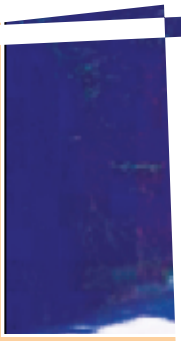


# CONTENTS

## 1.0 History of Gabion

A gabion (from Italian gabbione meaning "big cage"; from Italian gabbia and Latin cavea meaning "cage") is a cage, cylinder, or box filled with rocks, concrete, or sometimes sand and soil for use in civil engineering, road building, and military applications. First records of the use of Gabion system go back more than 2000 years, when Egyptians used cylindrical willow baskets full of small stones to protect the banks of the River Nile from erosion. For erosion control, caged riprap is used. For dams or in foundation construction, cylindrical metal structures are used. In a military context, earth- or sand-filled gabions are used to protect artillery crews from enemy fire. The most common civil engineering use of gabions is to stabilize shorelines, stream banks or slopes against erosion. Other uses include retaining walls, temporary floodwalls, silt filtration from runoff, for small or temporary/permanent dams, river training, or channel lining. They may be used to direct the force of a flow of flood water around a vulnerable structure.

A gabion wall is a retaining wall made of stacked stone-filled gabions tied together with wire. Gabion walls are usually battered (angled back towards the slope), or stepped back with the slope rather than stacked vertically.

Gabion baskets have some advantages over loose riprap because of their modularity and ability to be stacked in various shapes; they are also resistant to being washed away by moving water. Gabions also have advantages over more rigid structures because they can conform to ground movement, dissipate energy from flowing water, and drain freely. Their strength and effectiveness increases with time as silt and vegetation fill the interstitial voids and reinforce the structure. They are sometimes used to keep stones which may fall from a cutting or cliff from endangering traffic on a thoroughfare.

## 2.0 Machine Made Gabion

Gabions are baskets made of double twisted steel woven wire mesh made from machine with higher mechanical characteristics. Gabion retaining walls utilize double twisted woven wire mesh modular units, filled on site with hard, durable stone to form flexible mass gravity retaining structures for road projects. The hexagonal shape of the mesh is helpful to make a uniform distribution of forces. The double twisted wire will not unravel, even when cut. These are very easy to assemble, require no specialized labor and most onsite rock can be used for fill. Gabions are available with different levels of protective coating for durability. With 30 to 40% voids gabion structures offer free drainage providing a higher stability when used for retaining purposes. Gabion retaining walls can also be provided as toe wall to act as robust bottom drainage wall.


**Fig 1a, b & c: Photograph depicts mechanical woven Gabions to protect Reno river bank**

## 3.0 Comparison of Handmade & Machine made Gabion

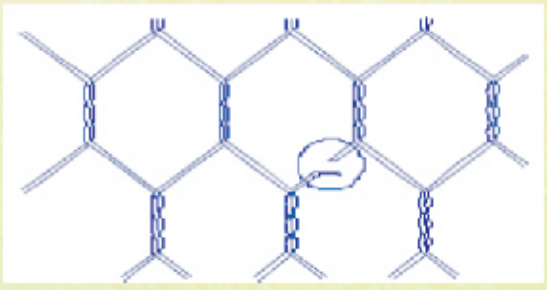
**There are three types of Gabions manufacturing process:**

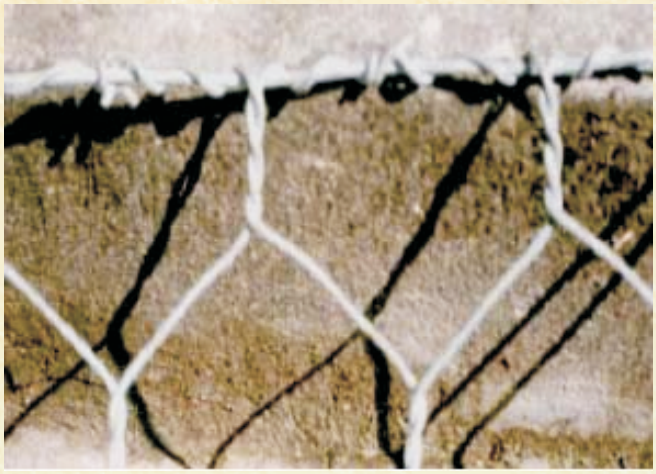
i. Machine made, mechanically selvedged hexagonal mesh gabions

ii. Handmade hexagonal mesh gabions

iii. Handmade rectangular mesh gabions

<table>
<tr><th>Handmade Gabion</th><th>Machine made Gabion</th></tr>
<tr><td>
1. Mesh Panel Strength
<table>
<tr><th>Mesh Panel</th><th>Mesh wire diameter (mm)</th><th>Strength (kN/m)</th></tr>
<tr><td>Rectangular (10x10)</td><td>4.06</td><td>No Test data available</td></tr>
<tr><td>Hexagonal (10x12)</td><td>3.25</td><td>19</td></tr>
</table>
</td><td>
1.Mesh Panel Strength
<table>
<tr><th>Mesh Panel</th><th>Mesh wire diameter (mm)</th><th>Strength (kN/m)</th></tr>
<tr><td>Hexagonal (10x12)</td><td>2.7</td><td>32</td></tr>
<tr><td>Hexagonal (10x12)</td><td>3.0</td><td>40</td></tr>
</table>
</td></tr>
<tr><td>2. Strength of Double Twist : For 10x12 mesh strength is 0.4 to 0.5 kN</td><td>2. Strength of Double Twist : For 10x12 Mesh strength is 1.4kN</td></tr>
<tr><td>3. Type of Coating: For handmade wire crates, wires are purchased locally from any vendor which doesn't specify the Zinc coating parameters. They are usually of commercial class coating, which eventually leads to rusting within 3-4 months.</td><td>3.Type of Coating : For mechanical woven Gabions minimum zinc coating is as per EN 10244-2.The adhesion of zinc coating for the wire should be such that when the wire is wrapped six turns around the mandrel having 4 times the diameter of wire, it does not flake or crack when rubbing with bare hand.</td></tr>
</table>

| | |
|---|---|
| **4) Mesh opening** is not uniform throughout the mesh which results in enlargement of mesh size and fills material escapes during load application.<br>  | **4) Mesh opening** is uniform throughout the mesh to prevent from bulging and escaping of fill material.<br>  |
| **5. Uniformity**: Due to Non uniformity of mesh, larger size of fill material is preferred which increases the void ratio, thus decreases the stability and increases cost of the structure. | **5. Uniformity**: Due to its Uniformity, considerable size of fill material is used which increases the stability of structure. |
| **6. Hexagonal Double Twist**: Mesh is made manually without using any engineering, if one wire breaks opening size will increase in due course of time which leads to instability of the structure | **6. Hexagonal Double Twist**: Openings of Hexagonal shape (10x 12) distributed load uniformly. Double twists avoid spreading of the damage caused by the accidental breaking of any wire or mesh.<br>  |

| | |
|---|---|
| **7.Connection to selvedge** :<br><br>No selvedging provided in hand made Gabions which leads to poor strength of overall mesh.<br><br>  | **7. Connection to selvedge**:<br><br>Selvedging in the gabions is done for reinforcing the structure in order to make the gabions as rigid as possible.<br><br>  |
| **8. Lacing wire:** No specifications are mentioned for joining the mesh of handmade gabions. | **8. Lacing wire:** Separate lacing wire of 2.2 mm(I.D) / 3.20mm (O.D) will be used for closing the box of Gabions after filling with Geo-textile bags @ 3% of weight of Gabions. |
| **9. Stress Distribution**: Non uniform opening size of mesh, the shorter wires will be loaded first (non uniform loading) which shall head to failure of wire & mesh panel. Also, due non uniform loading the possibility of structure bulging and toppling increases. | **9. Stress Distribution**: Uniform mesh size ensures uniform stress distribution leading to better performance than hand made wire crate. |
| **10. Flexibility**: Not applicable as too many joints and uneven opening. Slight uneven settlement will deform the opening and whole structure becomes unstable. | **10. Flexibility**: Being highly flexible ,due to its double twist hexagonal mesh, it is not immediately affect of any type of settlement in foundation |
| | |

| | |
|---|---|
| **11. Ease of Construction**: Production rate is slow as compared to machine made gabion. Excess time will be required for making a box gabion from the supplied wire netting sheets. | **11. Ease of Construction**: Being a fully mechanised system, production rate is fast. Since the Gabions come in readymade box form and we don't have to form the box, hence it will be having lesser jointed hence construction time can be reduced drastically. |
| **12. Quality Assurance**: No QA as whole this is handmade & no QA plan in place. | **12. Quality Assurance**: Quality of both the mesh & Gabion boxes are monitored & maintained as per the QA plan( ISO-9001). |
| **13. Durability**: Commercially Galvanized, durability expected 3-4 Months. | **13. Durability**: Since the wires are heavily Galvanised as per IS standards it will have less corrosion and long durability when used under water. |

## 3.1 Description of Machine made Gabions (Reference Indian Codes : IS-16014, MORTH Sec-2500)

Gabions are rectangular wire mesh baskets filled with rock at the project site to form flexible, permeable, monolithic structures. They are made of hexagonal shaped double twisted steel woven wire mesh, with high mechanical characteristics. The gabion is divided into cells by means of diaphragms positioned at approximately 1m centers. The steel wire used in the manufacture of the gabion shall be coated with zinc or zinc and PVC (Poly vinyl chlorides) coated for protection from corrosion. In order to reinforce the structure, all mesh panel edges are selvedged with a wire having a greater diameter. With 30 per cent voids, gabion structures offer free drainage providing bank stability when used for river bank protection.

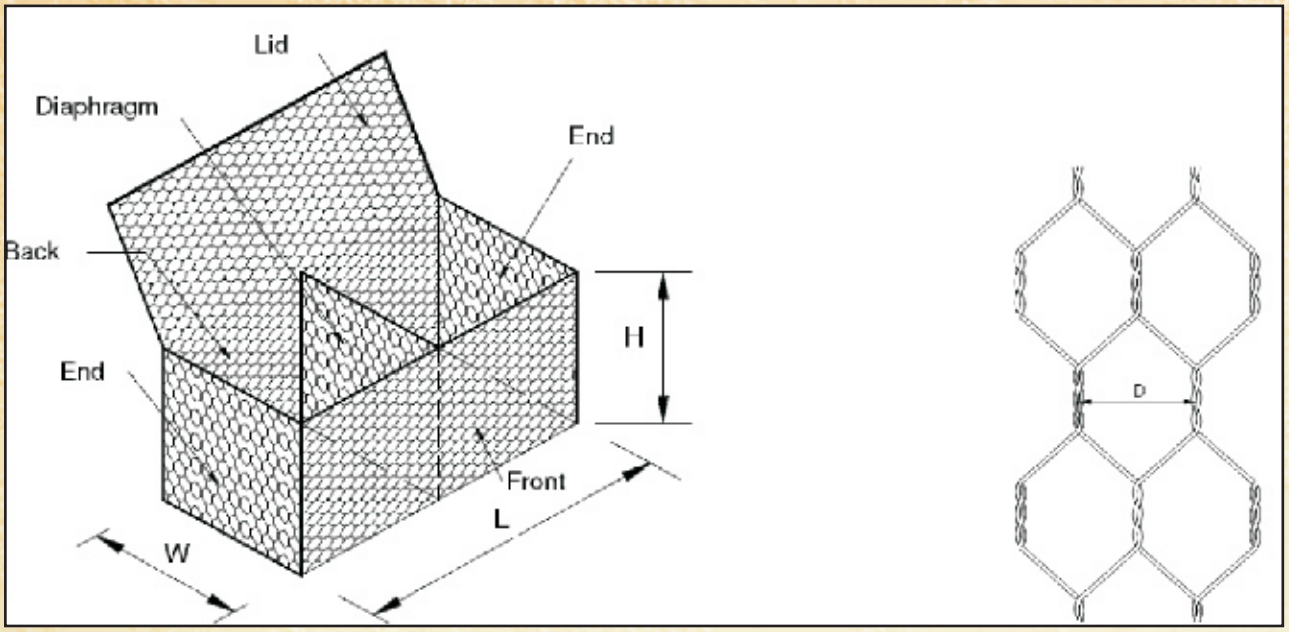



**Fig 2 : Typical Gabion box and Mesh details**

Gabions shall be provided on the eroding slopes at suitable locations to prevent the soil from moving down the slope and thus protecting the slope. Gabions can be used for construction of protection structures like toe walls or breast walls. They serve both purposes of protecting the slope from being eroded and provide stability to the slope, if the slope is unstable.

### 3.2 Component of Gabion Box

**3.2.1 Double-Twisted Wire Mesh**: A non-raveling mesh made by twisting continuous pairs of wires through three one-half turns (commonly called double-twisted) to form hexagonal shaped openings which are then interconnected to adjacent wires to form hexagonal openings.

**3.2.2 Selvedge Wire**: A terminal wire used to edge the wire mesh perpendicular to the double twist by mechanically wrapping the mesh wires around it at least 2.5 times.

**3.2.3 Edge Wire**: A terminal wire of the same diameter as the selvedge wire used to edge the wire mesh parallel to the double twist by continuously weaving it mechanically into the wire mesh.

**3.2.4 Lacing Wire:** A galvanized wire or galvanized wire with PVC coating used to assemble and interconnect empty units, to close and secure stone-filled units, and for internal stiffeners.

**3.2.5 Diaphragm:** An internal partition made of same wire mesh panel in a gabion/mattress that is attached to the bottom, the sides, and, after the gabion cage is packed with stones, to the lid of the cage.

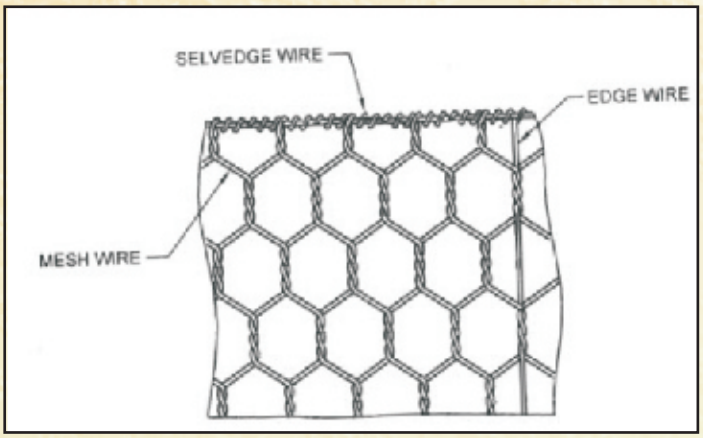
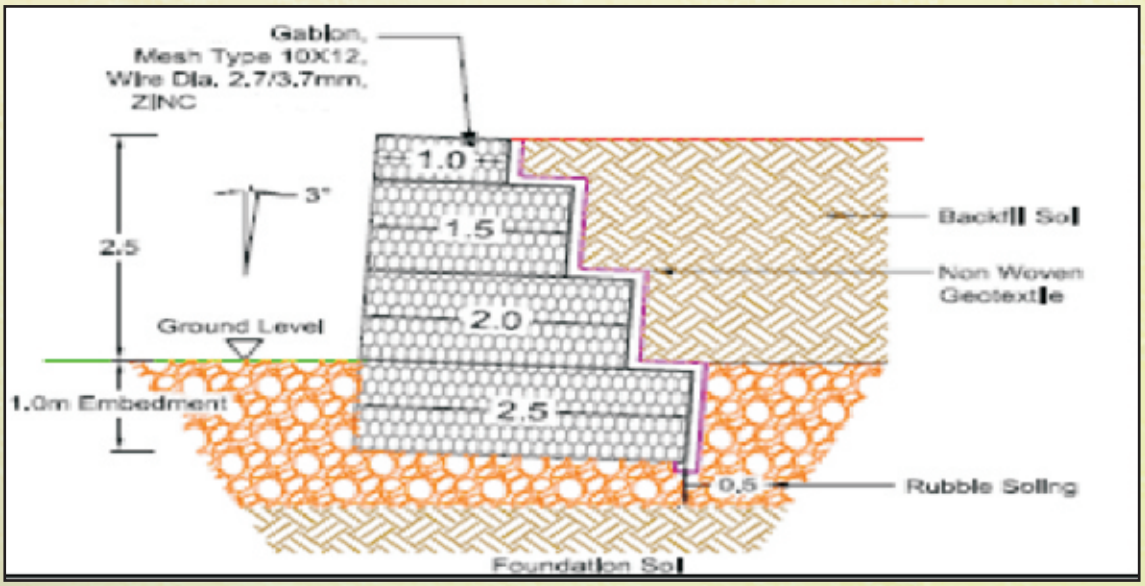



**Fig 3: Typical details of Mesh wire, Selvedge wire and edge wire**

## 3.3 General Components of Gabion Retaining walls

- Gabion boxes as per standard dimensions
- Filling Stones
- Filter media (Non Woven Geo textile)
- Backfill Material or Existing fill



## 4.0 Technical Parameter of Gabion Mesh

| S.N | Characteristics | Mesh type 10x12 ( Zn + PVC coated) |
|---|---|---|
| 1 | Mesh wire diameter (mm) | 2.7/ 3.7 (ID/OD)* |
| 2 | Edge/Selvedge wire diameter (mm) | 3.4/ 4.4 (ID/OD)* |
| 3 | Lacing wire diameter (mm) | 2.2/ 3.2 (ID/OD)* |
| 4 | PVC coating thickness (mm) | Nominal - 0.5 |
| 5 | Tensile Strength (N/mm2) | 350 - 550 |
| 6 | Elongation (%) | Not less than 10% |
| 7 | Zinc coating (gm/sqm) | Wire dia (mm) 2.2 2.7 3.4<br>Zinc coating 240 260 270 |
| 8 | PVC coating (mm) | 0.5 to 0.38 (min) |

* ID = inner diameter / OD = outer diamter

## 4.1 Typical standard sizes of Gabion box (10x12 Mesh type)

| Length(m) | Width (m) | Height (m) | No. of Diaphragms |
|---|---|---|---|
| 4 | 1 | 1 | 3 |
| 3 | 1 | 1 | 2 |
| 2 | 1 | 1 | 1 |
| 1.5 | 1 | 1 | 0 |
| 4 | 1 | 0.5 | 3 |
| 3 | 1 | 0.5 | 2 |
| 2 | 1 | 0.5 | 1 |

## 5.0 Features & Characteristics of Gabions

**5.1 Permeability :** Empty spaces between stone fill in Gabions, allow fluid movement through them. For this reason Gabion works are not generally affected by hydraulic pressure thus work much more efficiently under such circumstances. As for hydraulic works such as canal and river bank support, Gabions allow water flows in both directions river-land and land-river, without forming an impermeable barrier.

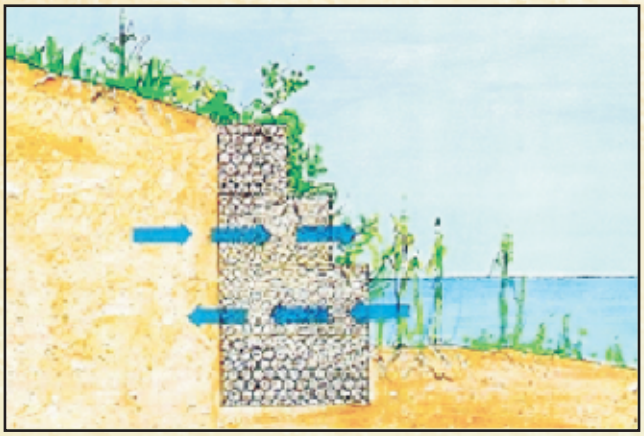


**Fig.4 : Permeability through Gabion structure**

**5.2 Flexibility :** The Gabion System being the most flexible soil reinforcing system helps the structure to stand stable during seismic effect. Flexibility of Gabions helps the structure to accommodate ground settlement without any compromise in structural integrity. Flexibility, within technically acceptable limits, gives Gabion structures the capability of deforming while maintaining its function whereas such situations would cause rigid or near rigid structure to collapse.

**Fig 5: Flexibility of structure**

**5.3 Durability :** The double twist, in case of a break in any single wire, prevents unravelling of the mesh and the movement of stones out of Gabion Unit. Heavy zinc coating of wires assures that eventual deterioration of the netting by rusting is very slow under normal conditions. Where corrosion is a more severe process, it is possible to considerably extend wire life by making use of PVC coating. The passage of time Soil Reinforced structure shall provide natural balances with the environment.

**5.4 Environmental Impact :** The most distinct advantage of this ki nd of system is that it has a very positive impact on the environment. Reinforced soil wall/slope covered with a lush green vegetation topping offer an excellent opportunity to enhance the urban landscape. Soil pockets can be introduced in between stone fillings and locally available healthy species of plants / creepers can be used at intervals for having a lush green effect on the gabion fascia. These structures are the least damaging to the environment as they are built basically with stone.

**Fig. 6: Environmental friendly Gabions**

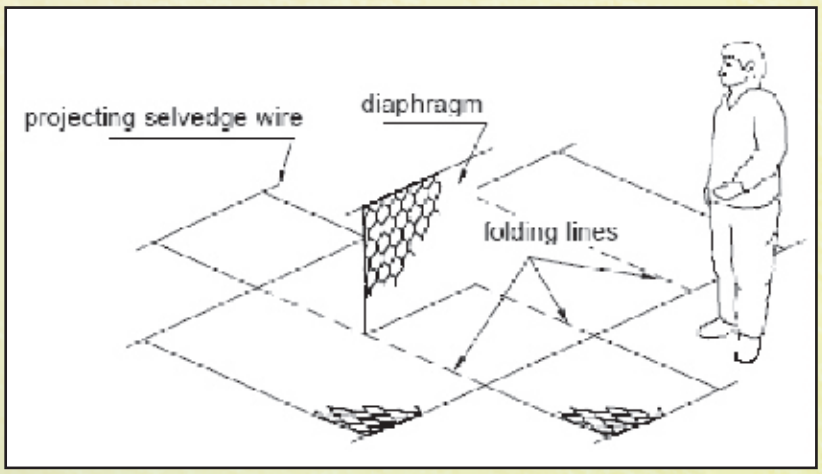
**5.5 Versatility :** They can either be manufactured manually or mechanically. If there is need for a rapid integration with local nature and environment, seeds can be scattered inside Gabion facia unit.

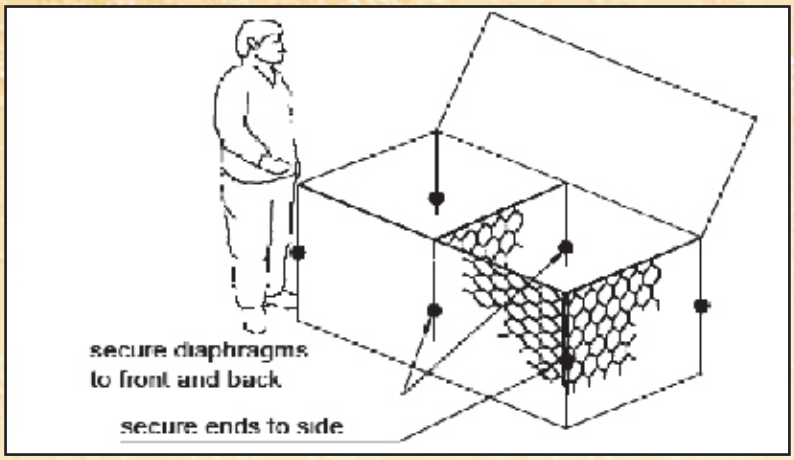
**Fig. 7: Vegetation over Gabion structure**

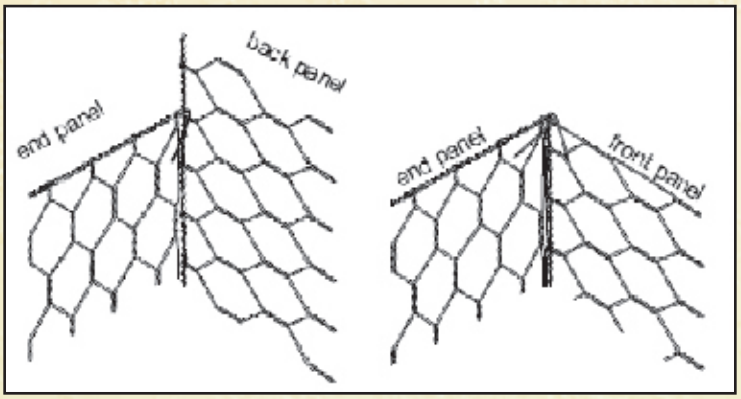
**5.6 Economical Solution :** Being simple, Reinforced soil structure does not require a skilled labour force or special equipment. Simple tools are usually needed such as pliers, tweezers, crowbars and, occasionally, any other easily available tools.

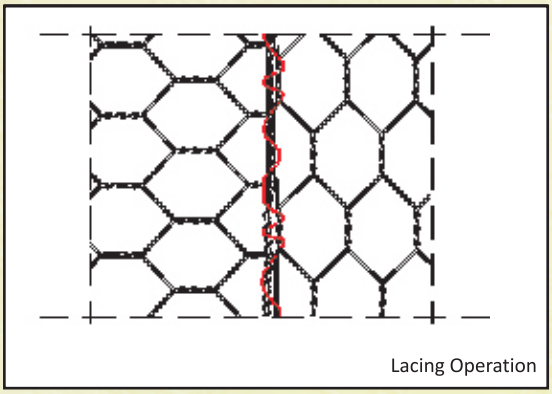
## 6.0 Gabion Installation Steps

Gabions shall be opened, unfolded and pressed out to their original shape. Front, back and end panels shall be lifted to a vertical position to form an open box shape. Inner diaphragm panels shall be lifted into a vertical position and secured by lacing wire. All edges of the diaphragms and end panels shall be tied to the front and back of the gabion by lacing.







Lacing Operation

**Lacing Procedure**

A sufficient length of wire shall be cut and twisted to secure lacing wire to the wire mesh. Proceed tying with alternate double and single loops with every mesh opening. Double loops shall be made at intervals not greater than 150 mm. The basket pieces

should be pulled tightly together during the tying operation. The other end of the tie wire shall be secured by again looping and twisting the wire around itself. Pliers may be used to create tight joints

**Foundation/Surface preparation**

The foundation/surface on which the gabions are to be placed shall be levelled. Geo-textile required to be installed behind or underneath gabion structures shall comply with the requirements for subsurface drainage applications.

**Installation of gabion and Filling of stones**

After the foundation/surface has been prepared, the pre-assembled gabions are placed in position empty, and shall be tied to adjacent gabions along all containing edges in order to form a continuously connected, monolithic structural unit. Gabions shall be placed front to front and back to back in order to expedite the stone filling and lid lacing operations. Rocks for gabions may be produced by any suitable quarrying method, and by the use of any device that yields the required sizes within the gradation limits chosen. Gabion rocks shall range between 150 mm and 250 mm. Rock shall be placed in 300 mm lifts for 1 m high gabions, and 250 mm for 0.5 m high gabions. The fill layer shall never be more than 300 mm higher than any adjoining cell. After a layer of rock has been placed in the cell, sufficient hand manipulation of the rock shall be performed to minimize voids and achieve a maximum density of the rock in the gabion. The rock in exposed vertical faces shall be hand placed to reduce voids in the outer face. Internal cross ties shall be installed connecting the front and back faces of any supported or

exposed face at the vertical third points for a gabion 1 m high, as the cell is being filled. Gabion units installed at the wall ends, having two exposed sides, shall also include a set of cross ties installed perpendicularly to the lateral exposed face.

**Lid Closing**

After the rock has been levelled and the voids minimized, fold the lid down and pull edges of the panels together. It should require a light stretching of the lid in order to match with the filled up gabion box. The lid shall be tightly tied along all edges, ends and tops of diaphragms. Adjacent lids may be tied or attached simultaneously. All projecting sharp ends of wire shall be turned in on the completed gabion structure.

## 7.0 Typical Application of Gabions for Rural Roads

### 7.1 Gabion toe wall and confinement

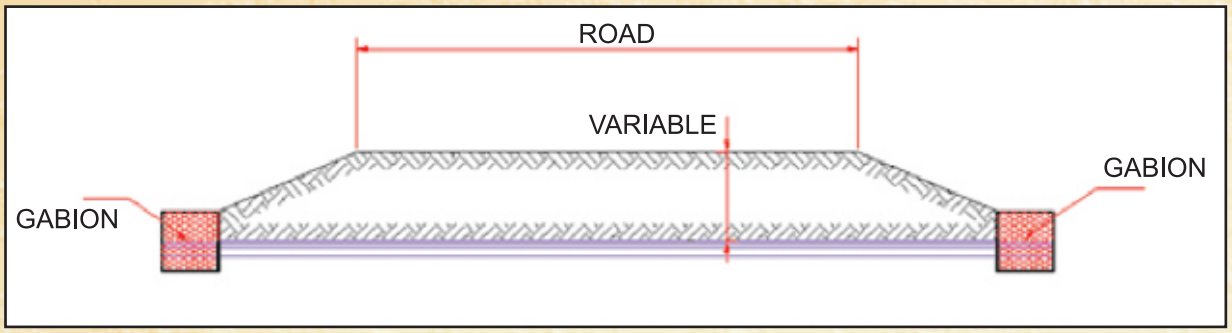



Fig. 8: Typical scheme of Gabion wall for road application

Fig 9: Typical photos of Gabion wall for along the road side

## 7.2 Gabion and mattress for river bank protection

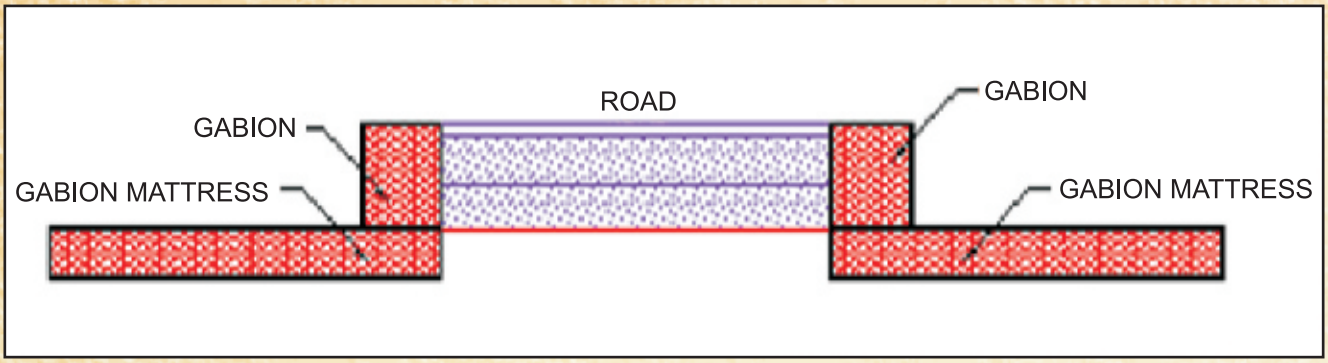



**Fig 10: Typical scheme of river bank protection with Gabion wall**

**Fig 11a,b &c : Typical photos of river bank protection with Gabion wall along road**

Culvert are the commonly used both as cross-drains for ditch relief and to pass water under a road at natural drainage and stream crossings. In either case, they need to be properly sized and installed, and protected from erosion and scour. Natural drainages need to have pipes large enough to pass the expected flow plus extra capacity to pass debris without plugging. Discharge (design flow) will depend on the watershed drainage area, runoff characteristics, design rainfall intensity, and return period (frequency) of the design storm.

### 7.3 Culvert protection with Gabion for road

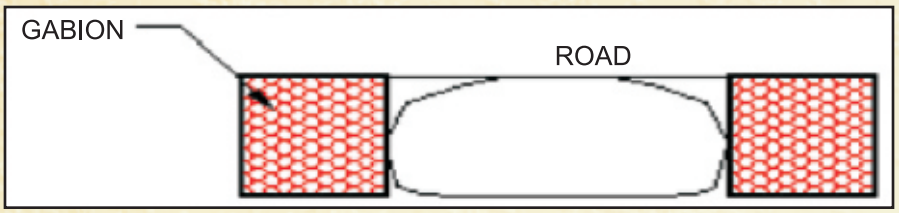



**Fig 12: Typical scheme of culvert protection with Gabion wall**

**Fig 13: Typical Photo of Culvert with Gabion Gravity Retaining wall**

## 7.4 Multiple pipe or River crossing structure

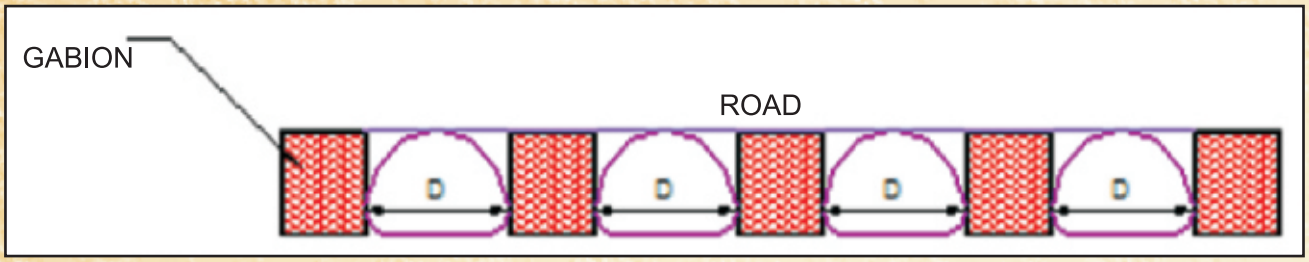



**Fig 14: Typical scheme of multiple pipe protection with Gabion Retaining wall**

**Fig 15a,b&c : Photos of multiple pipe protection with Gabion Gravity Retaining wall**

## 7.5 Minor Bridge pillars and abutment protection with Gabion wall

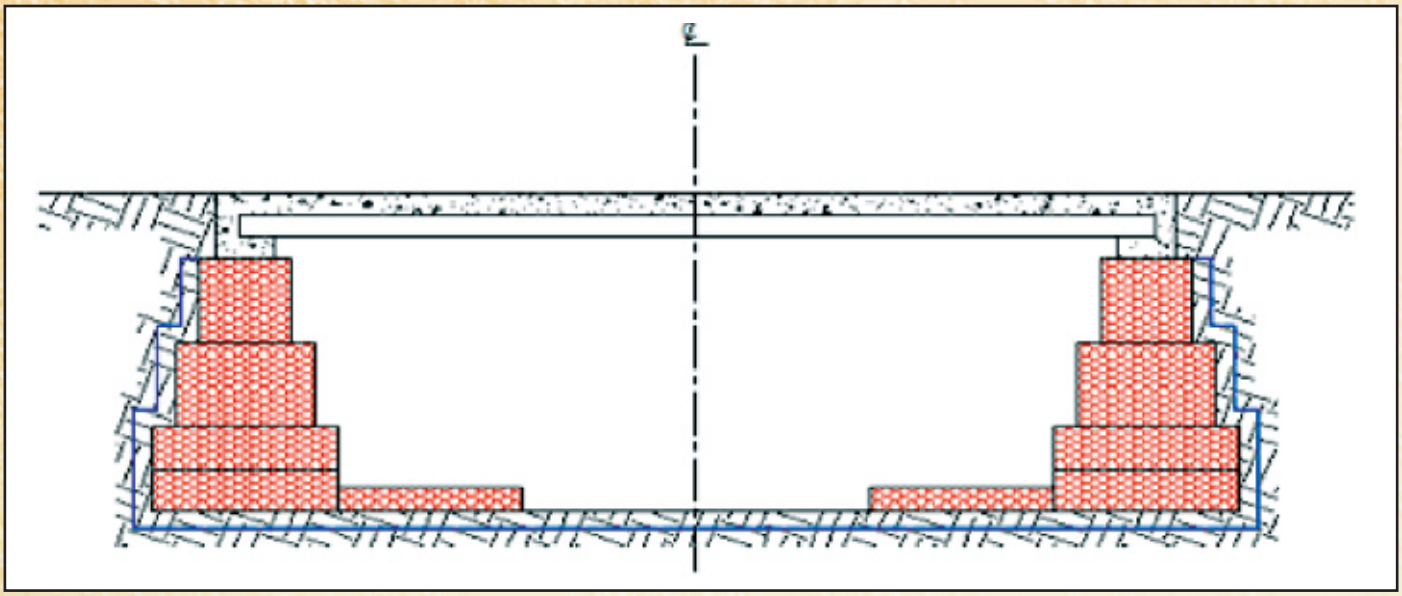


Fig 16: Typical scheme of minor bridge protection with Gabion retaining wall

Fig 17: Photograph of Minor bridge protection with Gabion retaining wall

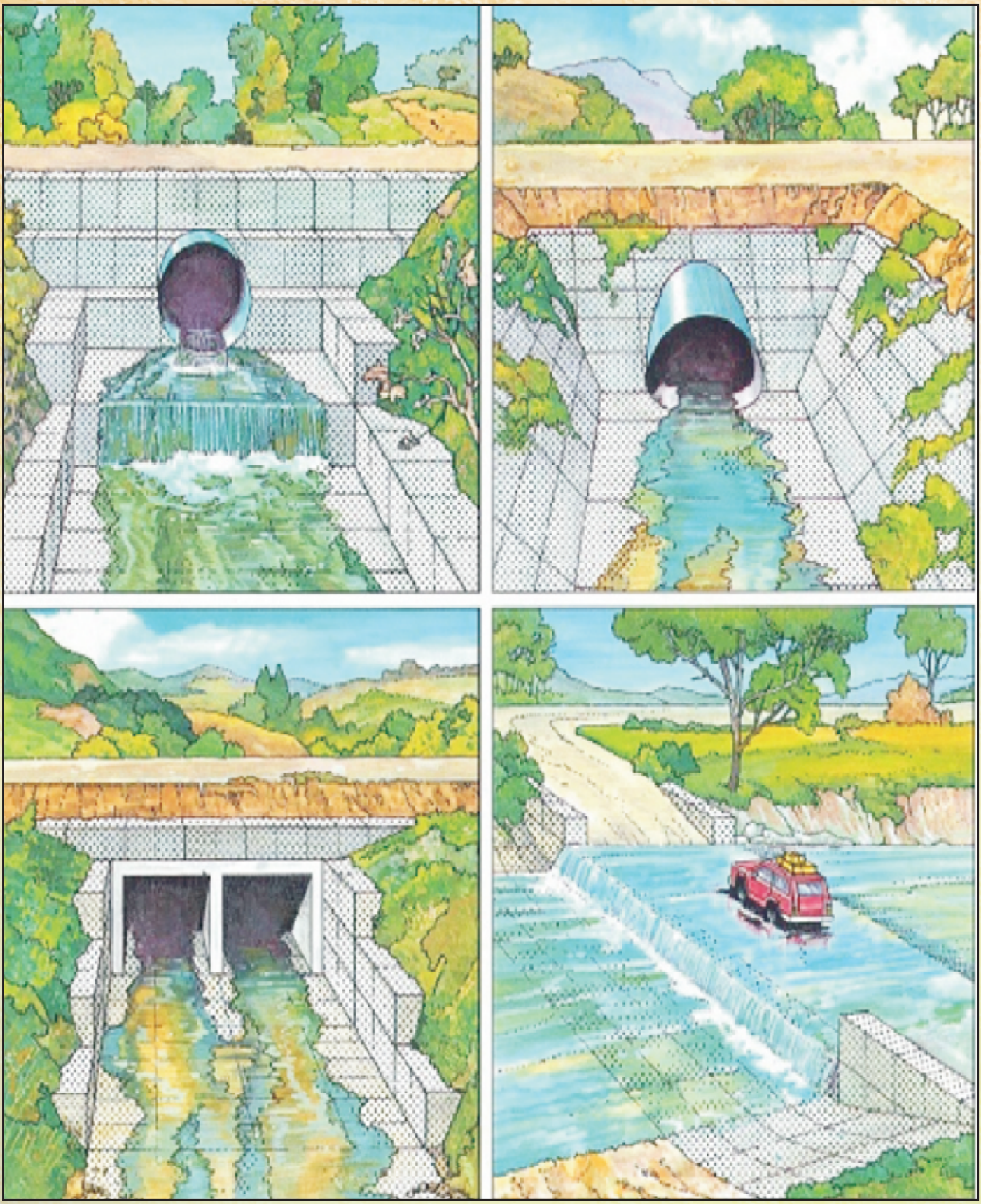
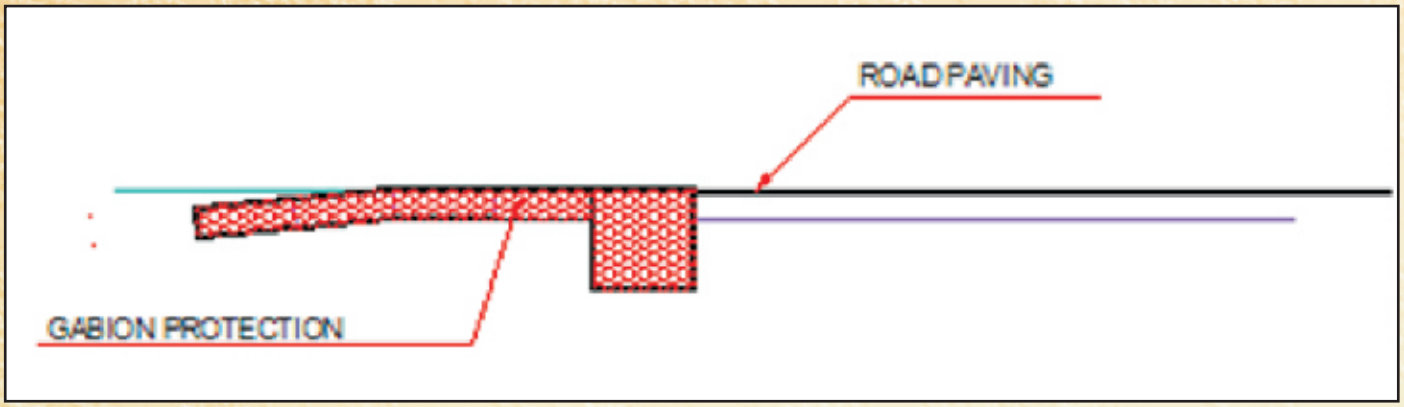


**Fig 18 : Typical different scheme of culvert with Gabion Retaining wall**

## 7.6 Bank protection with Mattress for Rural Road



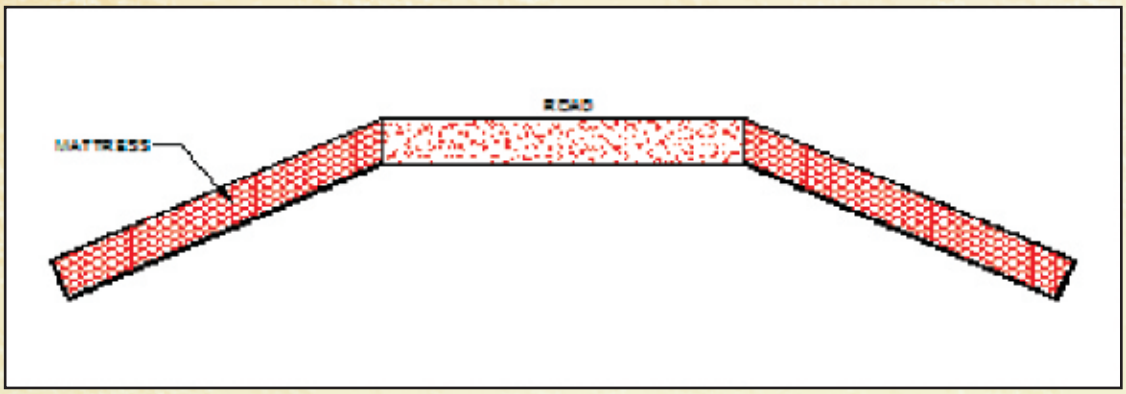




**Fig 19 a & b: Typical Scheme of Gabion mattress for slope protection in conjunction with water front structure for pavement protection**

**Fig 20 a & b : Photograph of Gabion mattress for slope protection on River & Road**

## 7.7 Gabions as Crash Barrier on Sharp Curves

Fig 21 : Photo of Concrete crash Barrier on Sharp Curve on Hilly Terrain

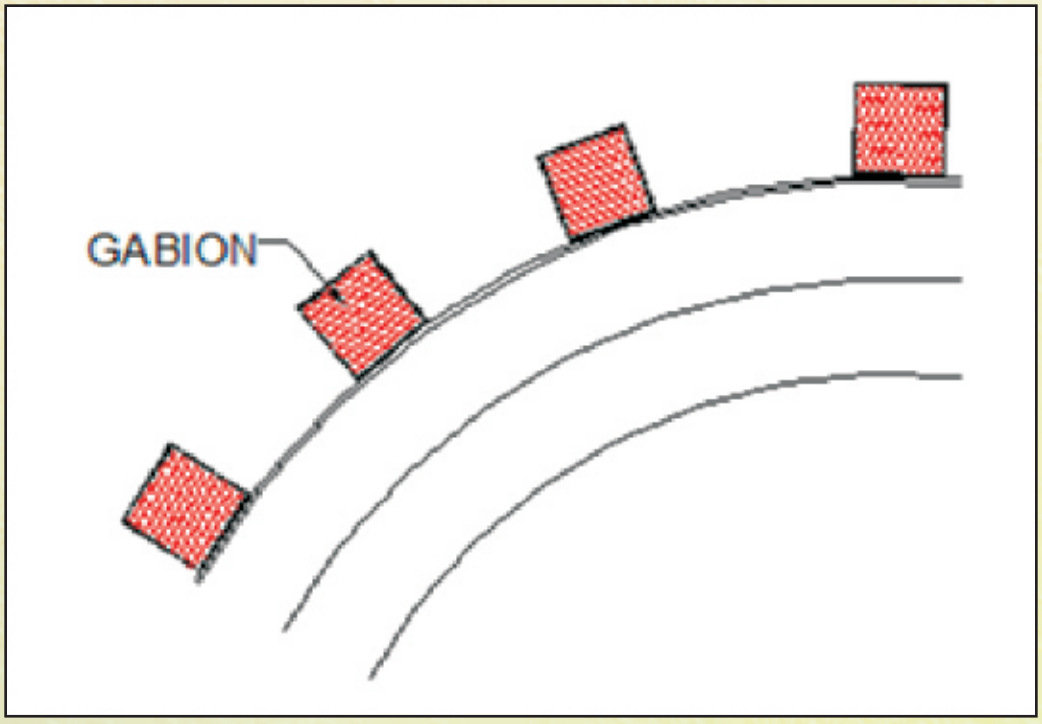



Fig 22 : Typical scheme of Gabions as Crash Barrier on Hilly Roads

Fig 23 : Photo depicts Gabion wall as crash Barrier on Sharp Curve on Hilly Road

### 7.8. Typical road failure on valley & hill side

Fig 24 a & b: Typical Road Failure problem

The most appropriate stabilization or retention measure will depend on site-specific conditions such as the size of the slide, soil type, road use, alignment constraint, and the cause of the failure. Here is a range of common types slope stabilization/retention (Fig. 24a&b) appropriate for low-volume roads, presented roughly from simplest and least expensive.

Retaining structures are necessary in steep areas to gain roadway space or to support the roadbed on a steep slope, rather than make a large cut into the hillside. They can also be used for slope stabilization. Fig 25 a&b presents information on common types of Gabion Gravity retaining walls and Simple design criteria for Gabion walls, where the base width is commonly 0.5-0.7 times the wall height. Gabion structures are very commonly used for walls up to 6 meters high, particularly because they use locally available stones and are labor intensive.

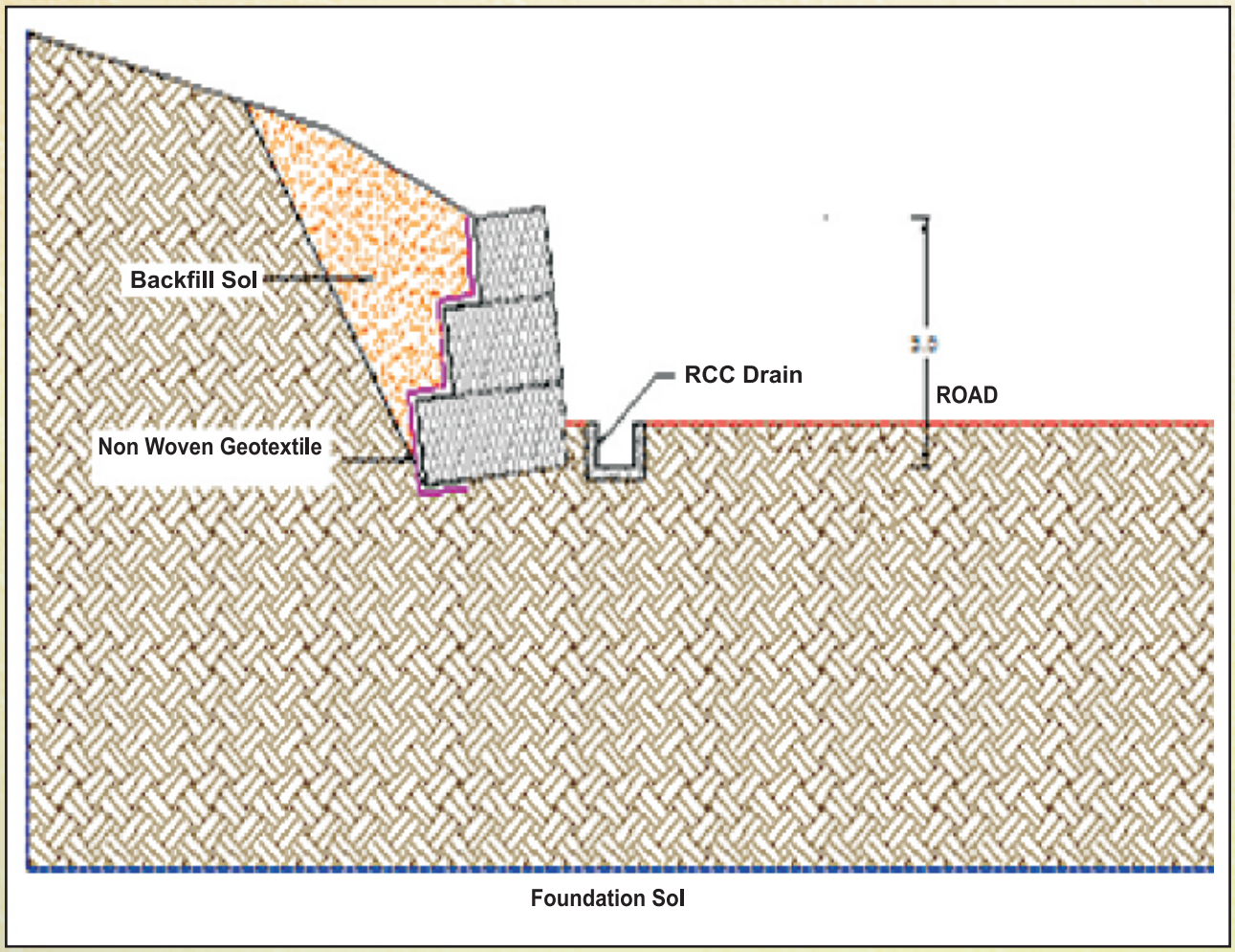



**Fig 25 a : Typical Scheme of Gabion Gravity Retaining wall for road in Hillside**

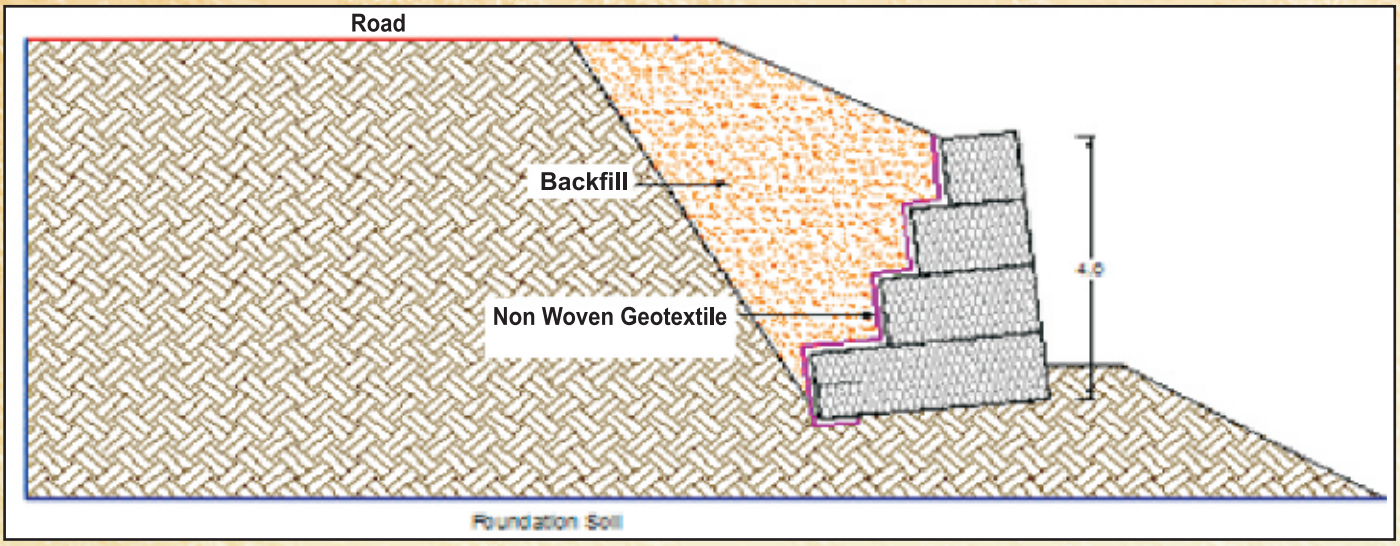



Fig. 25b : Typical Scheme of Gabion Gravity Retaining wall for road in Valleyside

Fig. 26a&b: Gabion wall for Earth retention at Road side

Fig 27a&b : Gabion Retaining wall for Road stabilisation in Rural Roads

For low to high walls in many geographic areas, Mechanically Stabilized Earth (MSE), or “Reinforced Soil” structures are the least expensive type of wall available. They are simple to build, and often they can use on-site granular backfill material.

They are consisting of Gabion basket facia units with an integrated double twist mesh as secondary reinforcing element. Structure consists of Gabions as an external face, and double twist mesh panel as tail/ reinforcing elements. They can be built with a stepped or vertical face, with or without a batter. They are specially designed for sites and situations where it is necessary to reconstitute the soil mass and where filling stone is scarce or expensive to obtain.

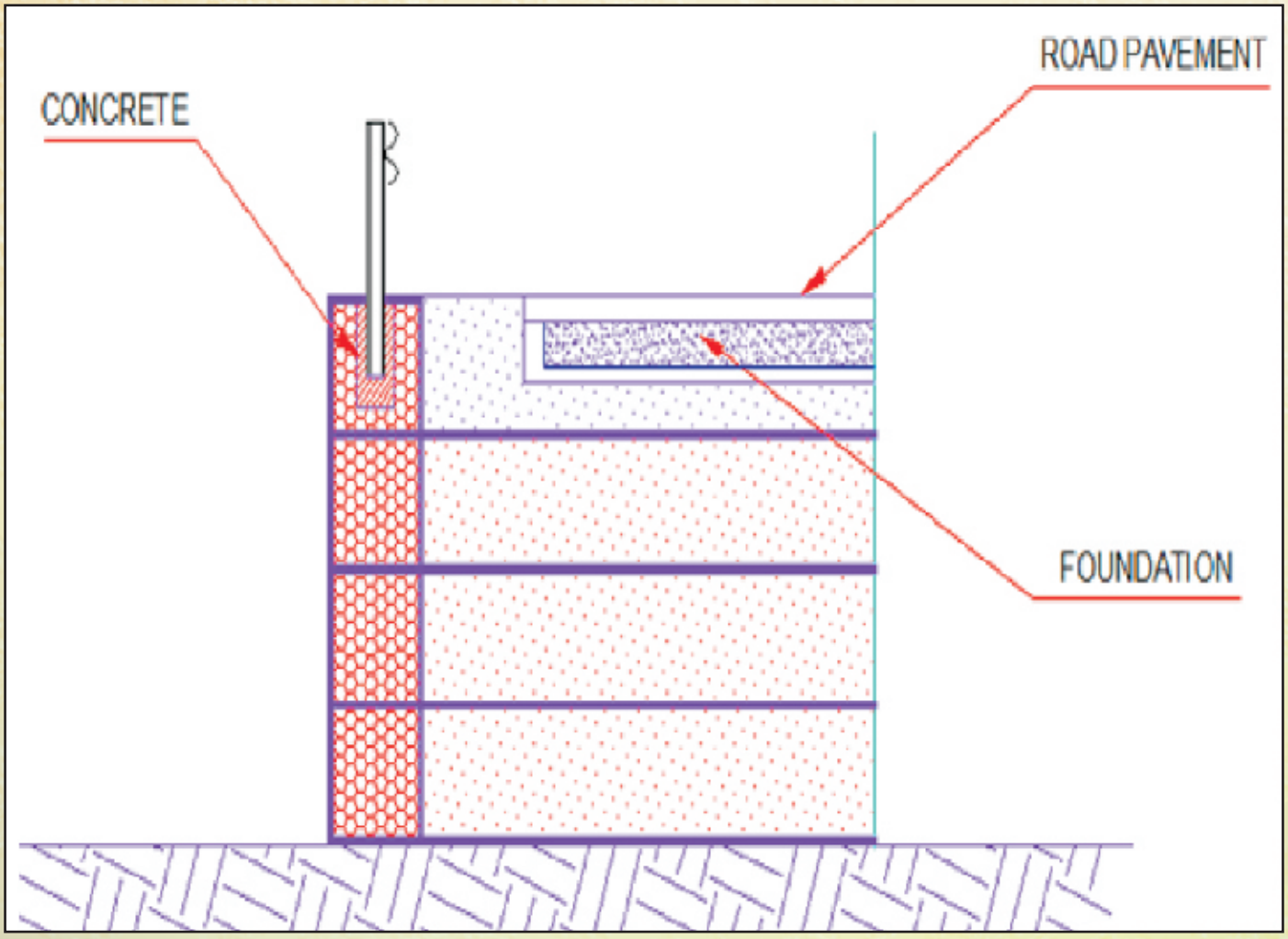



**Fig 28 : Typical Scheme of Reinfored soil wall with Gabion facia**

**Fig 29 : Typical photo of Reinfored soil wall with Gabion facia**

In stretches of road, where space is available, a vegetated slope face shall be provided for the soil reinforcement system. The Soil Reinforcement with green facia system consists of panels of double twist; mechanically woven hot dipped galvanized with PVC coated hexagonal wire mesh. These units are provided with a coir mat connected to the wire mesh during the manufacturing process to promote greenery on the Facia and to retain the fines in the backfill material. This system is also pr ovided with triangular steel brackets to provide support to the facia.Green Facia unit is best suited option since it enhances vegetation thereby stabilizing the slope. With this kind of solution we see that soil stabilization need and environmental balance are taken care off. The solution is aesthetically very pleasing appearance and is economical for smaller heights as well.

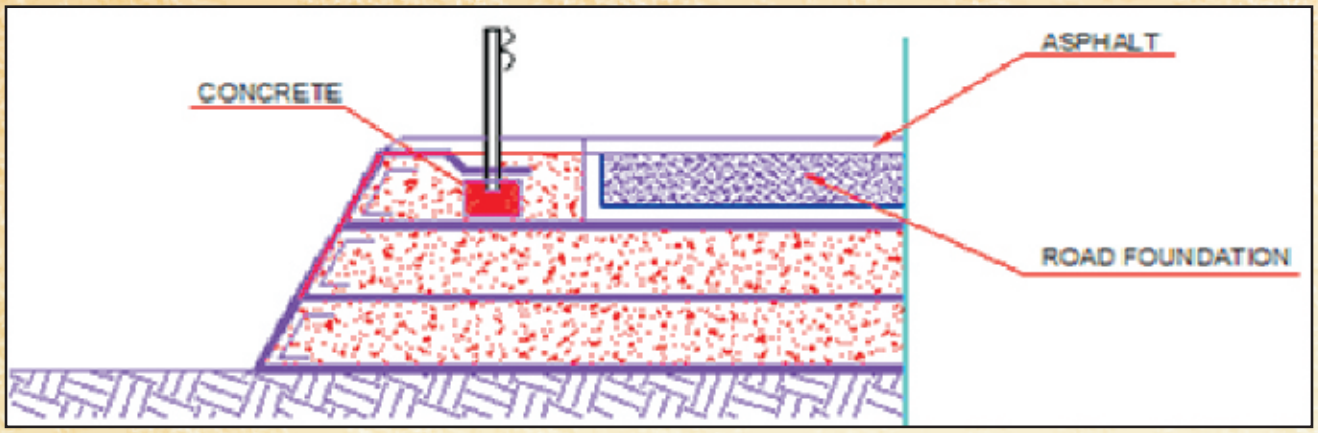



Fig 30 : Typical scheme of soil reinforced slope with Green facia

Fig 31 : Soil reinforced slope with Green facia at road side

## 7.9 Gabion embankment for Rockfall protection / Toe Wall

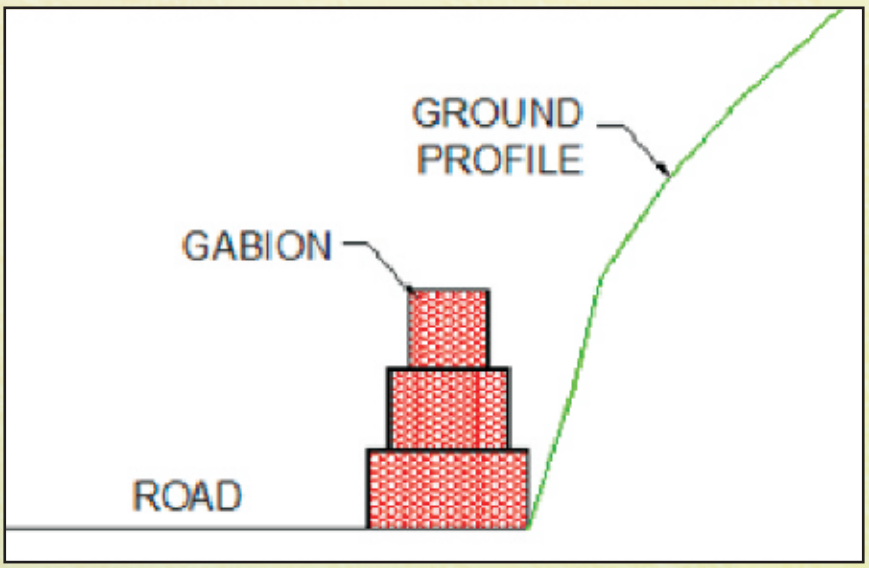
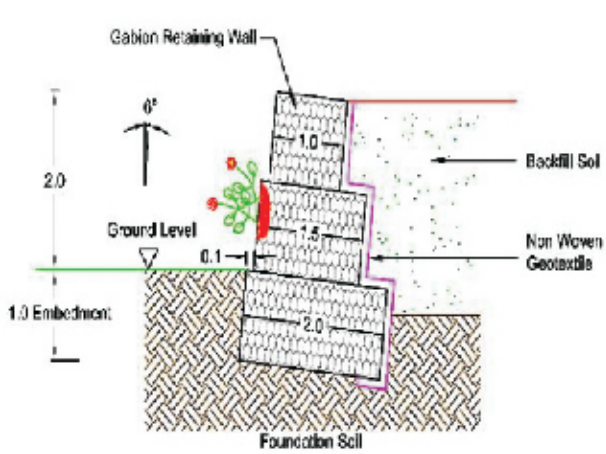


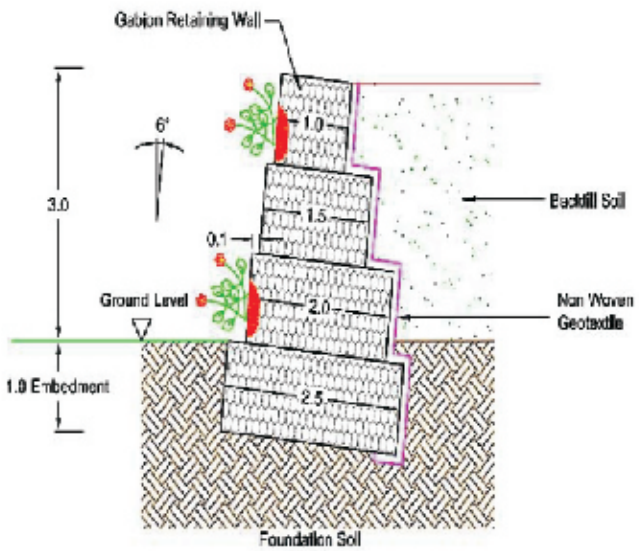

Fig.32: Typical scheme of Gabion wall for rockfall protection

**Fig.33: Photos depict Gabion toe wall on Valley side of Road**

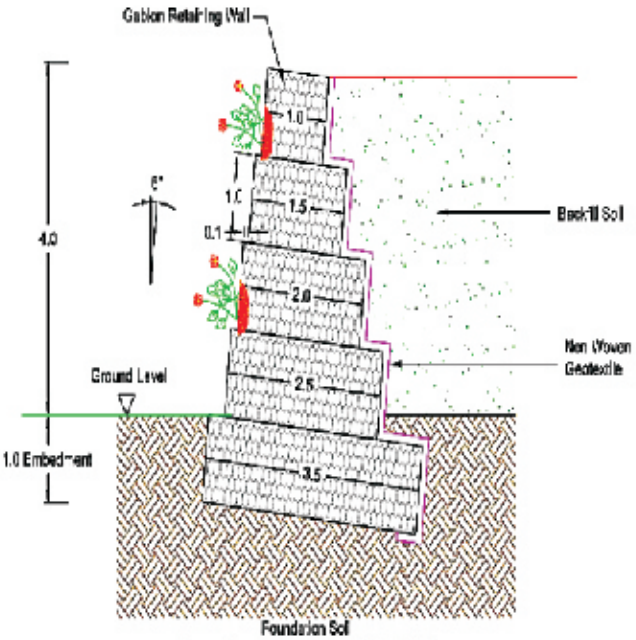
## 8.0 Typical Sections of Gabion Wall



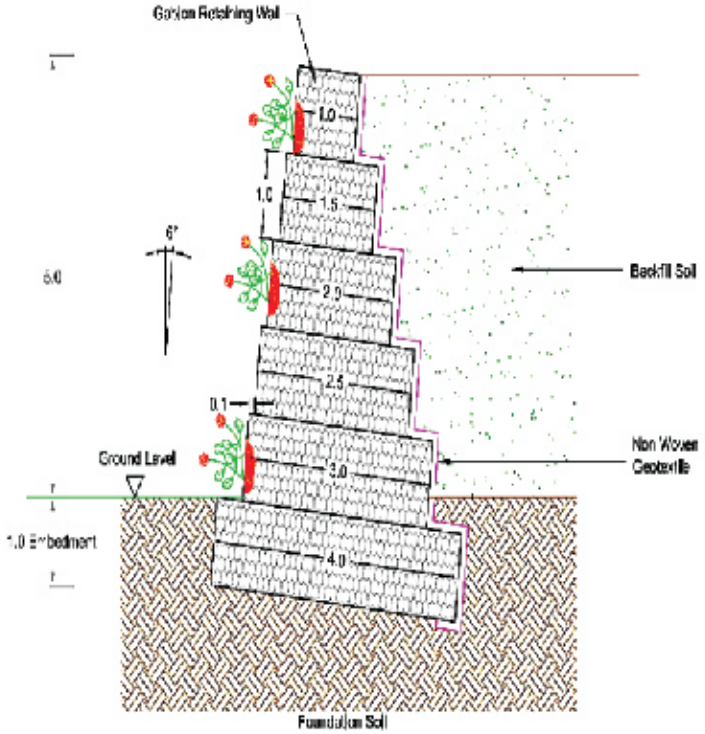

Cross Section of 2.0m high (AGL)
Gabion Retaining Wall



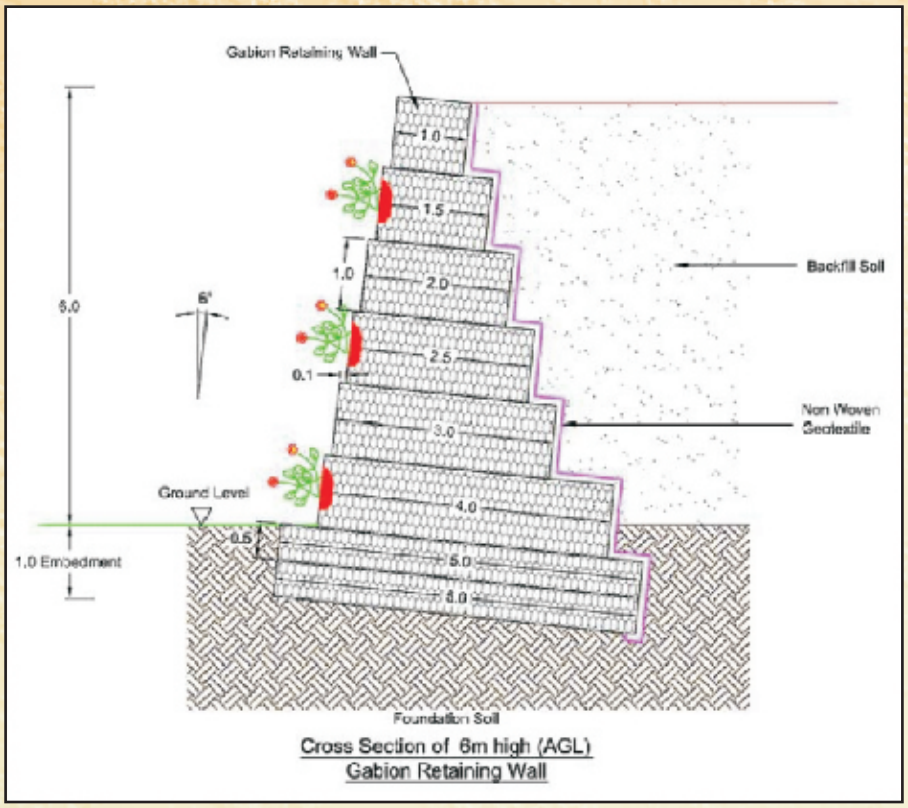

Cross Section of 3.0m high (AGL)
Gabion Retaining Wall



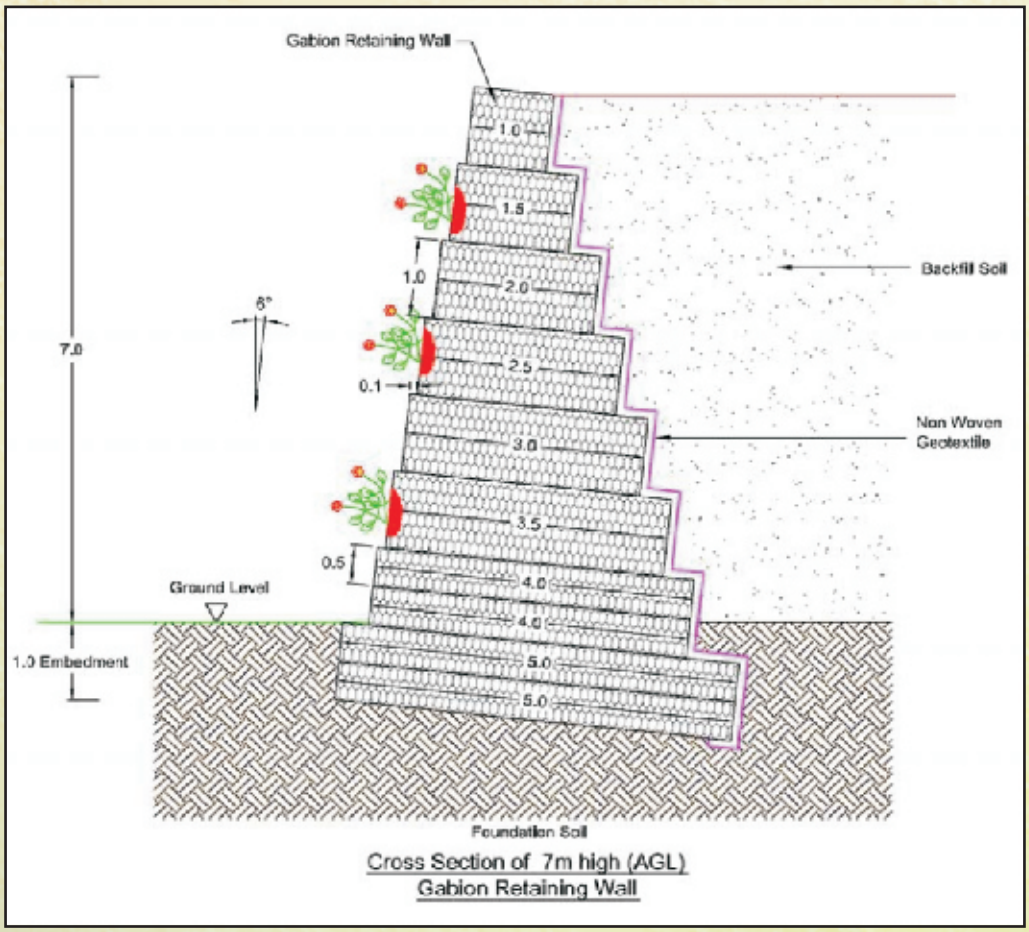

Cross Section of 4.0m high (AGL)
Gabion Retaining Wall



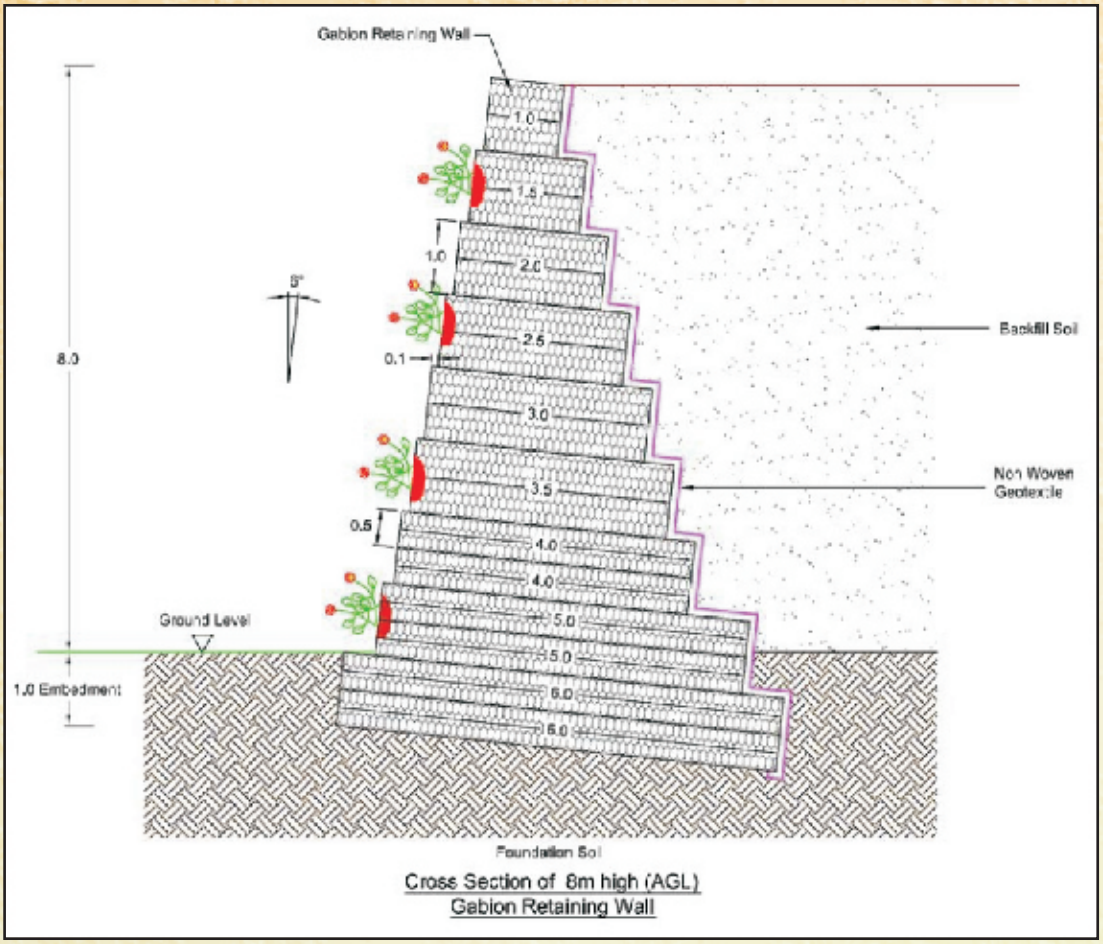

Cross Section of 5.0m high (AGL)
Gabion Retaining Wall




Cross Section of 6m high (AGL)
Gabion Retaining Wall




Cross Section of 7m high (AGL)
Gabion Retaining Wall



Cross Section of 8m high (AGL) Gabion Retaining Wall

## 9.0 Comparison of Gabion vs. PCC/RCC/RR Masonry Wall

| Parameters | Gabion Wall | PCC/RCC/ RR Masonry Wall |
|---|---|---|
| **Flexibility** | It is a flexible structure & can accommodate differential settlement without compromising structural integrity. | It is a rigid structure & cracks will occur due to differential settlement. |
| **Permeability** | The system is made up of gabion boxes filled with stones & permeability of the front face ensures the drainage of the backfill resulting in less hydrostatic pressure. | It is an impermeable structure and if sufficient drainage measures are not provided, very high hydrostatic pressure can occur. |

| | | |
|---|---|---|
| **Simplicity / Economy** | Gabions do not require skilled labour force or special equipment. Tools like pliers, tweezers, crowbars or any other easily available tools. | Specialized labour, steel formwork and machinery required. Material cost is also high comparatively. |
| **Environmental Friendliness** | These systems are environmental friendly. Gabion wall covered with a lush green vegetation topping offer an excellent opportunity to enhance the landscape. In general, Carbon foot print emission for gabion facia structures are relatively less | Cement concrete construction is non-eco friendly technology. Growth of vegetation leads to cracks thereby making the structure more unstable. Doesn't have noise absorbing property; instead, echo is created that results in noise pollution. |
| **Impact Resistance** | Good shock absorbent during sudden impact. Flexible facia are well resistant to damages. | Crack develops in the rigid concrete when there is sudden impact. Being a continuous structure, local rectification is not possible. |
| **Foundation Consideration** | Flexible in nature, it can be founded on yielding foundations. Hence, chances of failure due to settlement are minimum. In extreme cases, systems can be placed with nominal ground improvement techniques like soil replacement etc. | Systems are rigid in nature & highly sensitive to slightest of settlement in foundations. They exert huge amount of pressures in the foundation and requires extensive ground improvement techniques or wall needs to be founded on hard strata. Huge earth work, extra items & extra cost. |
| **Seismic & Dynamic forces** | Flexible in nature, these systems are accommodative to dynamic forces and don't collapse in event of seismic action. | This system attracts huge inertial forces due to rigidity and can fail instantly in case of seismic action. |
| **Failure Mode** | Flexible system, failure signs can be detected and rectified. | Rigid system, failure is spontaneous. |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