TERRA AQUA GABION SYSTEMS
GABION GRAVITY RETAINING WALLS

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Gabion retaining walls are monolithic gravity mass structures and follow typical design standards for gravity retaining walls. The following information is intended as a guide to assist designers in designing gabion gravity walls. Gabion walls must be able to resist the imposing soil forces, and allow for drainage, therefore, it is important that the density and dimension of the gabion stone fill used for the design analysis directly correlate with the material utilized for actual construction.

GABION LAYOUT AND PLACEMENT

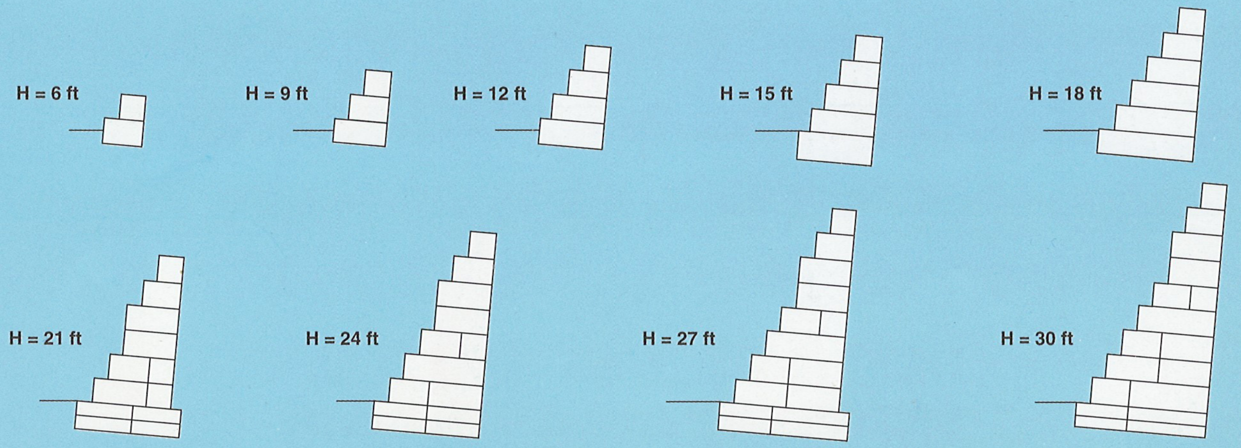
Gabions may be placed directly on a soil grade foundation or if necessary a base layer of granular stone fill foundation. A geotextile filter fabric shall be placed between the gabion basket and the specified backfill soil interface to ensure that no soil is lost during drainage. To provide the maximum resistance to soil forces the gabion baskets may be placed with the length dimension of the unit running from the back of the wall to the front face of the wall. This will result in the internal diaphragms being placed perpendicular to the wall face and parallel to soil thrust. When gabion units shall be placed with the length dimension of the unit parallel with the length dimension of the wall the vertical seams shall be offset. For gabion gravity walls that are 15′ to 30′ in height the foundation and bottom courses shall be 1.5′ in depth to better absorb the compression and shear stresses. Double twisted mesh gabions shall withstand compression loads of 60,000 - 80,000 pounds per square foot. G the shear modulus of elasticity shall vary between 5,000 - 8,000 pounds per square foot and are relevant to deformation.

GABION GRAVITY WALL SIZES AND DIMENSIONS

Gabion walls follow typical design standards for gravity retaining walls, Terra Aqua has provided the diagram below to illustrate a starting point for designers in relation to the base width of wall to height of wall. A conservative rule to use when starting a gabion wall stability analysis is Base Width = 2/3 height of wall. The stability analysis checks may determine that the wall base width be less or more than 1/2 - 2/3 wall height. Additional stability may be achieved by placing the foundation depth of the wall below sub grade or by adding a wall batter of 6-10 degrees, also counterforts may be used to gain additional stability and increase drainage. Gabion walls can be designed with a stepped front face, or with a smooth front face. When utilizing a gabion wall with a smooth front face, the wall shall always be placed on a 6-10 batter and is not recommended for wall heights above 18′. Gabion walls shall have a minimum 1.5′-3′ horizontal set back for each 3′ vertical lift.

GABION WALL DIMENSIONS

Height:	6′	9′	12′	15′	18′	21′	24′	27′	30′
Width:	4.5′	6′	7.5′	9′	10.5′	15′	15′	18	18′



TerraAqua LandWater GABIONS

GABION WALL DESIGN DATA

Proper design and construction of gabion retaining walls requires a thorough knowledge of the lateral forces acting between the retaining structures and the soil masses being retained. These lateral forces are due to lateral earth pressure. Therefore, analysis and determination of lateral earth pressure are necessary to design gabion retaining walls.

The classical lateral earth pressure analysis and calculations are based on the Rankine theory by considering the soil in a state of plastic equilibrium, and the Coulomb theory by assuming a plane failure surface. Both Rankine and Coulomb approached and developed lateral earth pressure problem with several essential assumptions such as an isotropic and homogeneous backfill soil, a plane backfill surface, a rigid failure wedge body and etc.

The equations for computing lateral earth pressure based on the Rankine and Coulomb theories are as follows:

The lateral earth pressure is obtained as

$$P_a = 1/2\, K_a \gamma H^2$$

$$P_p = 1/2\, K_p \gamma H^2$$

Rankine's active and passive earth pressure coefficients (K_a and K_p) **are given by**

$$K_a = \cos\beta \frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}$$

$$K_p = \cos\beta \frac{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}$$

Coulomb's active and passive earth pressure coefficients (K_a and K_p) **are given by**

$$K_a = \frac{\sin^2(\alpha + \phi)}{\sin^2\alpha \cdot \sin(\alpha - \delta)\left[1 + \sqrt{\dfrac{\sin(\phi + \delta)\cdot\sin(\phi - \beta)}{\sin(\alpha - \delta)\cdot\sin(\alpha + \beta)}}\right]^2}$$

$$K_p = \frac{\sin^2(\alpha - \phi)}{\sin^2\alpha \cdot \sin(\alpha + \delta)\left[1 - \sqrt{\dfrac{\sin(\phi + \delta)\cdot\sin(\phi + \beta)}{\sin(\alpha + \delta)\cdot\sin(\alpha + \beta)}}\right]^2}$$

Where

P_a	=	active earth pressure
P_p	=	passive earth pressure
γ	=	unit weight of back fill soil
H	=	wall height
β	=	slope angle of backfill surface
α	=	angle between back side of wall and a horizontal line
δ	=	friction angle between wall and soil
ϕ	=	internal friction angle of back fill soil

As for the conditions which do not fit the Rankine and Coulomb theories such as an irregular backfill surface, multiple soils and etc., the Trial-Wedge (Limit Equilibrium) method, a graphical solution can be applied for estimating the lateral earth pressure, and an analytical solution based on the Theory of Elasticity can also be used. Currently these methods are practical and popular by utilizing a computer program.

TerraAqua LandWater GABIONS

GABION WALL DESIGN DATA

Gabions may be filled with almost any stone type. Stone fill having a higher specific gravity is preferable especially if the structure shall be submerged or exposed to water.

UNIT WEIGHT OF GABION STONE FILL

TYPE OF ROCK	(LBS/CUBIC FT)
BASALT	180
GRANITE	160
LIMESTONE	138
SANDSTONE	140

UNIT WEIGHT OF GABION STONE FILL

Based on a Porosity of 0.30 or 30%

SPECIFIC GRAVITY OF MATERIALS	
BASALT	3.0
BRICK	2.0
BROKEN CONCRETE	2.4
GRANITE	2.7
LIMESTONE	2.5
SANDSTONE	2.2
TRAP ROCK	2.7

EXAMPLE

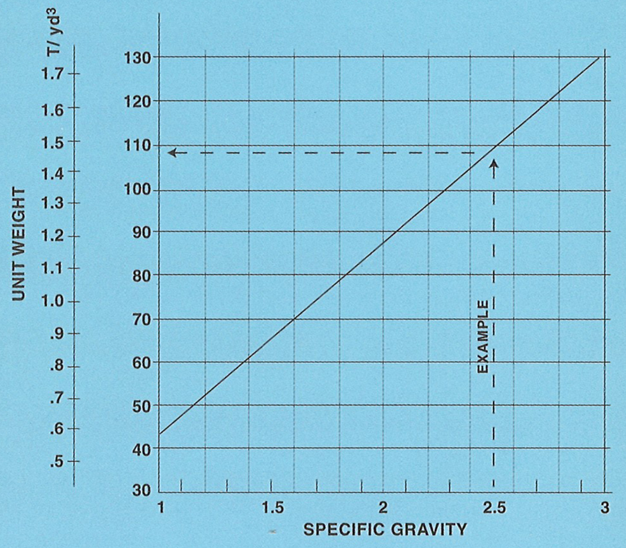
Given specific gravity = 2.5
Find unit weight in (a) Pcf, (b) T/yd³

SOLUTION

Proceed vertically from S.G. 2.5 to intersection of diagonal line then proceed horizontally to intersection of vertical line and find (A) unit weight =109 Pct
(B) " " =148 T/yd³

Table A

Unit Weight of Gabion Fill
Based on a Porosity of 0.30.



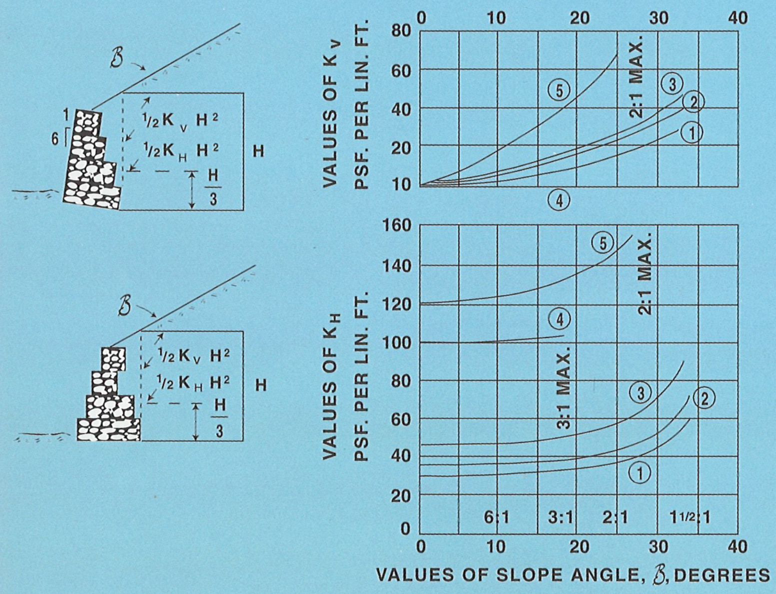


Table B

Design Loads for Low Gabion Retaining Walls, Straight Slope Backfill.

Circled numbers indicate the following soil types:

1. **Clean sand and gravel GW, GP, SW, SP.**
2. **Dirty sand and gravel of restricted permeability GM, GM-GP, SM, SM-SP.**
3. **Stiff residual silt and clays, silty fine sands, clays, sands and gravels: CL, ML, CH, MH, SM, SC, GC.**
4. **Very soft to soft clay, silty clay, organic silt and clay: CL, ML, OL, CH, MH, OM.**
5. **Medium to stiff clay deposited in chunks and protected from infiltration: CL, CH.**

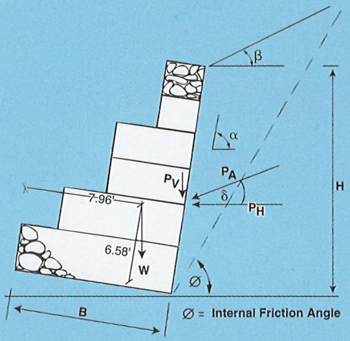
For type 5 material H is reduced by 4 ft. resultant Acts at a height of (H-4)/3 above base.

Adapted from Terzaghi and Peck

TerraAqua® Land Water GABIONS

DESIGN CALCULATIONS

Terra Aqua Gabions, Inc., always recommends that the soil data utilized for gabion wall design be based on a Certified Geotechnical Soils Report of the site location. Terra Aqua can provide a complete gabion retaining wall stability analysis upon request.



COULOMB'S THEORY METHOD OF CALCULATION

The magnitude of the soil force acting on a gabion wall is determined by using Coulomb's formula:

1) $P_A = \frac{1}{2}\gamma H^2 \dfrac{K_A}{\sin\alpha \cos\delta}$

Where:
- P_A = active earth pressure
- γ = unit weight of the retained soil
- H = height of the gabion wall
- K_A = coefficient of active earth pressure

2) Calculation of K_A:

$$K_A = \frac{\sin^2(\alpha+\phi)\cos\delta}{\sin\alpha\,\sin(\alpha+\phi)\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\,\sin(\phi-\beta)}{\sin(\phi+\delta)\,\sin(\phi-\beta)}}\right]^2}$$

Where:
- α = angle between the back of the wall and the horizontal surface of the ground in front of the wall.
- β = angle of the backfill above the gabion wall
- ϕ = angle internal friction of the retained soil
- δ = angle of wall friction = .9 ϕ

3) Overturning

The resultant of the weight of the wall and soil thrust must pass through the middle third of the base with the coefficient of overturning being greater than or equal to 1.5.

$$\frac{\Sigma M_r}{\Sigma M_a} \geq 1.5$$

4) Sliding

As in common engineering principles, the summation of the vertical forces over the summation of the horizontal forces, must be greater than or equal to 1.5 when multiplied by the tangent of the angle of internal friction of the soil.

$$\frac{\Sigma F_v}{\Sigma F_h} \tan\phi \geq 1.5$$

5) Pressure at the Base

The total pressure of the gabion wall must be less than the anticipated bearing capacity of the soil under the base of the wall. The contact pressure on a flexible gabion footing is not distributed in a planar fashion, but decreases from a maximum at the point of application of the resultant to lesser values at the edges of the footing. The pressure at the toe of a gabion wall is, therefore, generally less than for a rigid wall. The calculations for the subgrade reaction in flexible foundation are awkward and involve errors associated with evaluating the coefficient of subgrade reaction. The error in assuming this is on the safe side, since the reaction is assumed to have a planar distribution, as in rigid walls.

SAMPLE OF CALCULATION

A gabion retaining wall is to be used to retain a compact, fill slope with the following data:

1. Slope of backfill above wall (β) = 25°
2. Height of wall (H) = 18'
3. Angle of internal friction (ϕ) = 35°
4. Angle of wall friction (δ) = 31.5°
5. Unit weight of soil (γ) = 125pcf
6. Angle of Inclination (α) = 80°

1) Weight of the Gabion Wall:

Total Area: 117 ft.^{2}
Unit Weight: 110pcf
Total Weight = (117) (110)
= 12,870 #/L.F.

2) Soil Force:

Using the Coulomb formula, the wall must be heavy enough to withstand the greatest lateral pressure, $P_{max} = P_A$ = active earth pressure.

$$P_A = \frac{1}{2}\gamma H^2 \frac{K_A}{\sin\alpha \cos\delta}$$

Using the formula for calculating the coefficient of active earth pressure, $K_A = 0.440$ an substituting into the above equation, P_A = 10,611 #/L.F.

3) Overturning:

$\dfrac{\Sigma M_r}{\Sigma M_a} \geq 1.5$ $M_r = 8.98(w) + P_A \sin(\delta+10°)(12)$
= 199,945 ft.-lbs.

$\dfrac{199{,}945}{52{,}292} = 3.82 \geq 1.5$ $M_a = P_A \cos(\delta+10°)(6.58)$
= 52,292 ft.-lbs.

4) Sliding:

$\dfrac{\Sigma F_v}{\Sigma F_h} \tan 35° \geq 1.5$ $F_v = W\cos 10° + P_A \sin(\delta+10°)$
= 19,706 lbs.

$\dfrac{19{,}706}{5{,}712}(0.7) = 2.42 \geq 1.5$ $F_h = P_A \cos(\delta+10°) - W \sin 10°$
= 5,712 lbs.

5) Pressure at Base:

For the pressure intensity, $P = \left(\dfrac{\Sigma F_v}{b}\right)\left(1 \pm \dfrac{6e}{b}\right)$

where B = width of base = 12'
e = eccentricity = μ - b/2
μ = distance from toe at which the resultant of the force passes through the base of the wall

$$\mu = \frac{\Sigma F_r - \Sigma M_a}{\Sigma F_v} = 7.49$$

e = 7.49 - 9 = 1.51

$\therefore$ P max = 1,645 psf, thus, the bearing capacity of the soil must be in the area of 1 ton per sq. ft.

TerraAqua®
Land Water
GABIONS

SPECIFICATIONS

STANDARD SIZES

LETTER CODE OF SIZE	LENGTH	WIDTH	HEIGHT	NO. OF DIAPHRAGMS	CAPACITY CUBIC YARDS	PAINTED COLOR CODE USED ON EACH UNIT TO DISTINGUISH SIZE
A	6'	3'	3'	1	2.0	BLUE
B	9'	3'	3'	2	3.0	WHITE
C	12'	3'	3'	3'	4.0	BLACK
D	6'	3'	1'6"	1	1.0	RED
E	9'	3'	1'6"	2	1.5	GREEN
F	12'	3'	1'6"	3	2.0	YELLOW
G	6'	3'	1'	1	0.66	BLUE-RED
H	9'	3'	1'	2	1.0	BLUE-YELLOW
I	12'	3'	1'	3	1.33	BLUE-GREEN
Q	9'	6'	6"	2	1	WHITE-YELLOW
R	12'	6'	6"	3	1.33	WHITE-GREEN
T	9'	6'	9"	2	1.5	RED-YELLOW
U	12'	6'	9"	3	2	RED-GREEN

METRIC SIZES

LETTER CODE OF SIZE	LENGTH-WIDTH HEIGHT IN METERS	APPROXIMATE EQUIVALENTS IN FEET	NO. OF DIAPHRAGMS	CAPACITY CUBIC METERS	CAPACITY CUBIC YARDS	PAINTED COLOR CODE USED ON EACH UNIT TO DISTINGUISH SIZE
A	2x1x1	6'6"x3'3"x3'3"	1	2	2.616	BLUE
B	3x1x1	9'9"x3'3"x3'3"	2	3	3.924	WHITE
C	4x1x1	13'1"x3'3"x3'3"	3	4	5.232	BLACK
D	2x1x.5	6'6"x3'3"x1'8"	1	1	1.308	RED
E	3x1x.5	9'9"x3'3"x1'8"	2	1.5	1.962	GREEN
F	4x1x.5	13'1"x3'3"x1'8"	3	2	2.616	YELLOW
G	2x1x.3	6'6"3'3"x1'	1	0.6	0.785	BLUE-RED
H	3x1x.3	9'9"x3'3"x1'	2	0.9	1.177	BLUE-YELLOW'
I	4x1x.3	13'1"x3'3"x1'	3	1.2	1.570	BLUE-GREEN
Q	3x2x.15	9'9"x6'6"x6"	2	0.9	1.17	WHITE-YELLOW
R	4x2x.15	13'1"x6'6"x6"	3	1.2	1.57	WHITE-GREEN
T	3x2x.23	9'9"x6'6"x9"	2	1.38	1.76	RED-YELLOW
U	4x2x.23	13'1"x6'6"x9"	3	1.84	2.40	RED-GREEN

GABION	GALVANIZED	PVC TYPE
Sizes & Mesh Opening:	Hexagonal, approx. 3 1/4"x4 1/2"	Same as for River Type
Wire For Netting:	0.120' diam. (3.0mm)	Core 0.106", finish .146" (2.7mm/3.7mm)
Wire For Selvedges & Corners:	0.153" (3.8mm)	Core 0.133", finish .173" (3.4mm/4.4mm)
Wire For Binding:	0.90" (2.2mm)	Core 0.087", finish .127" (2.2mm/3.2mm)
Zinc Coating:	.85 ounces per square foot	.85 ounces per square foot
Tolerance:	+ or -.005 (.0127cm)	+ or -.005 (.0127cm)

MATTRESS	GALVANIZED	PVC TYPE
Sizes & Mesh Opening:	Hexagonal, approx. 2 1/2"x3 1/4"	Same as for River Type
Wire For Netting:	0.087" (2.2mm)	Core 0.087", finish .127" (2.2mm/3.2mm)
Wire For Selvedges & Corners:	0.106" (2.7mm)	Core 0.106", finish .146" (2.7mm/3.7mm)
Wire For Binding:	0.087" (2.2mm)	Core 0.087", finish .127" (2.2mm/3.2mm)
Zinc Coating:	.85 ounces per square foot	.85 ounces per square foot
Tolerance:	+ or -.005 (.0127cm)	+ or -.005 (.0127cm)

Wire conforms to Federal Specifications QQ-W-461 H, Finish 5, Class 3 and ASTM A-641

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