates using Wedge Analysis.

The following design method is based on Coulomb's Analysis. Being mathematical it is relatively easy to carry out design.

Data required for design

Geometry :-	Slope wall height	h	m
	Slope angle of the retained soil	ε	degrees
Soil parameters	Soil friction angle	ϕ	degrees
	Density	γ	kN/cum
Loadings	Surcharge	po	kN/sqm
Allowable bearing pressure		σ	

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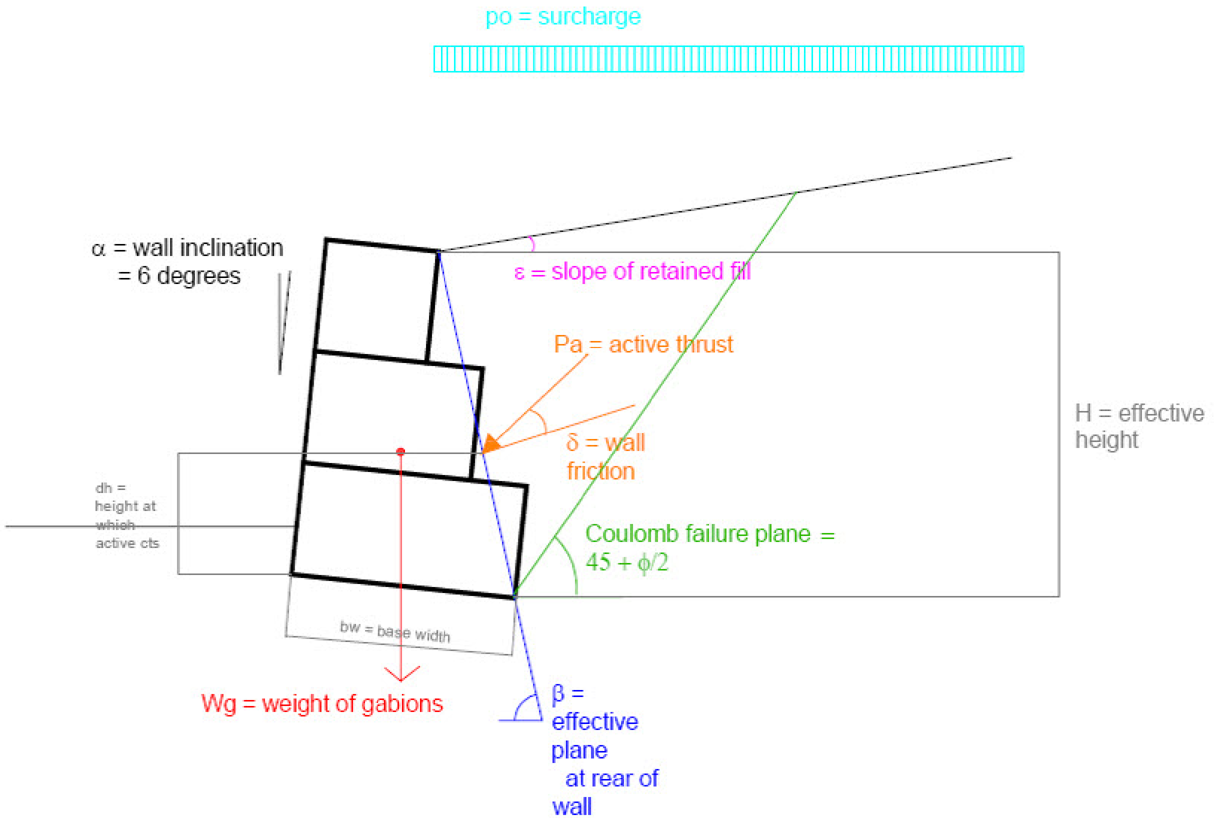
Active Thrust Calculations

From the code of practice for gabions, the wall friction δ is taken as equal to ϕ where no geo-textile separator is required behind the wall and 0.9 x ϕ where a geotextile is required.

For the base frictional value, the code of practice suggests a value of 0.66 x ϕ, however based on experience and historical test trials, the value can be taken as the same as the frictional value of the founding soil.

The section can now be drawn and the forces that act on the wall are shown



Forces acting on the wall

By considering the vector diagram of the forces on the wall based on Coulomb's failure plane, the Active Thrust can be determined from the Coefficient of Active Thrust Ka

$$ka = \frac{\sin^2(\beta+\varphi)}{\sin^2\beta \sin(\beta-\varphi)\left[1+\sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\varepsilon)}{\sin(\beta-\delta)\sin(\beta+\varepsilon)}}\right]^2}$$

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Active Thrust Calculations

Active thrust due to soil and surcharges are as follows:-

$$Pa_{soil} = 0.5 \times ka\, \gamma H^2$$

$$Pa_{surcharge} = po \times ka \times H$$

where Pa_{soil} *= active thrust due to soil*
$Pa_{surcharge}$ *= active thrust due to imposed loadings*
H *= effective wall height*
po *= surcharge loading above the wall*

Total Active thrust *Pa*

$$Pa = Pa_{soil} + Pa_{surcharge}$$

The active thrust due to the soil acts at 1/3rd the effective height of the wall and for the surcharge it acts at ½ the wall height. The resultant point of application of total active thrust above the toe of the wall can be calculated from :-

$$dh_{soil} = H/3\ [(H + 3hs) / (H + 2hs)]$$

$$dh = dh_{soil} - bw \times \sin \alpha$$

where bw *= base width of gabion structure*
hs *= the equivalent height of soil equal to the surcharge loading* $= po / \gamma_s$

Resolve the active thrust *Pa* into its horizontal and vertical components. *Ph* and *Pv* respectively

$$Ph = Pa \times \cos(90 - \beta + \delta)$$

$$Pv = Pa \times \sin(90 - \beta + \delta)$$

$\delta = \phi_{des}$ *of soil if no geo-textile is required*

$\delta = 0.9 \times \phi_{des}$ *of soil if geo-textile is present*

Gabion Computations

Weight of gabion Structure

$$Wg = \sum_{1}^{n} uw \ x \ ud \ x \ \gamma_d$$

where n	=	*number of courses*
uw	=	*width of each course*
ud	=	*depth of each unit*
γd	=	*density of gabion fill*
Wg	=	*Weight of gabion structure*

To determine the centre of gravity of the gabion structure, area moments are taken about the toe of the wall.

Sum the area moments of each gabion course about the toe of the wall. For walls with no inclination, determine area moments on the x axis only. For inclined walls determine the area moments on both the x and y axis then correct for the wall inclination.

$$xg = \frac{\sum_{1}^{n} st \ x \ (uw \ x \ ud)}{\sum_{1}^{n} (uw \ x \ ud)} \qquad yg = \frac{\sum_{1}^{n} hc \ x \ (uw \ x \ ud)}{\sum_{1}^{n} (uw \ x \ ud)}$$

where st = horizontal offset of centre of gravity of each course about the toe of the wall considering wall inclination = 0 degrees
Xg = horizontal distance of the centre of gravity of the structure about the toe of the wall considering the wall inclination = 0 degrees
hc = vertical height to the centre of gravity of each course from the toe of the wall considering wall inclination = 0 degrees
Yg = vertical distance of the centre of gravity of the structure about the toe of the wall considering wall inclination = 0 degrees

Correcting for the wall inclination α

$$Xg = xg \cos \alpha + yg \sin \alpha$$

where Xg = vertical height to the centre of gravity of the structure corrected for the inclination of the wall.

α = inclination of the wall

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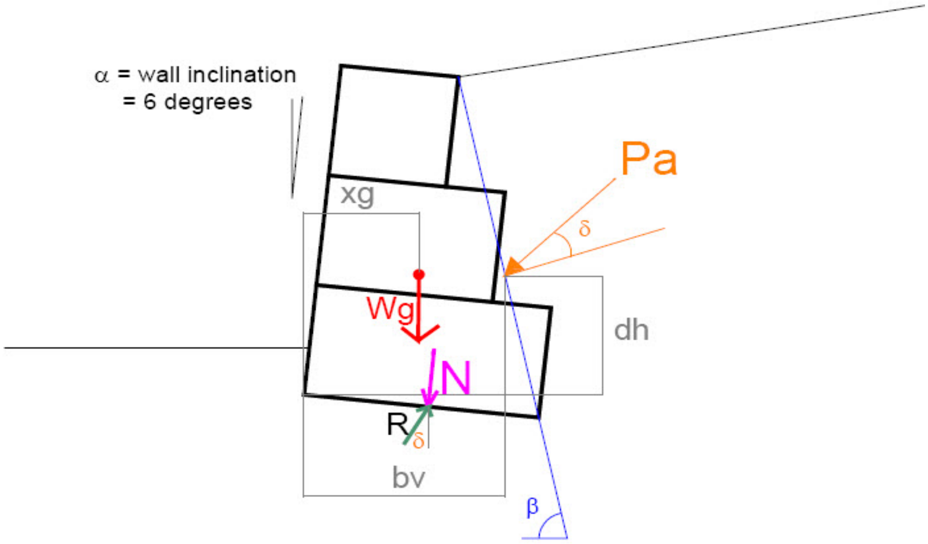
Gabion Computations
Stability Calculations



Forces due to the wall

Overturning Stability

Overturning stability is the ratio of the disturbing moment (overturning moment) due to the horizontal component of the active thrust *Ph* and the restoring moments (moments of resistance) due to the mass of the wall *Wg* and the vertical component of active thrust *Pv*. (*Ph* and *Pv* are computed for the soil and each surcharge unless the combined value of active thrust *Pa* was used:- as computed in Coulomb's analysis)

Mo (moment of overturning) = Ph x dh

Mr (moment of resistance) = Pv x bv + Wg x Xg

Fo (Factor of Safety Overturning) = Mr / Mo

Fo = > 2.0 for Ultimate Limit State Design
Fo = > 1.0 for Serviceability Limit State Design
`

bv = horizontal distance from toe to point of application of active thrust Pa

$= bw \times \cos \alpha - dh_{soil} / \tan \beta$

bw = base width of gabion course under consideration

Gabion Computations
Stability Calculations

Sliding Stability

Sliding Stability is the ratio of the forces resisting sliding (due to the mass of the gabions ***Wg*** and the vertical component of active thrust ***Pv)*** and the disturbing forces (due to the horizontal component of active thrust moment ***Ph***) on the plane of sliding.

N (normal force on plane of sliding) = $Wg + \Sigma Pv$

T (tangential force on plane of sliding) = ΣPh

Fs (Factor of Safety Sliding)

$$= \frac{(N \cos\alpha + T \sin\alpha)\tan\phi_{des\ (founding\ soil)}}{(T\cos\alpha - N\sin\alpha)}$$

Fs = > 1.5 for Ultimate Limit State Design
Fs = > 1.0 for Serviceability Limit State Design

Bearing Capacity

The loading on the founding soil must not exceed its allowable bearing capacity. The resultant load is normally eccentric to the centre of the base.
Good design practice is to equalise the toe and heel pressures as much as possible either by stepping the gabions or by the inclination of the wall, but do not exceed 6 degrees for standard gabion 39 system or 10 degrees for gabion 27 system.

e (eccentricity of result on the base) = B/2 – (Mr – Mo) / N

e <= B/6 (resultant must lie within the middle third of the base)

σ *(bearing pressure on base) = N / B (1+ 6e/B) at the toe*

σ *(bearing pressure on base) = N / B (1- 6e/B) at the heel*

σ <= *allowable bearing capacity of the soil*

Gabion Computations
Design Criteria and Gabion Densities

Design Criteria

A design check must be carried out for each course. The frictional value of gabion to gabion interface is taken as 35 degrees based on actual tests undertaken.

Factor of safety against overturning >2.0
Factor of safety against sliding >1.5

In the case of a factor of safety of sliding on the sub grade which is within the range of 1.3 to 1.5, then the wall can founded on a granular sub base of minimum 300mm thick to improve sliding resistance. Re-evaluate the factor of safety on sliding with the phi value for a granular material to see if its above the required minimum factor of safety of 1.5. If not then the design section of the wall should be increased.

Stability can be improved by backfilling behind the wall with granular material.

If the cut slope is 45 degrees or less, then the wall is designed as if it is retaining a granular fill.

If the cut slope is 45 to 90 degrees, then the wall is designed on the existing soils. However the wall friction can be increased to 34 degrees in the evaluation of the vertical and horizontal components of active thrust.

Eccentricity (e) must fall within the mid third of the base width of the gabion.

The maximum bearing pressures computed must be less than the allowable for the underlying soil.

Gabion Densities

Below are given the typical design densities for various types of gabion fill material:

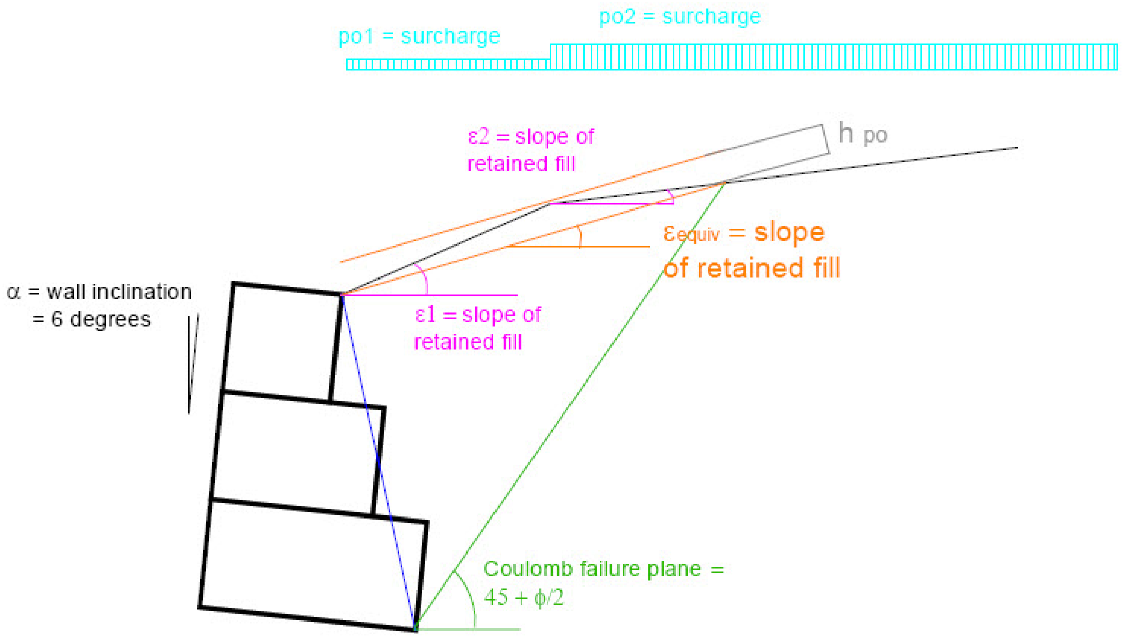
Flint rejects and whole stone	14.5 kN/cum
Crushed Concrete	15 kN/cum
Sandstone	15.5 kN/cum
Limestone	16 kN/cum
Granite	17 kN/cum
Basalt	18 kN/cum
Aggregate fill	16 kN/cum (geotextile lined units)

Gabion Computations

Complex Crest Profiles

Where the retained surface profile is complex, Coulomb's Analysis cannot be used unless it is rationalised to a single slope.

The following method is an approximation of dealing with the complex condition.



complex crest details

In the above diagram, the wall is subject to two surcharge loadings - po1 and po2 together with two slopes.

To evaluate this condition, the Coulomb failure plane is drawn until it intersects the free surface. A line is then drawn from the intersection to the rear of the wall at the crest. The angle this makes with the horizontal is then the value of the slope used in the analysis (ε_{equiv}).

A line is then drawn parallel to the apex of the triangle above it, the perpendicular is measured (hs), this height is equivalent to a surcharge of soil on the assumed slope. This surcharge is then calculated:-

$$po_{assumed} = h_{po} \times soil$$

$$po_{design} = po1 + po_{assumed} \text{ or } po2 \text{ whichever is the greater}$$

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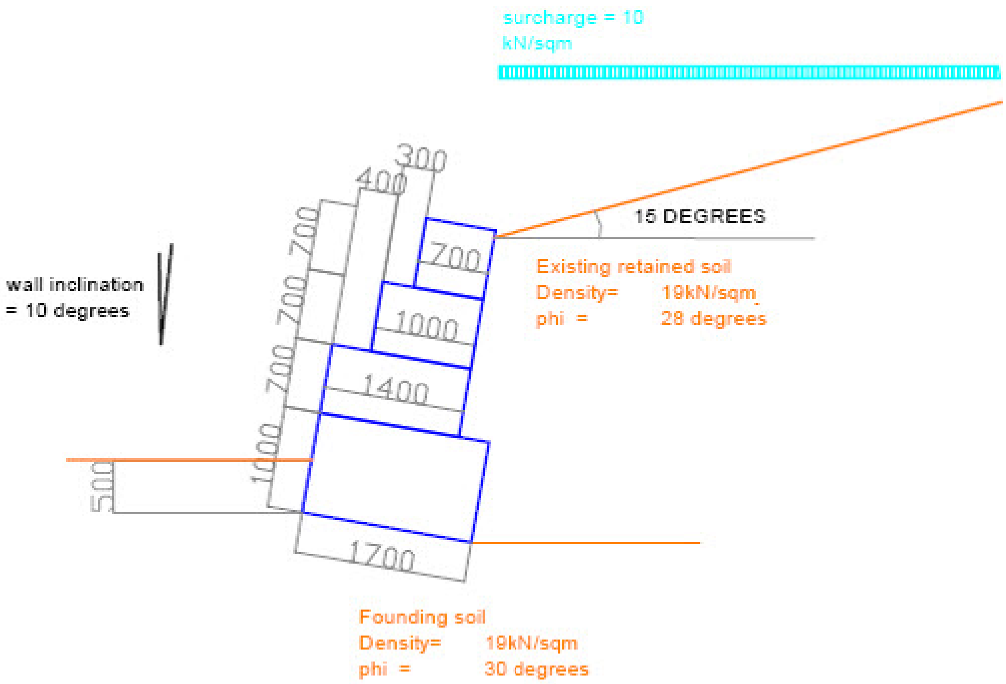
Design Example



Design example

In the above problem, the gabions are to be filled with a limestone fill having a filled density of 16kN/cum.
The wall is inclined at 10 degrees to the vertical.
Determine the weight of the gabions and its centre of gravity. Initially consider the wall vertical and then correct for the inclination.

Course	Course Dimensions width m	height m	Area sqm	Mass kN	Offset m	Centre of gravity about toe xx plane m	yy plane m	Area Moments about toe xx plane m	yy plane m	
4	0.7	0.7	0.49	7.84	0.7	1.05	2.75	0.5145	1.3475	
3	1	0.7	0.7	11.2	0.4	0.8	2.05	0.56	1.435	based on wall being vertical
2	1.4	0.7	0.98	15.68	0	0.7	1.35	0.686	1.323	
1	1.7	1	1.7	27.2	0	0.85	0.5	1.445	0.85	
Totals			3.87	61.92				3.2055	4.9555	
						xg	yg			
centre of gravity						0.83	1.28			
correcting for wall inclination of 10 degeees Xg						1.04				
Effective slope at rear of wall in degrees B						94.46				
Effective height of wall						xg	yg			
co-ords of top of wall (consdider as vertical)						1.40	3.10			
co-ords heel of wall (consider as vertical)						1.70	0.00			
correcting for inclination top of wall						1.92	2.81			
heel of wall						1.67	-0.30			
effective wall height H							3.10			

ENVIROMESH

Design Example

Determine the co-efficient of active thrust *ka*

Where $\varepsilon =$ 15 degrees $\beta = 94.46$ $\phi =$ 28 degrees $\delta =$ 28 degrees (no geotextile)

$$ka = \frac{\sin^2(\beta + \varphi)}{\sin^2\beta \sin(\beta - \varphi)\left[1 + \sqrt{\frac{\sin(\varphi + \delta)\sin(\varphi - \varepsilon)}{\sin(\beta - \delta)\sin(\beta + \varepsilon)}}\right]^2}$$

ka = 0.364

Active thrust due to existing soils per metre run of wall

Where $\gamma =$ density of retained soil

$Pa_{soil} = 0.5 \times ka\ \gamma H^2$ = 33.23 kN/m run

$Pa_{surcharge} = po \times ka \times H$ = 11.28 kN/m run

$Pa = Pa_{soil} + Pa_{surcharge}$ = 44.51 kN/mrun

Height of application is h/3 for spoil loadings and H/2 for uniform surcharge loading

The height at which it acts can be determined from the following equation:-

$dh_{soil} = H/3\ [(H + 3hs) / (H + 2hs)]$ = 1.164 m above the heel

$dh = dh_{soil} - bw \sin \alpha$ = 0.87m above toe of wall

Where bw = width of bottom course of gabion

hs = surcharge loading as equivalent height of soil = po/γ

Design Example

Resolve the active thrust Pa into horizontal and vertical components (active thrusts acts at an angle δ to the normal of the effective plane of the rear face of the wall).

$Ph = Pa \times \cos(90 - \beta + \delta)$ = 40.81 kN/m run

$Pv = Pa \times \sin(90 - \beta + \delta)$ = 17.77 kN/m run

Overturning Stability

Mo = moment of overturning = *Ph x dh* = 35.50 kNm/m run

$bv = bw \times \cos \alpha - dh_{soil} / \tan \beta = 1.74$m

Mr = Moment of Resistance = *Pv x bv* + *Wg x Xg* = 95.32kNm/m run

Factor of Safety Overtuning *Fo= Mr/Mo* = 2.69 > 2.0 therefore satisfactory

Sliding Stability

Normal Force on plane of sliding $N = Wg + \sum Pv$ = 79.69 kN/m run

Tangential Forces $T = \sum Ph$ = 40.81 kN/m run

Factor of Safety Sliding $Fs = \dfrac{(N \cos \alpha + T \sin \alpha) \tan \phi_{des\ (founding\ soil)}}{(T \cos \alpha - N \sin \alpha)}$

Soil friction for founding soil is 30 degrees

Fs = 1.87 > 1.5 therefore satisfactory

Bearing

Eccentricity $e = bw / 2 - (Mr - Mo)/N = 0.14$ < 1.7/6 = 0.28 therefore satisfactory

$\sigma\, toe = N / bw\ (1 + 6e / bw) = 67$kN/sqm

$\sigma\, heel = N / bw\ (1 - 6e / bw) = 22.29$kN/sqm

Maximum bearing pressure > 67kN/sqm

Design computations above are for a check on the full height of the structure and are satisfactory. Further checks should be made at each course level considering the wall is founded on the unit below where phi = 34 degrees at the gabion to gabion interface.

The following pages give the design output using Enviromesh's software. The method of analysis is based on wedge theory which yields similar results.

CAD Design Example

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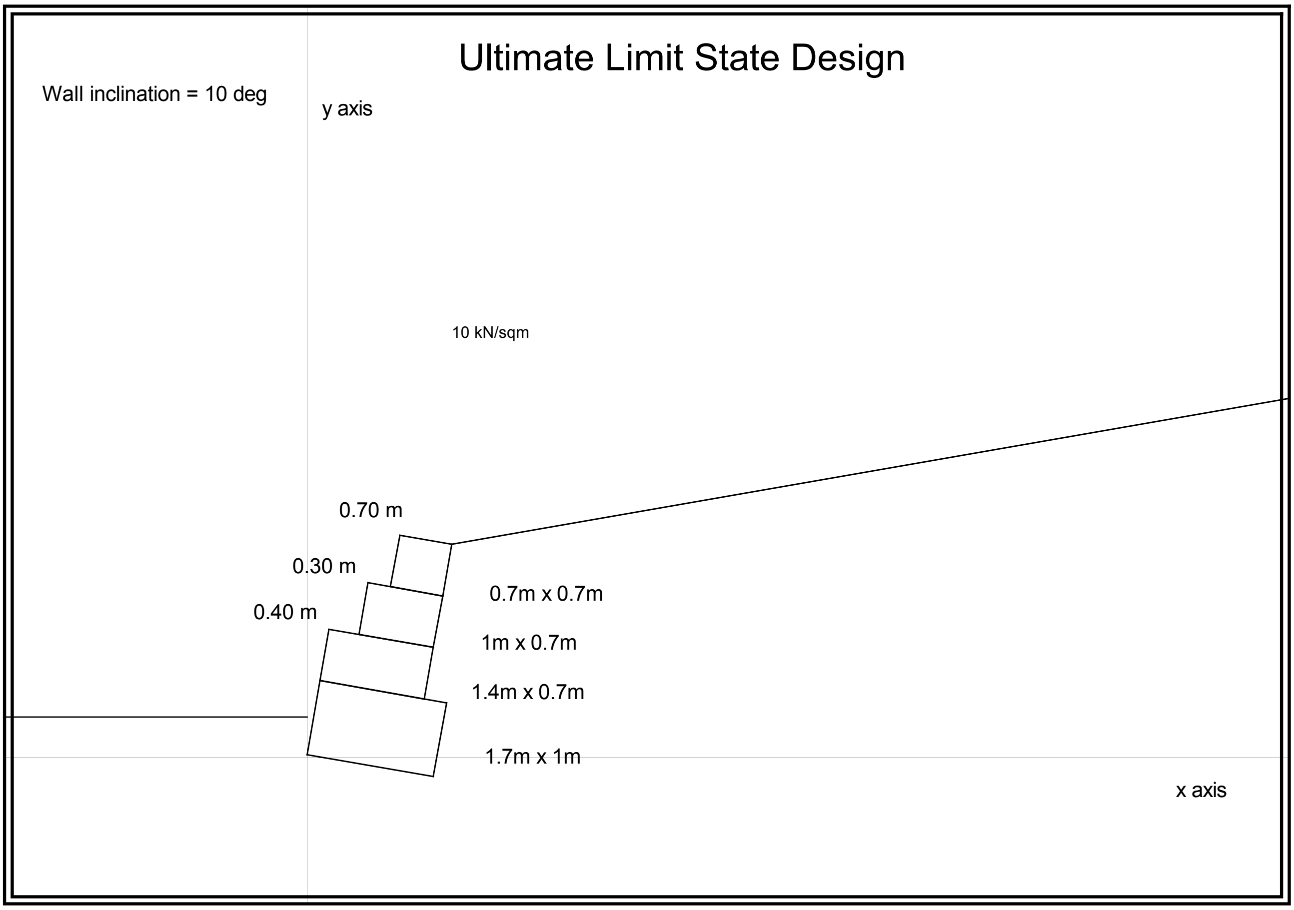
Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
www.enviromeshgabions.com

Retaining Wall Design Proposal

Project Reference:- MAN -01

Project Title:- DESIGN CHECK



This design proposal is based exclusively on the use of ENVIROMESH'S materials installed in accordance with the manufacturer's instructions.

Whilst every care has been taken in producing this design proposal, it is the customers's responsibility to satisfy himself that the design, analysis and specifications are correct. No responsibility is accepted by Cerana Limited for the accuracy of the design and specifications included in this proposal.

CAD Design Example

Design Data

Foundation Type :-

Sub Soil

Soil Parameters:-

Soil Ref	Density (kN/cum)	Friction (deg)	Cohesion (kN/sqm)
Retained soil	19	28	0
Backfill soil	19	28	
Foundation soil	19	30	0
Toe soil	19	28	0
Gabion	16 based on Limestone fill		

Loading Conditions:-

Load Type	Intensity	Start (m)	End (m)
Uniformly distributed load 1	10	0	10
Uniformly distributed load 2			
Line Load 1			
Line Load 2			
Horizontal Load			

General Wall Details :-

Wall height	3.1 m
Wall inclination	10 deg
Exposed crest width	0.7 m
Depth of Toe in (base course)	0.5 m

Sectional Details

Course	Offset	Unit width	Unit depth
1	0	1.7	1
2	0	1.4	0.7
3	0.4	1	0.7
4	0.7	0.7	0.7

Soil Profiles:-

Slope	Angle (deg)	Stretch (m)
1	10	
Toe Slope	0	

CAD Design Example

Stability Computations

Ultimate Limit State

Internal Stability

The internal stability design checks are carried out at every gabion course

for Factor of Safety on Overturning :-Fo

for Factor of Safety on Sliding :- Fs

for Eccentricity :- e

for outer bearing (toe)

for inner bearing (heel)

The Factor of Safety against Sliding at each course is computed considering the effective frictional angle on gabion to gabion interface is 35 degrees.

The minimum acceptable Factor of Safety against Sliding between courses ignoring any contribution of the wire is 1.3

The minimum acceptable Factor of Safety against Oveturning at each cousre is 2.0 excluding any contribution of the mesh or joint strength.

The eccentricity at each level must lie within the mid third, in the case of a flush faced vertical wall the eccentricity should be proportioned between 0m at the top of the wall to within the mid third at the base, in both cases if value is negative and outside the mid third the value is acceptable.

The bearing value at the back face must be positive.

Course	Factors of Safety		Eccentricity	Bearing	
	Overturning	Sliding		toe	heel
			(m)	(kN/sqm)	(kN/sqm)
4	5.68	2.13	-0.03	10.30	18.94
3	3.74	2.08	-0.04	19.30	30.67
2	3.74	2.12	-0.09	19.53	45.27

CAD Design Example

Stability Computations

Ultimate Limit State

Gabion Wall Analysis

Design requirements

The minimum acceptable Factor of Safety against Sliding must be greater than 1.5
The minimum acceptable Factor of Safety against Oveturning must be greater than 2.0
The eccentricity of the resultant force on the base must lie within the mid third of the base.
The maximum bearing value must not exceed the allowable bearing for the foundation soil.

Critical wedge details;

Critical wedge angle =	48.26 deg
Weight of Soil wedge =	87.27 kN
Total Active Thrust	40.67 kN/m run

Force	Horizontal Component kN	Lever arm about toe m	Moment due to Horizontal component kNm	Vertical Component kN	Lever arm about toe m	Moment due to Vertical component kNm
Soil	37.29	0.74	27.59	16.23	1.75	28.4
UDL1	9.54	1.26	12.02	4.15	1.8	7.47
UDL2						
LL1						
LL2						
HL						
Gabion				61.92	1.06	65.64
Sum Total	46.82		39.62	82.31		101.51

Factors of Safety

Overturning	2.57
Sliding	1.62

Eccentricity and Bearing

Eccentricity (m)	0.1 < 1.7 / 6
Outer Bearing (kN/sqm)	70.39
Inner Bearing (kN/sqm	34.53

Design notes

The stability calculations are carried out by a wedge analysis.
The Gabion wall is to be inclined at 10 degrees to the vertical.
The Gabion wall is be toed into the existing ground a minimum of 0.5 m below exiting ground level.
The gabion wall should be founded a minimum thickness of 75mm of type 1 as a blinding layer.

THE DESIGN IS BASED ON THE SOIL PARAMETERS AND GEOMETRIC PROFILE STATED. IF SOIL CONDITIONS DIFFER OR GEOMETRIC PROFILES DIFFER TO THAT IN THE DESIGN THE DESIGN MUST BE RE-EVALUATED

THE DESIGN IS BASED ON THE STRENGTH PROPERTIES, DURABILITY AND BEHAVIOUR OF ENVIROMESH WELDED MESH GABIONS AND THE RELEVANT GEOTEXTILE SPECIFICATION STATED,

DEPARTURE FROM THE SPECIFIED MATERIALS WILL NULIFY THIS DESIGN PROPOSAL

Typical Gabion Sections
Gabion 27 System and Gabion 39 System

Typical detailed sections are illustrated for various wall configurations from 1 to 4 courses high.

The full sectional details given, have been dimensioned to show the retained heights with a considered toe in of 300mm.

The sections drawn are based on the wall being founded on a granular material. The backfill is also of a granular material cut back to a line of 45 degrees. These typical sections can only be used as a basis for estimating, unless the founding and backfill materials are as described above, the surcharge does not exceed 10kN/sqm on the retained fill slope of 0 to 15 degrees, and does not exceed 5 kN/sqm on retained slopes of 15 to 34 degrees.

The slope above the wall cannot exceed the internal angle of friction of the backfill.

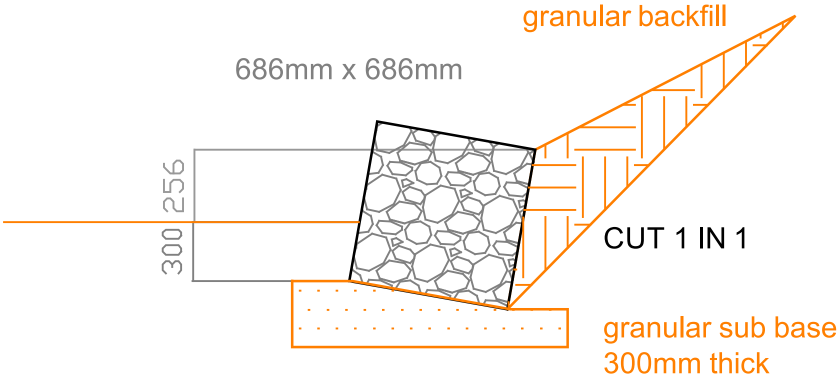
It is recommended that an applicable soil investigation survey is undertaken and that the wall is designed by a suitably qualified competent engineer.

Other configurations of coursing of gabions are given, however the retained heights will differ due to the varying stepping arrangements on each course.

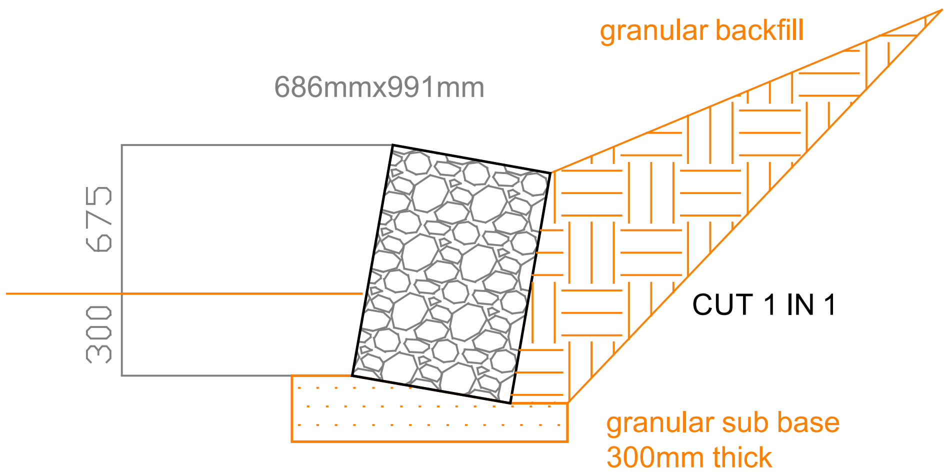
NOTE:-

No liability is accepted by Cerana Limited (Enviromesh) where a typical section as a basis for the final design is used. The details provided are guidelines only.

Single course high wall - inclined at 10 degrees
Granular foundation and backfill



Volume = 0.47cum/m run



Volume = 0.68cum/m run

DRA	RDF	SCALE	NOT TO SCALE	PROJECT TITLE
REVISIONS				TYPICAL SECTIONS GABION 27 SYSTEM
				PROJECT: G27-TYPSECTIONS-1
				NUMBER: 04-01-

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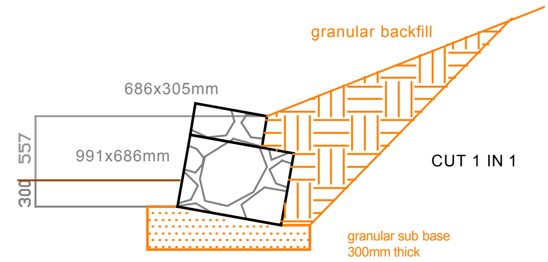
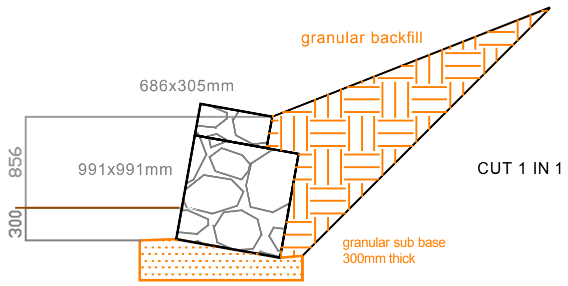
Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
www.enviromeshgabions.com

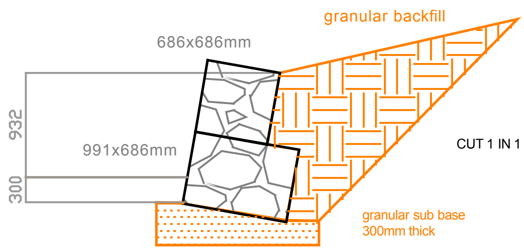
2 course high wall inclined at 10 degrees
Granular foundation and backfill



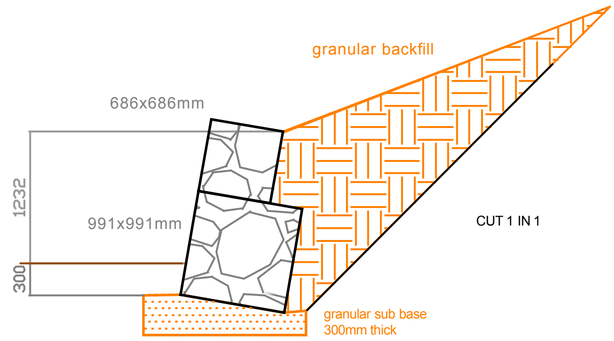
Volume = 0.89 cum/mrun



Volume = 1.19 cum/mrun

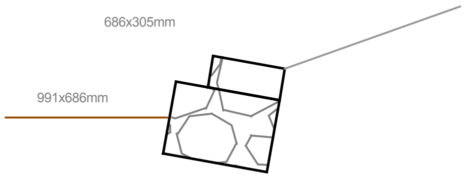


Volume = 1.15 cum/mrun

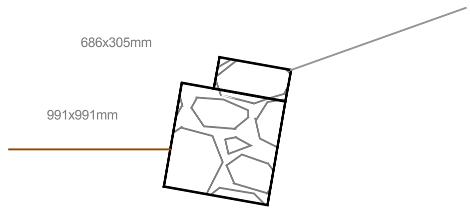


Volume = 1.45 cum/mrun

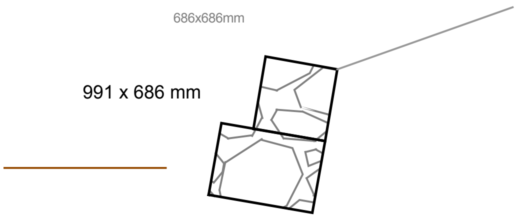
Other configurations



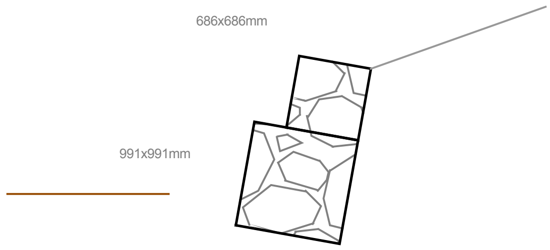
Volume = 0.89 cum/mrun



Volume = 1.19 cum/mrun



Volume = 1.15 cum/mrun



Volume = 1.45 cum/mrun

DRAWN	RDF	SCALE	NOT TO SCALE
REVISIONS			DATE

PROJECT TITLE

TYPICAL SECTIONS
GABION 27 SYSTEM

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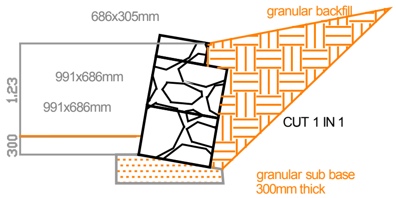
Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
www.enviromeshgabions.com

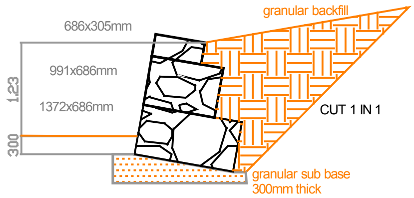
PROJECT NUMBER
G27-TYPSECTIONS-2

DATE
04-01-2007

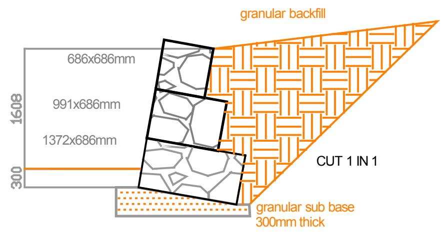
3 course high wall - inclined at 10 degrees
Granular foundation and backfill



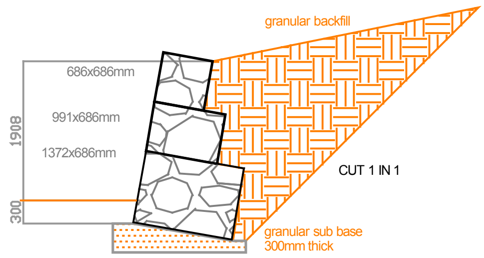
VOLUME = 1.56 CUM/MRUN



VOLUME = 1.83 CUM/MRUN

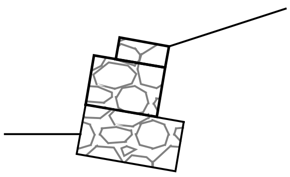


VOLUME = 2.09 CUM/MRUN



VOLUME = 2.51 CUM/MRUN

Other configurations



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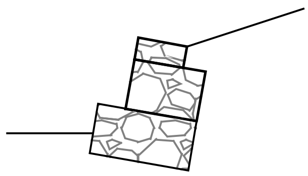

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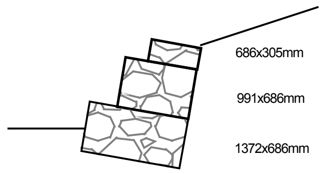

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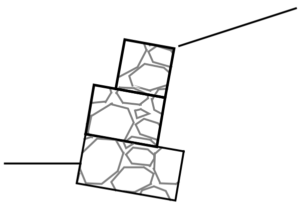

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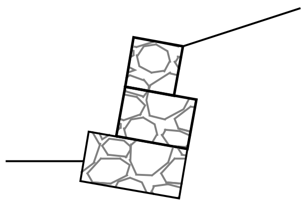

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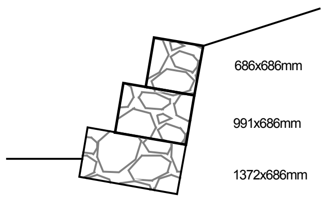

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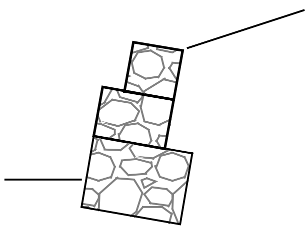

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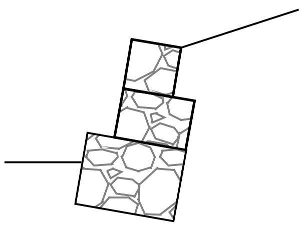

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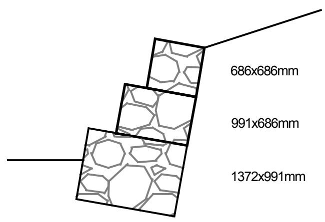
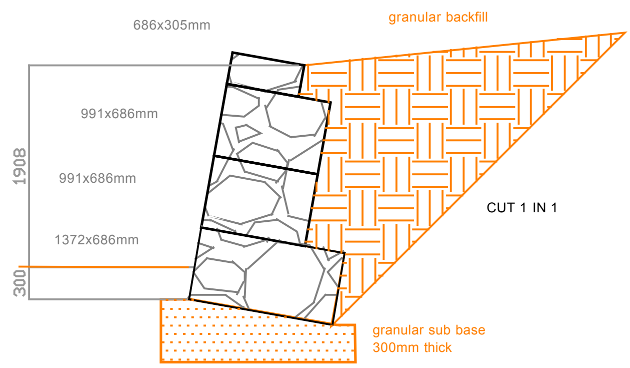


VOLUME = 2.51 CUM/MRUN

DRAWN	RDF	SCALE	NOT TO SCALE	PROJECT TITLE	
REVISIONS			DATE	TYPICAL SECTIONS GABION 27 SYSTEM	ENVIROMESH Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202 www.enviromeshgabions.com
				PROJECT NUMBER G27-TYPSECTIONS-3	DATE 04-01-2007

4 course high wall (part 1) - inclined at 10 degrees
Granular foundation and backfill



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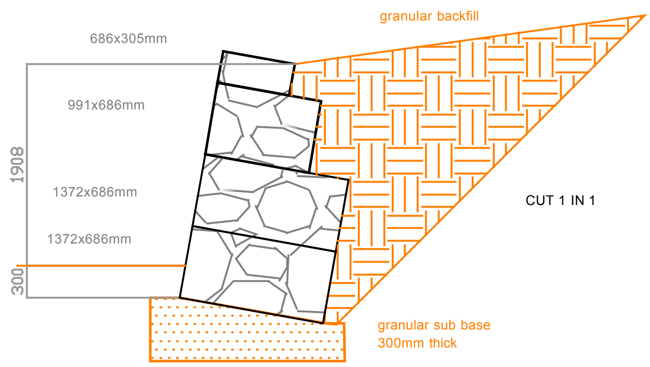
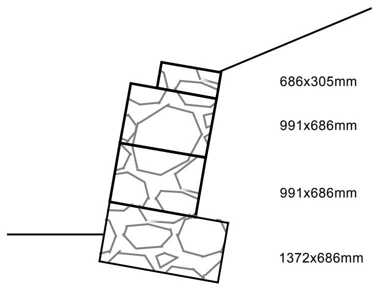


VOLUME = 2.77 CUM/MRUN

Other configurations



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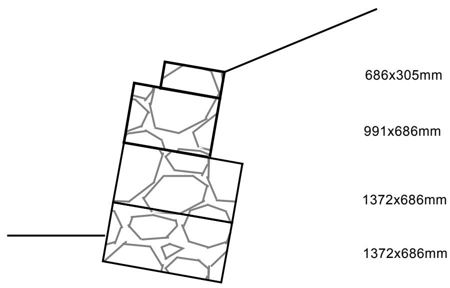

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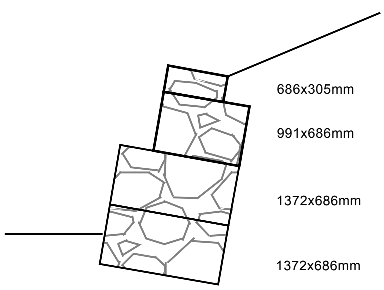

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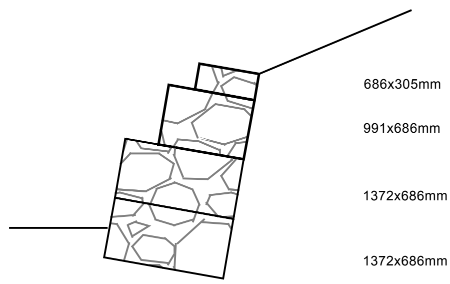

VOLUME = 2.77 CUM/MRUN

DRAWN	RDF	SCALE	NOT TO SCALE	PROJECT TITLE
REVISIONS			DATE	TYPICAL SECTIONS GABION 27 SYSTEM

PROJECT NUMBER
G27-TYPSECTIONS-4

DATE
04-01-2007

ENVIROMESH
Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
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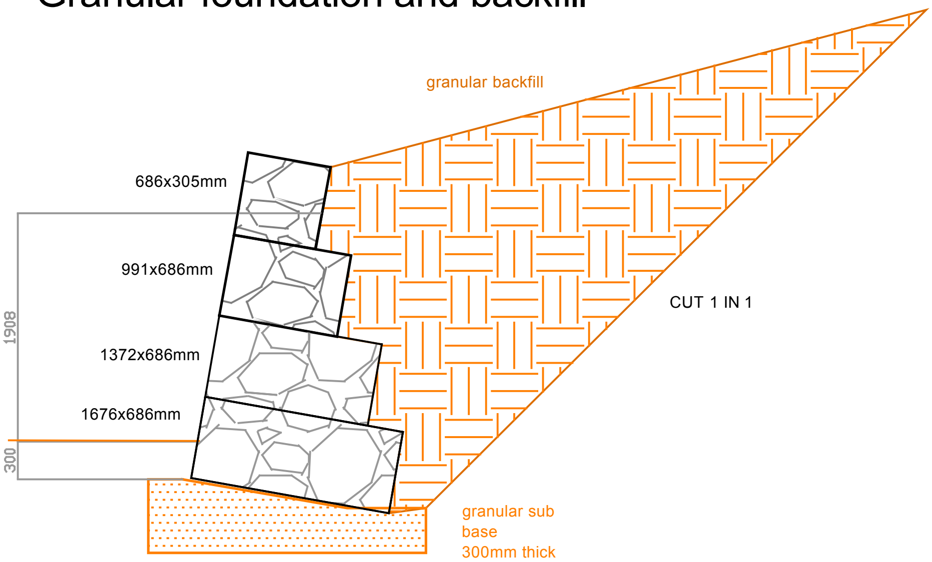
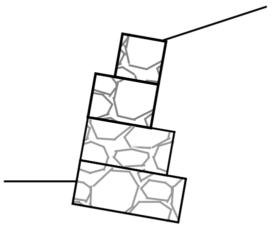
4 course high wall (part 2) - inclined at 10 degrees
Granular foundation and backfill

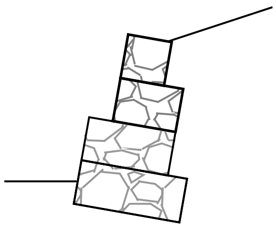


VOLUME = 3.24 CUM/M RUN

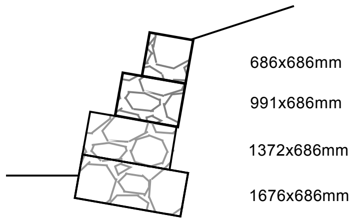
Other configurations



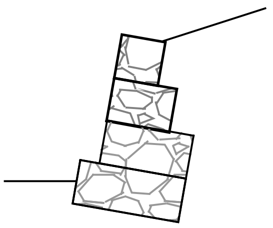
VOLUME = 3.24 CUM/M RUN

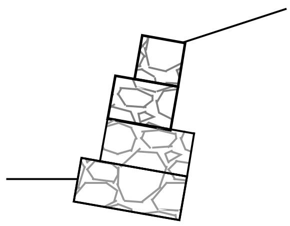


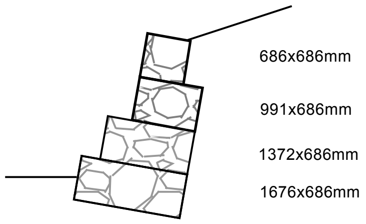
VOLUME = 3.24 CUM/M RUN

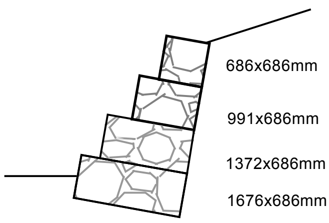


VOLUME = 3.24 CUM/M RUN





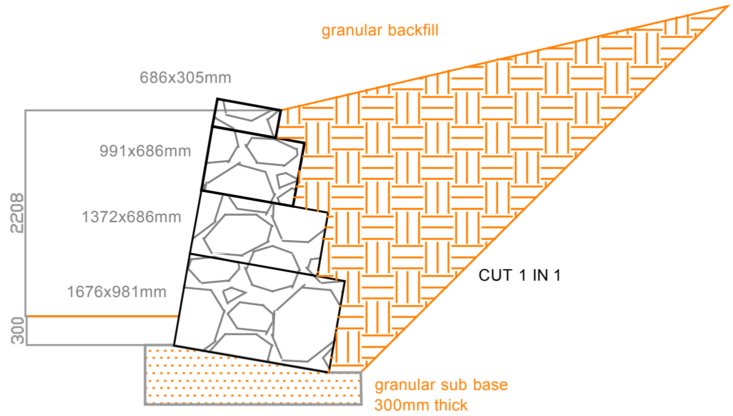




DRAWN	RDF	SCALE	NOT TO SCALE	PROJECT TITLE	
REVISIONS			DATE	TYPICAL SECTIONS GABION 27 SYSTEM	ENVIROMESH Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202 www.enviromeshgabions.com
				PROJECT NUMBER G27-TYPSECTIONS-5	DATE 04-01-2007

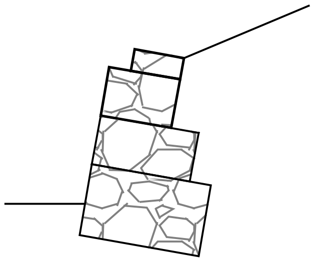
The design and specifications of gabions and associated materials are limited to materials sourced from (Enviromesh)

4 course high wall (part 3) - inclined at 10 degrees
Granular foundation and backfill

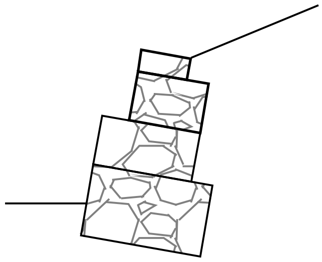


VOLUME = 3.49 CUM/MRUN

Other configurations



VOLUME = 3.49 CUM/MRUN



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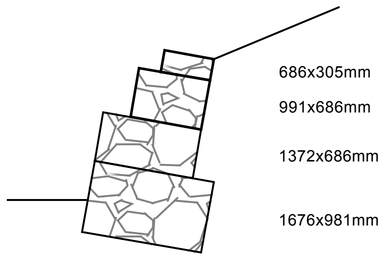

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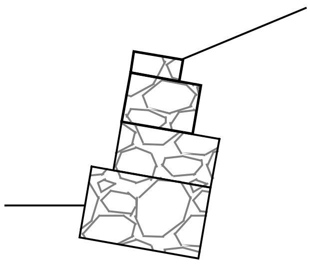

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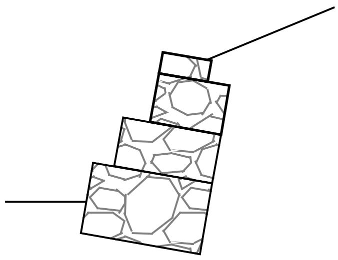

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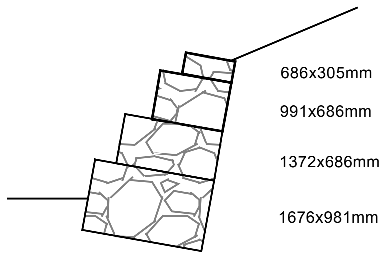


VOLUME = 3.49 CUM/MRUN

DRAWN	RDF	SCALE	NOT TO SCALE
REVISIONS			DATE

PROJECT TITLE

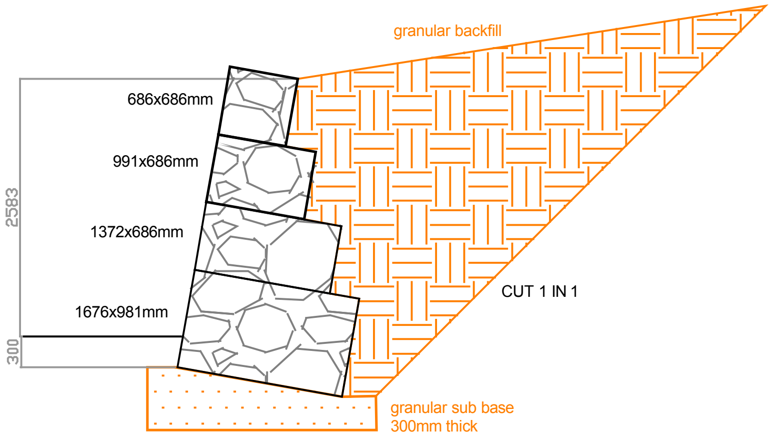
TYPICAL SECTIONS
GABION 27 SYSTEM

PROJECT NUMBER
G27-TYPSECTIONS-6

DATE
04-01-2007

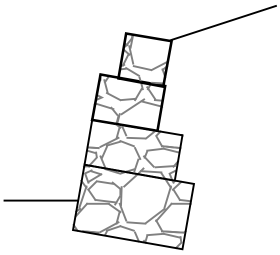
ENVIROMESH
Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
www.enviromeshgabions.com

4 course high wall (part 4) - inclined at 10 degrees
Granular foundation and backfill



VOLUME = 3.75 CUM/MRUN

Other configurations



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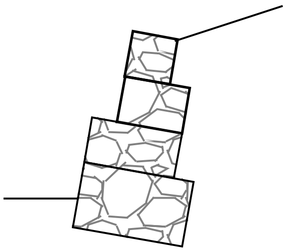

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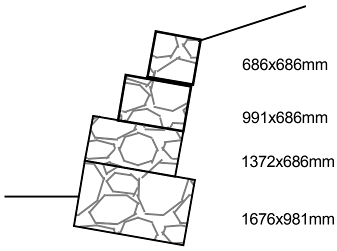

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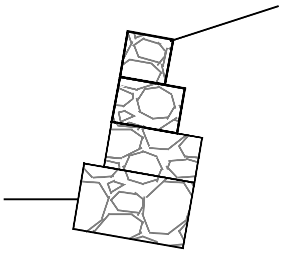

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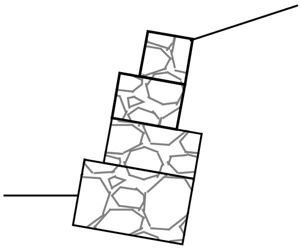

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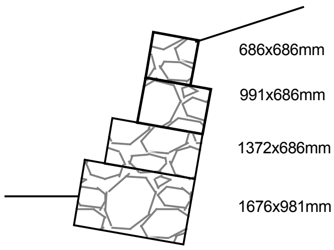

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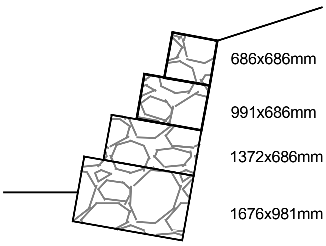


VOLUME = 3.75 CUM/MRUN

DRAWN RDF | SCALE NOT TO SCALE

REVISIONS | DATE

PROJECT TITLE
TYPICAL SECTIONS
GABION 27 SYSTEM

ENVIROMESH
Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
www.enviromeshgabions.com

PROJECT NUMBER
G27-TYPSECTIONS-7

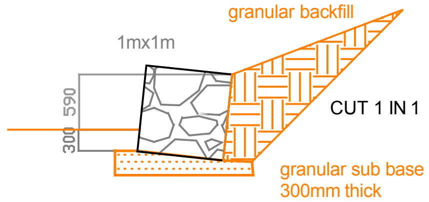
DATE
04-01-2007

NOTES :_

Retained height dimensions are indicative, true dimensions are dependant on which type of gabion is specified , welded mesh or woven mesh

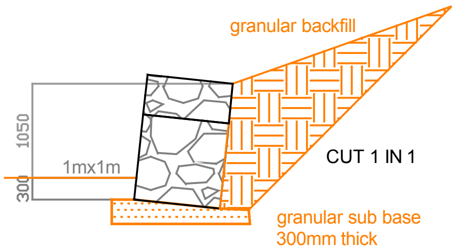
Offset on each gabion course can vary from 0 to max offset possible without gabions overhanging unit below

Single course high wall - inclined at 6 degrees
Granular backfiil and foundation

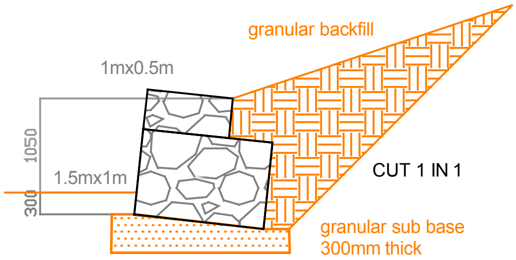


Volume =1.0cum/m run

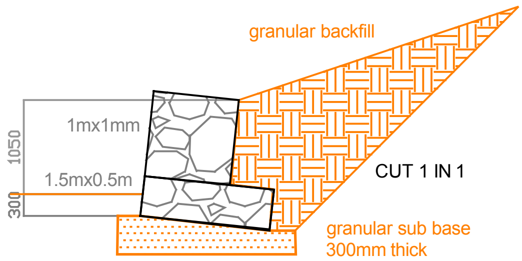
2 course high wall - inclined at 6 degrees
Granular backfiil and foundation



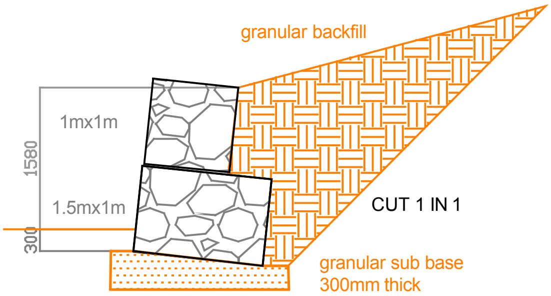
Volume =1.5cum/m run



Volume =2.0cum/m run

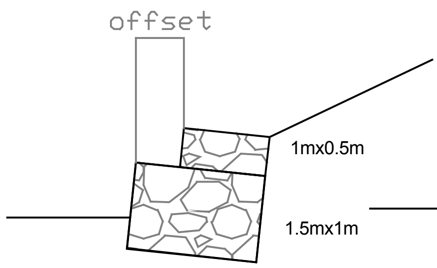


Volume =1.75cum/m run



Volume =2.5cum/m run

Other configurations



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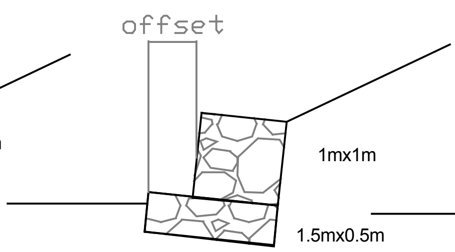
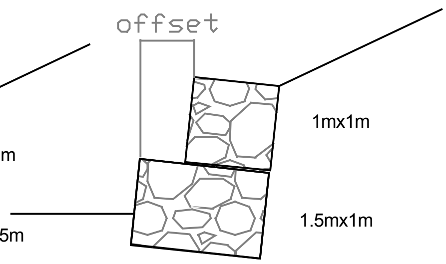


Volume =1.75cum/m run

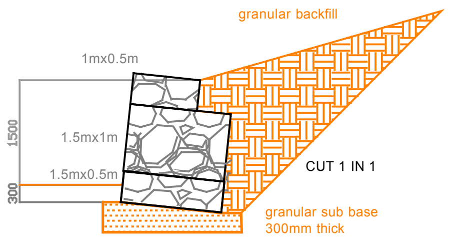


Volume =1.75cum/m run

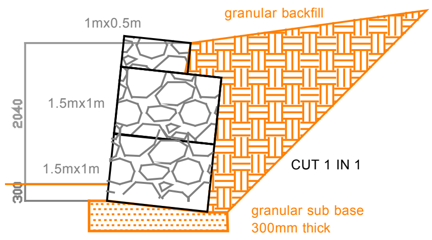
DRAWN	RDF	SCALE	NOT TO SCALE	PROJECT TITLE TYPICAL SECTIONS STANDARD GABION 29 SYSTEM	ENVIROMESH
REVISIONS			DATE	PROJECT NUMBER G39-TYPSECTIONS-1	DATE 04-01-2007

Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
www.enviromeshgabions.com

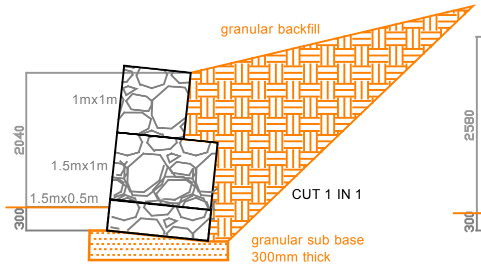
3 course high wall (part 1) - inclined at 6 degrees
Granular backfiil and foundation



Volume =2.75cum/m run



Volume =3.5cum/m run



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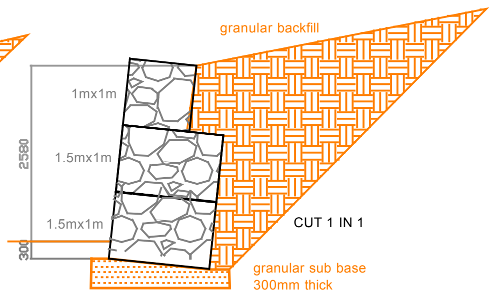
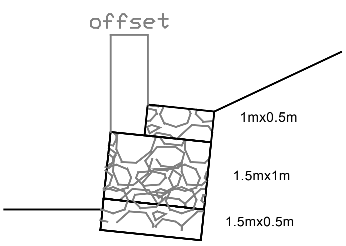


Volume =4cum/m run

Other configurations



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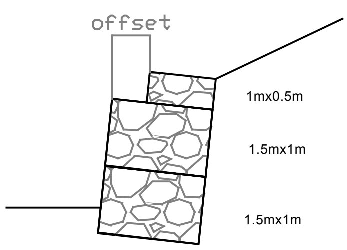
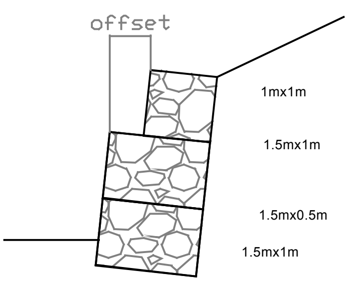


Volume =3.5cum/m run



Volume =3.5cum/m run

notes :_

Retained height dimensions are indicative, true dimensions are dependant on which type of gabion is specified , welded mesh or woven mesh

Offset on each gabion course can vary from 0 to max
offset possible without gabions overhanging unit below

DRAWN	RDF	SCALE	NOT TO SCALE
REVISIONS			DATE

PROJECT TITLE

TYPICAL SECTIONS
STANDARD GABION 39 SYSTEM

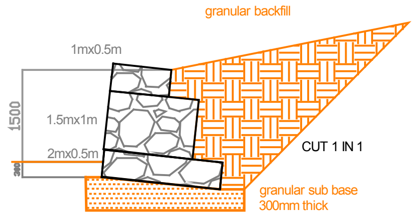
ENVIROMESH

Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
www.enviromeshgabions.com

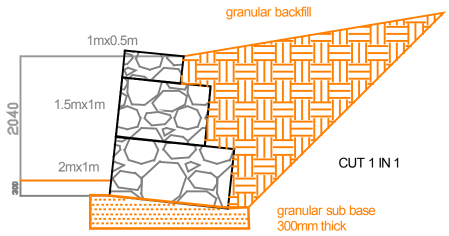
PROJECT NUMBER
G39-TYPSECTIONS-2

DATE
04-01-2007

3 course high wall (part 1) - inclined at 6 degrees
Granular backfiil and foundation



Volume =3.0cum/m run



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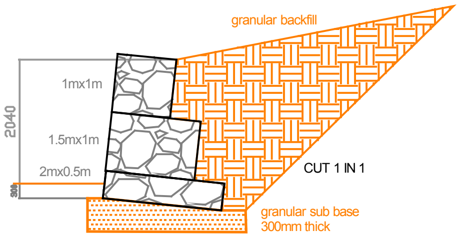
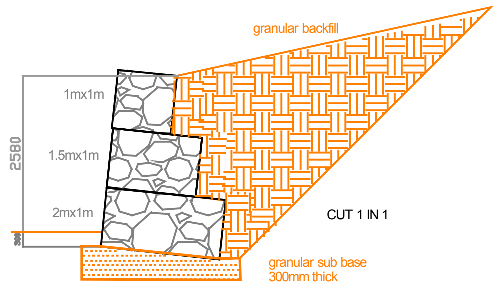
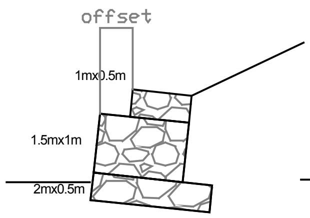


Volume =3.5cum/m run

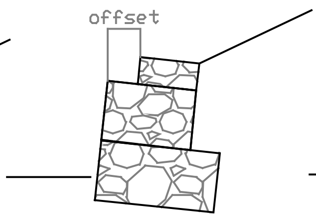


Volume =4.5 cum/m run

Other configurations



Volume =3.0cum/m run



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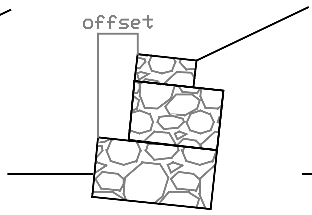

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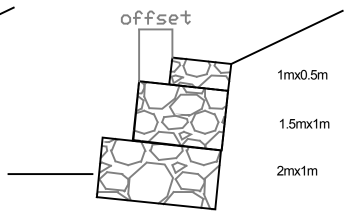
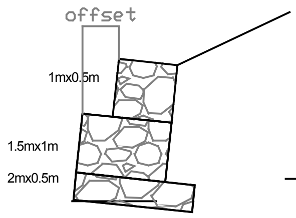
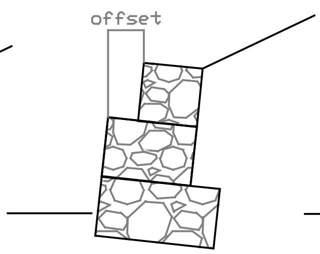


Volume =4cum/m run



Volume =3.5cum/m run



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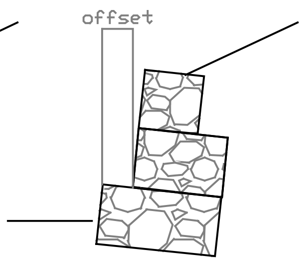

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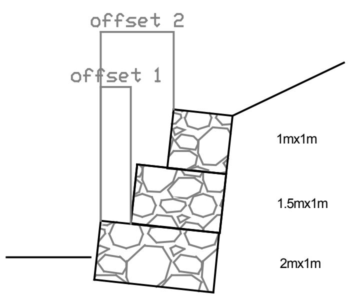

Volume =4.5 cum/m run

notes :_

Retained height dimensions are indicative, true dimensions are dependant on which type of gabion is specified , welded mesh or woven mesh

Offset on each gabion course can vary from 0 to max offset possible without gabions overhanging unit below

DRAWN	RDF	SCALE	NOT TO SCALE	PROJECT TITLE
REVISIONS			DATE	TYPICAL SECTIONS STANDARD GABION 39 SYSTEM
				PROJECT NUMBER G39-TYPSECTIONS-3
				DATE 04-01-2007

ENVIROMESH
Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
www.enviromeshgabions.com

System Comparison

Gabion 27 System V Gabion 39 System

RETAINED WALL HEIGHT	BASE WIDTH	VOLUME GABION 27	VOLUME STANDARD GABION 39	DRAWING
(m)	(m)	(cum)	(cum)	
0 TO 0.3	0.7 1.0	0.47	 1.0	G27 TYPSECTIONS-1 G39 TYPSECTIONS-1
0.3 TO 0.7	0.7 1.0 1.0	0.68 0.89	 1	G27 TYPSECTIONS-1 G27 TYPSECTIONS-2 G39 TYPSECTIONS-1
0.7 TO 1.0	1.0 1.0 1.0 1.5 1.5	1.19 1.15	 1.5 2.0 1.75	G27 TYPSECTIONS-2 G27 TYPSECTIONS-2 G39 TYPSECTIONS-1 G39 TYPSECTIONS-1 G39 TYPSECTIONS-1
1.0 TO 1.3	1.0 1.0 1.37 1.0 1.5 1.5	1.45 1.56 1.83	 1.5 2.0 1.75	G27 TYPSECTIONS-2 G27 TYPSECTIONS-3 G27 TYPSECTIONS-3 G39 TYPSECTIONS-1 G39 TYPSECTIONS-1 G39 TYPSECTIONS-1
1.3 TO 1.7	1.37 1.50 1.50	2.09	 2.75 2.5	G27 TYPSECTIONS-3 G39 TYPSECTIONS-2 G39 TYPSECTIONS-1
1.7 TO 2.0	1.37 1.37 1.67 1.5 1.5	2.51 2.77 2.97	 3.50 3.25	G27 TYPSECTIONS-3 G27 TYPSECTIONS-4 G27 TYPSECTIONS-4 G39 TYPSECTIONS-2 G39 TYPSECTIONS-2
2.0 TO 2.3	1.67 1.67 1.5 1.5	3.49 3.24	 3.50 3.25	G27 TYPSECTIONS-6 G27 TYPSECTIONS-5 G39 TYPSECTIONS-2 G39 TYPSECTIONS-2
2.3 TO 2.6	1.67	3.75		G27 TYPSECTIONS-7

The above table is a comparison based on the typical sectional details for Gabion 27 system and standard Gabion 39 systems.

For comparison, the volume and base widths for band heights are compared to the volumes for each section.

Gabion 27 system in most instances provides both a reduced volume for the wall and a reduced base width.

ENVIROMESH

Specifications

It is important to ensure that the correct specification is used for the gabions.

The following sheets give the specifications for:-

Welded Mesh Gabion 27 System

Welded Mesh Gabion 39 System

Hexagonal Woven Mesh Gabions

Where the gabions are subject to salt spray, saline water, acidic soils (out of range PH7 to 10) or brackish water, then PVC - Zinc coated hexagonal gabions should be specified.

For schemes where visual quality is not important, either woven or standard welded mesh gabions are acceptable.

For prestige schemes where the visual quality is important, the best specification is the Gabion 27 system.

ENVIROMESH

Garner Street Business Park, Mercurial, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
www.enviromeshgabions.com

WELDED MESH GABION SPECIFICATION

Gabion 27 System – Galfan Coated

Gabions shall comply with the following specifications:

MANUFACTURE: Gabions shall be manufactured from a hard drawn steel wire formed into a bi-axial mesh grid by electrically welding the cross wires at every intersection. The weld strength is to be 70% of the ultimate tensile strength of the wire. Gabions are to be factory assembled with stainless steel clips (minimum one every third mesh opening) connecting side panels and diaphragms to the base panel and the lid to the face panel. Diaphragms are to be at 686mm centres within the unit and a maximum of 1.38m across the width.

MESH SIZE: The mesh openings shall be square and of a nominal dimension of 76.2mm on the grid.

MESH WIRE: The nominal wire diameter shall be 3.0mm for the base, ends, diaphragms and the lid on the upper most unit and a 4.0mm diameter wire for the front and rear panels. All wire is in accordance with BS EN 10218-3: 1997 and of a tensile strength within the range of 540-770 N/mm2.

CORROSION PROTECTION: Wire shall be galfan coated (95% Zn / 5% Al) in accordance with BS EN 10244-2: 2001.

JOINTING: Gabions shall be provided with lacing wire and helical spirals for site assembly. The lacing wire shall be of a nominal wire diameter of 2.2mm and the helicals of 3.00mm (all in accordance with the corrosion protection specified) for final jointing.

ROCKFILL: Gabion fill shall be a hard durable and non frost susceptible (rock or stone type) having a minimum dimension of not less than the mesh opening and a maximum dimension of 200mm.

CONSTRUCTION: All rock fill shall be packed tightly to minimize voids and the rock fill on the exposed face of the gabion is to be hand packed. Corner bracing ties 2 per face and rear cell at mid height on 686mm high units and at 4 per face and rear cell at third heights on 1m high units. Adjacent units are to be jointed with helical spirals on the vertical joints and laced on the horizontal joints at the front and rear of coursed joints.
Units shall be filled such that the mesh base of the unit above bears down onto the rock fill. The lid shall be wired down on all joints and across the diaphragms.

Above jointing is supplied as standard, the following alternatives are also acceptable.

Pneumatically closed galfan coated "C" rings for horizontal jointing at 1 ring every other mesh opening.

ENVIROMESH

Garner Street Business Park, Etruria, Stoke-on-Trent, Staffordshire, ST4 7BH
Tel: +44 (0)845 136 0101 Fax: +44 (0)845 136 0202
www.enviromeshgabions.com

WELDED MESH GABION SPECIFICATION
Gabion 39 System - 3.00mm Wire Diameter - Galfan Coated

Gabions shall comply with the following specifications:

MANUFACTURE: Gabions shall be manufactured from a hard drawn steel wire formed into a bi-axial mesh grid by electrically welding the cross wires at every intersection. The weld strength is to be 70% of the ultimate tensile strength of the wire. Gabions are to be factory assembled with stainless steel clips (minimum one every third mesh opening) connecting side panels and diaphragms to the base panel and the lid to the face panel.
Diaphragms to be at nominal 1m centres on the unit length, except for 1.5m long gabions which have no internal diaphragm.

MESH SIZE: The mesh openings shall be square and of a nominal dimension of 76.2mm on the grid.

MESH WIRE: The nominal wire diameter shall be 3.0mm in accordance with BS EN 10218-2 1997. The tensile strength falls within a range of 540-770 N/mm^2.

CORROSION PROTECTION: Wire shall be galfan coated (95% Zn / 5% Al) in accordance with BS EN 10244-2: 2001.

JOINTING: Gabions shall be provided with lacing wire for site assembly. The lacing wire shall be of a nominal wire diameter of 2.2mm (all in accordance with the corrosion protection specified) for final jointing.

ROCKFILL: Gabion fill shall be a hard durable and non frost susceptible (rock or stone type) having a minimum dimension not less than the mesh opening and a maximum dimension of 200mm.

CONSTRUCTION: All rock fill shall be packed tightly to minimize voids and the rock fill on the exposed face of the gabion is to be hand packed. Internal windlass bracing ties are to be incorporated at 2 per 1sqm of face at 1/3rd & 2/3 intervals for 1m high units and 1 placed centrally for 0.5m high units. The adjacent gabion units are to be tied together with continuous lacing on the vertical joints as well as horizontally at the front and rear of coursed joints. The units shall be filled such that the mesh lid bears down onto the rock fill. The lid shall be wired down on all joints and across the diaphragms.

Above jointing and internal bracing is supplied as standard, the following alternatives are also acceptable:

Full height helicals in 3.0mm galfan coated wire for vertical jointing.
Pneumatically closed galfan coated "C" rings for vertical and horizontal jointing at 1 ring every other mesh opening.
Galfan coated preformed corner bracing ties, 4 per m2 of face.

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WELDED MESH GABION SPECIFICATION
Gabion 39 System - 4.00mm Wire Diameter - Galfan Coated

Gabions shall comply with the following specifications:

MANUFACTURE: Gabions shall be manufactured from a hard drawn steel wire formed into a bi-axial mesh grid by electrically welding the cross wires at every intersection. The weld strength is to be 70% of the ultimate tensile strength of the wire. Gabions are to be factory assembled with stainless steel clips (minimum one every third mesh opening) connecting side panels and diaphragms to the base panel and the lid to the face panel.
Diaphragms to be at nominal 1m centres on the unit length, except for 1.5m long gabions which have no internal diaphragm.

MESH SIZE: The mesh openings shall be square and of a nominal dimension of 76.2mm on the grid.

MESH WIRE: The nominal wire diameter shall be 4.0mm in accordance with BS EN 10218-2 1997. The tensile strength falls within a range of 540-770 N/mm^{2}.

CORROSION PROTECTION: Wire shall be galfan coated (95% Zn / 5% Al) in accordance with BS EN 10244-2: 2001.

JOINTING: Gabions shall be provided with lacing wire for site assembly. The lacing wire shall be of a nominal wire diameter of 2.2mm (all in accordance with the corrosion protection specified) for final jointing.

ROCKFILL: Gabion fill shall be a hard durable and non frost susceptible (rock or stone type) having a minimum dimension not less than the mesh opening and a maximum dimension of 200mm.

CONSTRUCTION: All rock fill shall be packed tightly to minimize voids and the rock fill on the exposed face of the gabion is to be hand packed. Internal windlass bracing ties are to be incorporated at 2 per 1sqm of face at 1/3rd & 2/3 intervals for 1m high units and 1 placed centrally for 0.5m high units. The adjacent gabion units are to be tied together with continuous lacing on the vertical joints as well as horizontally at the front and rear of coursed joints. The units shall be filled such that the mesh lid bears down onto the rock fill. The lid shall be wired down on all joints and across the diaphragms.

Above jointing and internal bracing is supplied as standard, the following alternatives are also acceptable:

Full height helicals in 3.0mm galfan coated wire for vertical jointing.
Pneumatically closed galfan coated "C" rings for vertical and horizontal jointing at 1 ring every other mesh opening.
Galfan coated preformed corner bracing ties, 4 per m2 of face.

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WELDED MESH GABION SPECIFICATION
Gabion 39 System - 3.00 / 4.00mm Wire Diameter - Galfan Coated

Gabions shall comply with the following specifications:

MANUFACTURE: Gabions shall be manufactured from a hard drawn steel wire formed into a bi-axial mesh grid by electrically welding the cross wires at every intersection. The weld strength is to be 70% of the ultimate tensile strength of the wire. Gabions are to be factory assembled with stainless steel clips (minimum one every third mesh opening) connecting side panels and diaphragms to the base panel and the lid to the face panel.
Diaphragms to be at nominal 1m centres on the unit length, except for 1.5m long gabions which have no internal diaphragm.

MESH SIZE: The mesh openings shall be square and of a nominal dimension of 76.2mm on the grid.

MESH WIRE: The nominal wire diameter shall be 3.0mm for the lid, base, back and internal panels and 4.00mm for the facing exposed panels. All wire is in accordance with BS EN 10218-2 1997. The tensile strength falls within a range of 540-770 N/mm^{2}.

CORROSION PROTECTION: Wire shall be galfan coated (95% Zn / 5% Al) in accordance with BS EN 10244-2: 2001.

JOINTING: Gabions shall be provided with lacing wire for site assembly. The lacing wire shall be of a nominal wire diameter of 2.2mm (all in accordance with the corrosion protection specified) for final jointing.

ROCKFILL: Gabion fill shall be a hard durable and non frost susceptible (rock or stone type) having a minimum dimension not less than the mesh opening and a maximum dimension of 200mm.

CONSTRUCTION: All rock fill shall be packed tightly to minimize voids and the rock fill on the exposed face of the gabion is to be hand packed. Internal windlass bracing ties are to be incorporated at 2 per 1sqm of face at 1/3rd & 2/3 intervals for 1m high units and 1 placed centrally for 0.5m high units. The adjacent gabion units are to be tied together with continuous lacing on the vertical joints as well as horizontally at the front and rear of coursed joints. The units shall be filled such that the mesh lid bears down onto the rock fill. The lid shall be wired down on all joints and across the diaphragms.

Above jointing and internal bracing is supplied as standard, the following alternatives are also acceptable:

Full height helicals in 3.0mm galfan coated wire for vertical jointing.
Pneumatically closed galfan coated "C" rings for vertical and horizontal jointing at 1 ring every other mesh opening..
Galfan coated preformed corner bracing ties, 4 per m2 of face.

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WELDED MESH GABION SPECIFICATION
Gabion 39 System - 5.00mm Wire Diameter - Galfan Coated

Gabions shall comply with the following specifications:

MANUFACTURE: Gabions shall be manufactured from a hard drawn steel wire formed into a bi-axial mesh grid by electrically welding the cross wires at every intersection. The weld strength is to be 70% of the ultimate tensile strength of the wire. Gabions are to be factory assembled with stainless steel clips (minimum one every third mesh opening) connecting side panels and diaphragms to the base panel and the lid to the face panel.
Diaphragms to be at nominal 1m centres on the unit length, except for 1.5m long gabions which have no internal diaphragm.

MESH SIZE: The mesh openings shall be square and of a nominal dimension of 76.2mm on the grid.

MESH WIRE: The nominal wire diameter shall be 5.0mm in accordance with BS EN 10218-2 1997. The tensile strength falls within a range of 540-770 N/mm^2.

CORROSION PROTECTION: Wire shall be galfan coated (95% Zn / 5% Al) in accordance with BS EN 10244-2: 2001.

JOINTING: Gabions shall be provided with lacing wire for site assembly. The lacing wire shall be of a nominal wire diameter of 2.2mm (all in accordance with the corrosion protection specified) for final jointing.

ROCKFILL: Gabion fill shall be a hard durable and non frost susceptible (rock or stone type) having a minimum dimension not less than the mesh opening and a maximum dimension of 200mm.

CONSTRUCTION: All rock fill shall be packed tightly to minimize voids and the rock fill on the exposed face of the gabion is to be hand packed. Internal windlass bracing ties are to be incorporated at 2 per 1sqm of face at 1/3rd & 2/3 intervals for 1m high units and 1 placed centrally for 0.5m high units. The adjacent gabion units are to be tied together with continuous lacing on the vertical joints as well as horizontally at the front and rear of coursed joints. The units shall be filled such that the mesh lid bears down onto the rock fill. The lid shall be wired down on all joints and across the diaphragms.

Above jointing and internal bracing is supplied as standard, the following alternatives are also acceptable:

Full height helicals in 3.0mm galfan coated wire for vertical jointing.
Pneumatically closed galfan coated "C" rings for vertical and horizontal jointing at 1 ring every other mesh opening.
Galfan coated preformed corner bracing ties, 4 per m2 of face.

ENVIROMESH

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WOVEN HEXAGONAL MESH GABION SPECIFICATION

2.70mm Wire Diameter Galvanised Coated

Gabions shall comply with the following specifications

MANUFACTURE: Gabions shall be manufactured from double twist hexagonal woven wire mesh in accordance with BS EN 10223-3:1998.

Diaphragms to be at nominal1m centres on the unit length, except for 1.5m long gabions which have no internal diaphragm.

MESH SIZE: The mesh openings shall be hexagonal and of a nominal dimension of 80mm x 100mm.

MESH WIRE: The nominal wire mesh diameter for the body of the gabion shall be 2.70mm in diameter and of a nominal 3.40mm for the edge selvedge wire.
All wire shall be in accordance with BS EN 10218-2:1997.
The tensile strength falls within a range of 350 to 575 N/mm^{2}.

CORROSION PROTECTION: Wire shall be zinc coated to BS EN10244-2: 2001

JOINTING: Gabions shall be provided with lacing wire or ‘C’ rings for site assembly. The lacing wire shall be of a nominal wire diameter of 2.2mm (all in accordance with the corrosion protection specified) for final jointing.

ROCKFILL: Gabion fill shall be a hard durable and non frost susceptible (rock or stone type) having a minimum dimension not less than the mesh opening and a maximum dimension of 200mm.

CONSTRUCTION: All rock fill shall be packed tightly to minimize voids and the rock fill on the exposed face of the gabion is to be hand packed. Internal windlass bracing ties are to be incorporated at 2 per 1sqm of face at 1/3rd & 2/3 intervals for 1m high units and 1 placed centrally for 0.5m high units. The adjacent gabion units are to be tied together with continuous lacing on the vertical joints as well as horizontally at the front and rear of coursed joints. Alternatively ‘C’ rings may be used with a pneumatic tool with one being placed every other mesh space.
The units shall be filled such that the mesh lid bears down onto the rock fill. The lid shall be wired down or “C” ringed as above on all joints and across the diaphragms.

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www.enviromeshgabions.com

WOVEN HEXAGONAL MESH GABION SPECIFICATION

2.70 / 3.70mm Wire Diameter Galvanised and PVC Coated

Gabions shall comply with the following specifications

MANUFACTURE: Gabions shall be manufactured from double twist hexagonal woven wire mesh in accordance with BS EN 10223-3:1998.

Diaphragms to be at nominal1m centres on the unit length, except for 1.5m long gabions which have no internal diaphragm.

MESH SIZE: The mesh openings shall be hexagonal and of a nominal dimension of 80mm x 100mm.

MESH WIRE: The nominal wire mesh diameter for the body of the gabion shall be 2.70mm in diameter and of a nominal 3.40mm for the edge selvedge wire.
All wire shall be in accordance with BS EN 10218-2:1997.
The tensile strength falls within a range of 350 to 575 $N/mm^{2.}$

CORROSION PROTECTION: Wire shall be zinc coated to BS EN10244-2 2001.
An additional extruded u-PVC coating of nominal 0.5mm radial thickness is applied over the galvanised wire.

JOINTING: Gabions shall be provided with lacing wire or ‘C’ rings for site assembly. The lacing wire shall be of a nominal wire diameter of 2.2mm (all in accordance with the corrosion specified) for final jointing.

ROCKFILL: Gabion fill shall be a hard durable and non frost susceptible rock or stone type having a minimum dimension not less than the mesh opening and a maximum dimension of 200mm.

CONSTRUCTION: All rock fill shall be packed tightly to minimize voids and the rock fill on the exposed face of the gabion is to be hand packed. Internal windlass bracing ties are to be incorporated at 2 per 1sqm of face at 1/3rd & 2/3 intervals for 1m high units and 1 placed centrally for 0.5m high units. The adjacent gabion units are to be tied together with continuous lacing on the vertical joints as well as horizontally at the front and rear of coursed joints. Alternatively ‘C’ rings may be used with a pneumatic tool with one being placed every other mesh space.
The units shall be filled such that the mesh lid bears down onto the rock fill. The lid shall be wired down or “C” ringed as above on all joints and across the diaphragms.

Tips on Gabion Wall Design

When designing walls the following tips may be of help:

1 Gabion courses should fully bear down on the unit below and not overhang at the rear.

2 Slopes of retained fill cannot exceed the internal angle of friction of the soil.

3 In poor ground bearing conditions opt for a larger base and / or stepped wall configuration to even bearing pressures. Embed a wider founding gabion to spread the loading over a greater area.

4 Avoid where possible walls built with a vertical face. The section will increase and deformation on the face will be more visible.

5 For quality installations, use the Gabion 27 system which has a heavier mesh face and smaller cell size.

For standard system 39 gabions, opt for a heavier facing mesh

6 When using standard gabion 39 system, nominally step the face of the wall at each course.

7 Gabion 27 system has factory preset offsets for each course or can be flush.

8 Ensure that the design is based on factual soil investigations.

9 Select the gabion system based on stability, economy of design, volume of earth works required and quality of installation required.

Gabion 27 system will give the best overall performance.

10 Seek design support from the manufacturer / supplier of gabions.

<u>Enviromesh provide a free desktop design feasibility service.</u>

ENVIROMESH

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Staffordshire, ST4 7BH

Tel: +44 (0) 845 136 0101   Fax: +44 (0) 845 136 0202

www.enviromeshgabions.com

CONTACTS:

Roger Farmer **Technical Director**	**Mob: +44 (0) 7725 244 636** **Email: roger.farmer@enviromeshgabions.com**
Neil Holmes **Commercial Director**	**Mob: +44 (0) 7725 244 637** **Email: neil.holmes@enviromeshgabions.com**

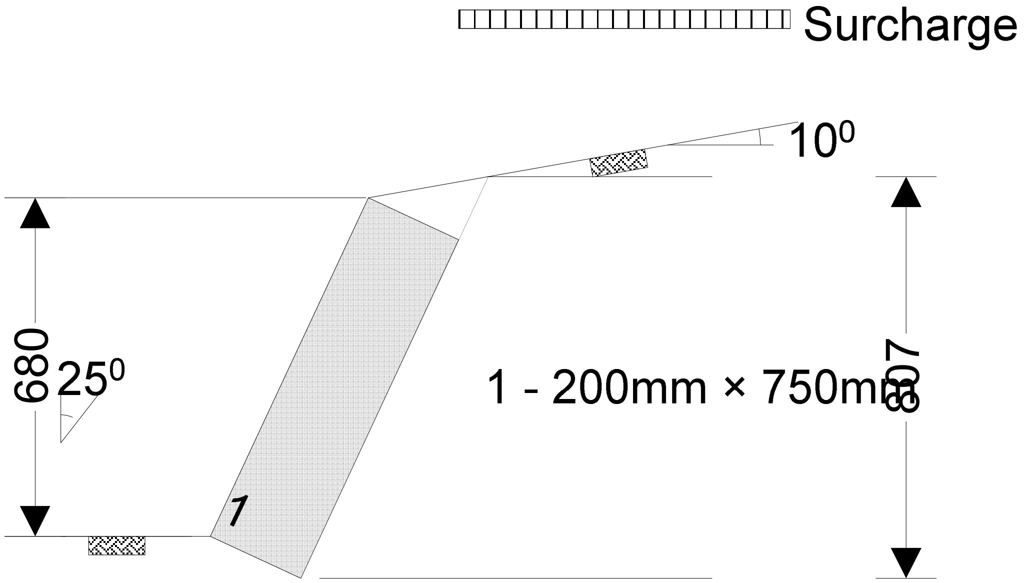
01/02/07 Edition 1

GABION RETAINING WALL ANALYSIS & DESIGN (BS8002)

GABION RETAINING WALL ANLYSIS & DESIGN

In accordance with BS8002:2015 - Code of Practice for Earth Retaining Structures and the UK National Annex

Tedds calculation version 2.0.00



Wall geometry

Width of gabion 1 — w_1 = **200** mm

Height of gabion 1 — h_1 = **750** mm

Wall inclination — ε = **25** deg

Gabion properties

Unit weight of fill — γ_d = **10.0** kN/m^3

Friction between gabions — $\delta_{bg.k}$ = **35.0** deg

Loading

Permanent surcharge — $p_{o,G}$ = **5** kN/m^2

Variable surcharge — $p_{o,Q}$ = **2** kN/m^2

Soil properties

Slope of retained soil — β = **10.0** deg

Characteristic peak shearing resistance angle — $\phi'_{pk.k}$ = **38.0** deg

Characteristic saturated density of retained soil — γ_{sr} = **19.0** kN/m^3

Coefficient for wall friction — $k_{membrane}$ = **1.00**

Wall friction angle — $\delta_{r.k}$ = **38.0** deg

Characteristic base friction angle — $\delta_{bb.k}$ = **30.0** deg

Bearing capacity of founding soil — q = **100** kN/m^2

Wall geometry

Horizontal distance to centre of gravity gabion 1 — $x_{g1} = w_1 / 2 =$ **100** mm

Vertical distance to centre of gravity gabion 1 — $y_{g1} = h_1 / 2 =$ **375** mm

Weight of gabion 1 — $W_{g1} = \gamma_d \times w_1 \times h_1 =$ **1.5** kN/m

Weight of entire gabion — $W_g = W_{g1} =$ **1.5** kN/m

Horiz distance to centre of gravity entire gabion — $x_g = ((W_{g1} \times x_{g1})) / W_g =$ **100** mm

Vert distance to centre of gravity entire gabion $y_g = ((W_{g1} \times y_{g1})) / W_g =$ **375** mm

Correcting for wall inclination horiz dist $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) =$ **249** mm

Vertical change in height due to wall inclination $H_f = y_{g1} + h_1/2 - ((y_{g1} + h_1/2) \times \cos(\varepsilon) - (x_{g1} + w_1/2) \times \sin(\varepsilon)) =$ **155** mm

Design dimensions

Effective angle of rear plane of wall $\alpha = 90 \text{ deg} + \varepsilon =$ **115.0** deg

Effective face angle $\theta = 90\text{deg} - \varepsilon =$ **65.0** deg

Effective height of wall $H = (y_{g1} + h_1 / 2) + (w_1 \times \sin(\varepsilon)) - H_f + (\cos(90 - \alpha) \times \sin(\beta + \varepsilon) \times w_1) / \sin(180 - (\alpha + \beta)) =$ **807** mm

Height of wall from toe to front edge of top gabion $H_{incl} = ((y_{g1} + h_1 / 2) \times \cos(\varepsilon) - (x_{g1} - (w_1 / 2)) \times \sin(\varepsilon)) =$ **680**mm

Active pressure using Coulomb theory $K_a = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times [1 + \sqrt{[\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))]}]^2) =$ **0.084**

Active thrust due to soil $P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2 =$ **0.5** kN/m

Minimum surcharge (cl.4.6.3.2) $p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} =$ **2.7** kN/m²

Pressure at base

Horizontal forces

Retained soil $F_{soil\_h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r.k}) =$ **0.5** kN/m

Height of soil thrust resolved vertically $d_{h,soil} = H / 3 - w_1 \times \sin(\varepsilon) =$ **184** mm

Surcharge $F_{surch\_h,q} = \max((p_{o,G} + p_{o,Q}), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r.k}) =$ **0.5** kN/m

Height of surcharge thrust resolved vertically $d_{h,surch} = H / 2 - w_1 \times \sin(\varepsilon) =$ **319** mm

Vertical forces

Gabion weight $F_{gabion\_v,q} = W_g =$ **1.5** kN/m

Retained soil $F_{soil\_v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r.k}) =$ **0.1** kN/m

Horizontal dist to where soil thrust acts $b_{v,soil} = w_1 \times \cos(\varepsilon) - (H / 3) / \tan(\alpha) =$ **307** mm

Surcharge $F_{surch\_v,q} = \max((p_{o,G} + p_{o,Q}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r.k}) =$ **0.1** kN/m

Horizontal dist to where surcharge thrust acts $b_{v,surch} = w_1 \times \cos(\varepsilon) - (H / 2) / \tan(\alpha) =$ **369** mm

Total horizontal unfactored force $T_q = F_{soil\_h,q} + F_{surch\_h,q} =$ **1.0** kN/m

Total vertical unfactored force $N_q = F_{gabion\_v,q} + F_{soil\_v,q} + F_{surch\_v,q} =$ **1.7** kN/m

Force normal to base $N_s = N_q \times \cos(\varepsilon) + T_q \times \sin(\varepsilon) =$ **2.0** kN/m

Total unfactored overturning force $M_{o,q} = F_{soil\_h,q} \times d_{h,soil} + F_{surch\_h,q} \times d_{h,surch} =$ **0.2** kNm/m

Total unfactored restoring force $M_{R,q} = F_{gabion\_v,q} \times X_g + F_{soil\_v,q} \times b_{v,soil} + F_{surch\_v,q} \times b_{v,surch} =$ **0.4** kNm/m

Eccentricity $e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s =$ **-6** mm

Reaction acts within middle third of base

Pressure at toe $\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) =$ **8.0** kN/m²

Pressure at heel $\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) =$ **11.7** kN/m²

Factor of safety $FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) =$ **8.554**

Allowable factor of safety $FoS_{Q\_allow} =$ **1.000**

PASS - Design FoS for allowable bearing pressure exceeds min allowable pressure to base

Partial factors on actions - Section A.3.1 - Combination 1

Permanent unfavourable action $\gamma_G =$ **1.35**

Permanent favourable action $\gamma_{G,f} =$ **1.00**

Variable unfavourable action $\gamma_Q =$ **1.50**

Variable favourable action $\gamma_{Q,f} =$ **0.00**

Partial factors for soil parameters - Section A.3.2 - Combination 1

Angle of shearing resistance $\gamma_{\phi'}$ = **1.00**

Weight density γ_{γ} = **1.00**

Design soil properties

Design effective shearing resistance angle $\phi'_{r.d} = \text{Atan}(\tan(\phi'_{pk.k}) / \gamma_{\phi'})$ = **38.0** deg

Design saturated density of retained soil $\gamma_{s.d} = \gamma_{sr} / \gamma_{\gamma}$ = **19.0** kN/m^3

Design wall friction angle (cl.5.4.2.1) $\delta_{r.d} = \min(\text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}), \phi'_{r.d} \times k_{membrane})$ = **38.0** deg

Design base friction angle $\delta_{bb.d} = \text{Atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **30.0** deg

Design friction between gabions $\delta_{bg.d} = \text{Atan}(\tan(\delta_{bg.k}) / \gamma_{\phi'})$ = **35.0** deg

Active pressure using Coulomb theory $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2)$ = **0.084**

Active thrust due to soil $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2$ = **0.5** kN/m

Minimum surcharge (cl.4.6.3.2) $p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min}$ = **2.7** kN/m^2

Horizontal forces

Retained soil $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d})$ = **0.7** kN/m

Surcharge $F_{surch\_h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r.d})$ = **0.6** kN/m

Vertical forces

Gabion weight $F_{gabion\_v,f} = \gamma_{G,f} \times W_g$ = **1.5** kN/m

Retained soil $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d})$ = **0.1** kN/m

Surcharge $F_{surch\_v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r.d})$ = **0.1** kN/m

Overturning stability - take moments about the toe

Overturning moment $M_o = F_{soil\_h} \times d_{h,soil} + F_{surch\_h} \times d_{h,surch}$ = **0.3** kNm/m

Restoring moment $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{surch\_v,f} \times b_{v,surch}$ = **0.4** kNm/m

Factor of safety $FoS_M = M_R / M_o$ = **1.327**

Allowable factor of safety FoS_{M_allow} = **1.000**

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force $T = F_{soil\_h} + F_{surch\_h}$ = **1.3** kN/m

Total vertical force $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{surch\_v,f}$ = **1.7** kN/m

Sliding force $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon)$ = **0.5** kN/m

Sliding resistance $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bb.d})$ = **1.2** kN/m

Factor of safety $FoS_S = F_R / F_f$ = **2.509**

Allowable factor of safety FoS_{S_allow} = **1.000**

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Partial factors on actions - Section A.3.1 - Combination 2

Permanent unfavourable action γ_G = **1.00**

Permanent favourable action $\gamma_{G,f}$ = **1.00**

Variable unfavourable action γ_Q = **1.30**

Variable favourable action $\gamma_{Q,f}$ = **0.00**

Partial factors for soil parameters - Section A.3.2 - Combination 2

Angle of shearing resistance $\gamma_{\phi'}$ = **1.25**

Weight density γ_{γ} = **1.00**

Design soil properties

Design effective shearing resistance angle: $\phi'_{r.d} = \text{Atan}(\tan(\phi'_{pk.k}) / \gamma_{\phi'}) = \mathbf{32.0}$ deg

Design saturated density of retained soil: $\gamma_{s.d} = \gamma_{sr} / \gamma_{\gamma} = \mathbf{19.0}$ kN/m^3

Design wall friction angle (cl.5.4.2.1): $\delta_{r.d} = \min(\text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}), \phi'_{r.d} \times k_{membrane}) = \mathbf{32.0}$ deg

Design base friction angle: $\delta_{bb.d} = \text{Atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) = \mathbf{24.8}$ deg

Design friction between gabions: $\delta_{bg.d} = \text{Atan}(\tan(\delta_{bg.k}) / \gamma_{\phi'}) = \mathbf{29.3}$ deg

Wall geometry

Horizontal distance to centre of gravity gabion 1: $x_{g1} = w_1 / 2 = \mathbf{100}$ mm

Vertical distance to centre of gravity gabion 1: $y_{g1} = h_1 / 2 = \mathbf{375}$ mm

Weight of gabion 1: $W_{g1} = \gamma_d \times w_1 \times h_1 = \mathbf{1.5}$ kN/m

Weight of entire gabion: $W_g = W_{g1} = \mathbf{1.5}$ kN/m

Horiz distance to centre of gravity entire gabion: $x_g = ((W_{g1} \times x_{g1})) / W_g = \mathbf{100}$ mm

Vert distance to centre of gravity entire gabion: $y_g = ((W_{g1} \times y_{g1})) / W_g = \mathbf{375}$ mm

Correcting for wall inclination horiz dist: $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{249}$ mm

Vertical change in height due to wall inclination: $H_f = y_{g1} + h_1/2 - ((y_{g1} + h_1/2) \times \cos(\varepsilon) - (x_{g1} + w_1/2) \times \sin(\varepsilon)) = \mathbf{155}$ mm

Design dimensions

Effective angle of rear plane of wall: $\alpha = 90 \text{ deg} + \varepsilon = \mathbf{115.0}$ deg

Effective face angle: $\theta = 90\text{deg} - \varepsilon = \mathbf{65.0}$ deg

Effective height of wall: $H = (y_{g1} + h_1 / 2) + (w_1 \times \sin(\varepsilon)) - H_f + (\cos(90 - \alpha) \times \sin(\beta + \varepsilon) \times w_1) / \sin(180 - (\alpha + \beta)) = \mathbf{807}$ mm

Height of wall from toe to front edge of top gabion: $H_{incl} = ((y_{g1} + h_1 / 2) \times \cos(\varepsilon) - (x_{g1} - (w_1 / 2)) \times \sin(\varepsilon)) = \mathbf{680}$mm

Active pressure using Coulomb theory: $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2) = \mathbf{0.135}$

Active thrust due to soil: $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{0.8}$ kN/m

Minimum surcharge (cl.4.6.3.2): $p_{o,min} = \min(H / H_{ref}, 1) \times q_{d,min} = \mathbf{2.7}$ kN/m^2

Horizontal forces

Retained soil: $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{0.8}$ kN/m

Surcharge: $F_{surch\_h} = \max((p_{o,G} \times \gamma_G + p_{o,Q} \times \gamma_Q), p_{o,min}) \times K_a \times H \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{0.8}$ kN/m

Vertical forces

Gabion weight: $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{1.5}$ kN/m

Retained soil: $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{0.1}$ kN/m

Surcharge: $F_{surch\_v,f} = \max((p_{o,G} \times \gamma_{G,f} + p_{o,Q} \times \gamma_{Q,f}), p_{o,min}) \times K_a \times H \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{0.1}$ kN/m

Overturning stability - take moments about the toe

Overturning moment: $M_o = F_{soil\_h} \times d_{h,soil} + F_{surch\_h} \times d_{h,surch} = \mathbf{0.4}$ kNm/m

Restoring moment: $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{surch\_v,f} \times b_{v,surch} = \mathbf{0.4}$ kNm/m

Factor of safety: $FoS_M = M_R / M_o = \mathbf{1.038}$

Allowable factor of safety: $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force: $T = F_{soil\_h} + F_{surch\_h} = \mathbf{1.6}$ kN/m

Total vertical force: $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{surch\_v,f} = \mathbf{1.7}$ kN/m

Sliding force: $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{0.8}$ kN/m

Sliding resistance: $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bb.d}) = \mathbf{1.0}$ kN/m

Factor of safety $FoS_S = F_R / F_f =$ **1.296**

Allowable factor of safety $FoS_{S\_allow} =$ **1.000**

PASS - Design FOS for sliding exceeds min allowable FOS for sliding