

TECHNICAL SPECIFICATION OF GABION STRUCTURES

1 INTRODUCTION

A Gabion structure is prepared from pre-assembled rectangular cages made of double twisted steel woven wire mesh filled with rocks/ boulders. It is a simple gravity retaining structure, which retains soil with its weight. These types of structures are in use in highways, bridges, canal linings, buildings, shore protection works, etc., as shown in **Fig. 1a to d**. The porosity of gabions prevents the pore-water pressure development behind the walls which, is one of the major advantages of these kinds of systems. These structures blend with the surroundings and allow vegetation to take roots through the structure which enhances the life of the structure. Reduced carbon foot prints are also a noticeable feature when compared to conventional solutions.



Fig. 1a Soil Retaining behind an Abutment



Fig. 1b Apron Works



Fig. 1c Shore / Bank Protection



Fig. 1d Bridge Abutment Protection

3 ELEMENTS OF GABION

Following sections describe the characteristics of the materials used in construction of gabion walls. In addition to the gabion elements, the performance of the gabion structure hinges on the properties of infill, retained fill and the rockfill and other components and measures for efficient design and adoptability.

3.1 Mechanically Woven, Double-Twisted Hexagonal Wire Mesh Gabions

Gabion is rectangular box made from mechanically woven double twisted hexagonal mesh filled with rock or stones (**Fig. 2c**). A terminal wire is used to edge the wire mesh perpendicular to the double twist by mechanically wrapping the mesh wires around it at least 2.5 times (**Fig. 2a**). The hexagonal shape of the mesh helps in achieving uniform distribution of forces. Mesh should be non-corrosive and should possess high tensile strength. The details of the different mesh types, sizes and various tests are available in IS 16014 and are reproduced in and **Table 3**. The wires of the mesh should be galvanised with zinc and/or polymeric (coating like Polyvinyl Chloride (PVC), Polyamide (PA6), other polymer etc.) coated to prevent corrosion. Better coatings of Zn Al alloy like Zn 95% Al 5% and Zn90% Al 10% are used which are better than only Zinc. Similarly better polymeric coatings like polyamide are used.

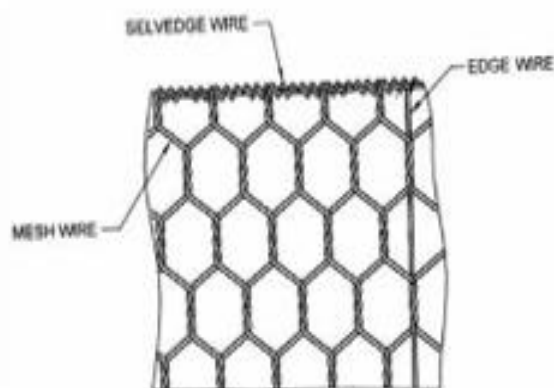


Fig. 2a Details of Mesh Wire, Selvedge and Edge Wire

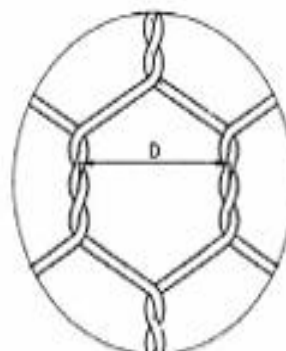


Fig. 2b: Mesh Type and Nominal Size (D)

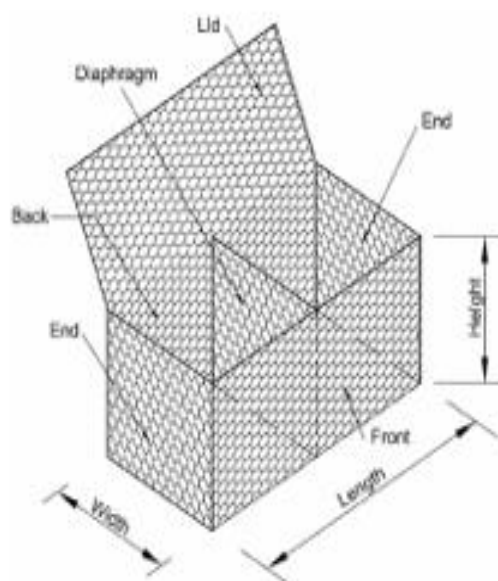


Fig. 2c: Details of Assembled Gabion Box

Gabion boxes are generally transported in collapsed condition and are restructured into boxes of required dimensions at the site. These boxes are joined using stainless steel fasteners or lacing wires or galvanised rings depending on the specifications. All these materials should be tested and confirmed to the specifications as per IS 4826, IS 12753, IS 4454 (IV). The tensile strength of mesh wire lacing wires, stiffeners and fasteners should be in accordance with the specifications and requirements as directed by IS 280, with minimum elongation of 10 percent with the test performed on a gauge length of test specimen of 200 mm. Minimum tensile strength of the wire mesh and zinc and polymeric coating shall be as per **Table 5**. **Table 14** gives the requirements of wire coating according to the environmental conditions.

3.4 Prefilled Gabions / Revet Mattress

Gabions are filled on site manually or with machinery. In case of underwater application, gabion filling is not possible. Also, in case of emergency filling of gabion is not feasible. In such conditions gabions are prefilled and installed. Generally, gabions for prefilled application are filled in the plant or suitable nearby location.

4 COMPONENTS OF GABION RETAINING WALL

Gabion walls are mass gravity walls having three major components like gabion box, stone for filling gabion, filter media and backfill (Fig. 5). This section presents specifications of various materials used in gabion structures.

- Technical Specification of Gabion / revet Mattress Mesh
- Rocks for filling the Gabion
- Filter media
- Foundation and Backfill soil properties

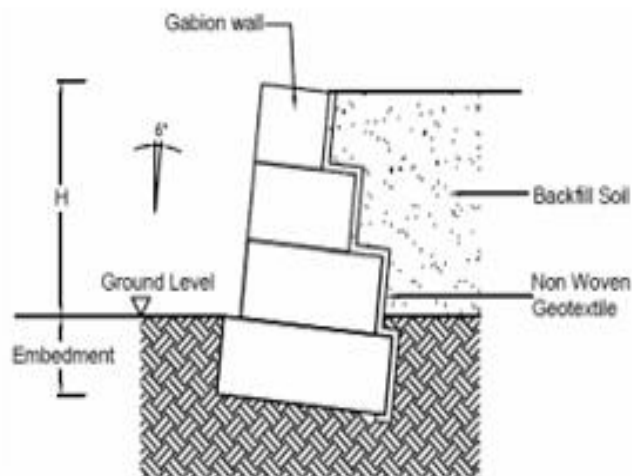


Fig. 5: Typical Section of Gabion Wall with Different Component

4.1 Technical Specification of Gabion / Revet Mattress Mesh

a) Wire technical specification used in Gabion / revet Mattress mesh

All tests on the mesh, lacing wire and selvedge wire (Fig. 2a) must be performed prior to manufacturing the mesh.

Tensile strength: The wire used for the manufacture of Mesh shall have a tensile strength minimum 350 N/mm² – 550 N/mm² in accordance with IS 280. Wire tolerances shall be in accordance with IS 16014 (Class T1).

Elongation: Elongation of wire shall not be less than 10%. Test must be carried out on a sample at least 20 cm long.

Metallic coating: The wire shall have minimum quantities of metallic coating given in accordance with IS 4826 and Zn Al alloy coating has been given as per **Table 1**.

Ageing and corrosion resistance

1. Zinc metallic coating- When subjected to test in a sulphur dioxide environment according to the procedures in ISO 6988 (0,2 dm³ SO₂ per 2 dm³ water) after 14 cycles of discontinuous test, the mesh samples surface shall not show more than 5 % of DBR (Dark Brown Rust).

When subjected to the neutral salt spray test according to the procedures in ISO 9227 after a period of 500 h of exposure, the mesh sample surface shall not show more than 5 % of DBR.

2. 95% Zn+ 5%Al - When subjected to test in sulphur dioxide environment according to procedures in ISO 6988 after 28 cycles of discontinuous test, the test samples shall not show more than 5% of DBR (Dark Brown Rust).

When subjected to the neutral salt spray test according to the procedures in ISO 9227 after a period of 1000 hr of exposure, the mesh samples shall not show more than 5 % of DBR.

3. 90% Zn+ 10%Al - When subjected to test in sulphur dioxide environment according to procedures in ISO 6988 after 56 cycles of discontinuous test, the test samples shall not show more than 5% of DBR (Dark Brown Rust).

When subjected to the neutral salt spray test according to the procedures in ISO 9227 after a period of 2000 hr of exposure, the mesh samples shall not show more than 5 % of DBR.

Adhesion of metallic coating: The adhesion of the zinc coating to the wire shall be such that, when the wire is wrapped six turns around a mandrel having four times the diameter of the wire, it does not flake or crack when rubbing it with the bare fingers in accordance with EN 10244-1 and IS 4826.

Table 1 Minimum Mass of Metallic Coating for Heavily Coated, Soft Type for Different Wire Sizes Used in Gabion and revet Mattresses^[4]

Sr. No	Nominal Diameter of Galvanized Wire mm	Mass of Zinc/Zinc Alloy coating g/m ²	Permitted Tolerances on wire diameters mm
1	2.00	240	±0.05
2	2.20	240	±0.06
3	2.40	260	±0.06
4	2.70	260	±0.07
5	3.00	270	±0.08
6	3.40	270	±0.09
7	3.90	280	±0.10

b) Internal Connecting Wires

Cross Ties/ stiffener wire: Galvanized wire diameter 2.2 mm, and with Polymeric coating, 3.2mm when measured with Polymeric coating.

c) PVC (Polyvinyl Chloride) Coating

- Specific gravity — in the range from 1.30 to 1.35 when tested in accordance with IS 13360(Part 3) / ISO 1183.
- Tensile strength — Not less than 20.6 MPa when tested in accordance with IS 13360 (Part 5) /ISO 527. Elongation at break: not less than 200% in accordance with ISO 527.
- Hardness — Shore 'D' between 50 and 60,when tested in accordance with IS 13360 (Part 5) / ISO 868.
- Resistance of PVC coating to sodium chloride solution — When PVC coated wire is tested in accordance with IS 16014 ,there shall be no loss of mass.
- Salt spray exposure — The PVC shall show no effect after 3000 h of salt spray exposure in accordance with IS 13360 (Part 8)/ ISO 9227
- Coating thickness – Nominal 0.5mm and minimum 0.4 mm

- d) **Mesh opening:** Mechanically woven wire mesh has mesh opening as show in **Fig. 2b**. Mesh opening for different mesh type is shown in **Table 2**.

Table 2 Mesh Opening Size

Mesh Type	'D' Mesh Opening Nominal Size (mm)	Tolerance (%)
6x8	60	0 to + 8
8x10	80	0 to +12
10x12	100	- 4 to +12

Table 3 Technical Specification of Gabion ⁽⁴⁾

Sr. No.	Characteristics	Mesh Type					
		10x12			8x10		
		Only Zn / Zn Al alloy		Zn / Zn Al alloy + Polymer coated	Only Zn / Zn Al alloy		Zn / Zn Al alloy + Polymer coated
1	Mesh wire dia,mm	2.70	3.00	2.70/3.70 (ID/OD)*	2.70	3.00	2.7/3.7(ID/OD)*
2	Edge/Selvedge wire dia,mm	3.40	3.90	3.40/4.40(ID/OD)*	3.40	3.90	3.40/4.40(ID/OD)*
3	Lacing wire dia,mm	2.20	2.20	2.20/3.20(ID/OD)*	2.20	2.20	2.20/3.20(ID/OD)*
4	Polymeric coating thickness, mm	NA		Nominal-0.50, Minimum-0.40			Nominal-0.50, Minimum-0.40
5	Typical sizes-Length x Width x Height (in meter) (Number of diaphragms)	4x1x1(3 Nos), 3x1x1(2 Nos), 2x1x1(1Nos), 1.5x1x1(0 Nos), 2x1x0.5(1 Nos), 3x1x0.5(2 Nos), 4x1x0.5(3 Nos), 2x1x0.3(1 Nos), 3x1x0.3(2 Nos), 4x1x0.3(3 Nos)					
6	Tolerance in size of gabion box	Length and Width ±5 percent; Height >0.3 m ±5 percent; Heights≤0.3m ±10 percent;					

* ID/OD - Internal diameter/Outer diameter of Polymer coated wire

Table 4: Technical Specification of Revet Mattresses⁽⁴⁾

Sr. No.	Characteristics	Mesh Type	
		6x8	
		Only Zn / Zn Al alloy	Zn / Zn Al alloy + Poly coated
1	Mesh wire dia, mm	2.20	2.20/3.20 (ID/OD)*
2	Edge/Selvedge wire dia, mm	2.70	2.70/3.70(ID/OD)*
3	Lacing wire dia,mm	2.20	2.20/3.20(ID/OD)*
4	Polymeric coating thickness, mm	NA	Nominal-0.50, Minimum-0.40
5	Typical sizes-Length x Width x Height (in meter) (Number of diaphragms)	4x2x0.17(3Nos), 3x2x0.17(2 Nos), 2x2x0.17(1 No), 4x2x0.23(3 Nos), 3x2x0.23(2 Nos), 2x2x0.23(1Nos), 4x2x0.30(3 Nos), 3x2x0.30(2 Nos), 2x2x0.30(1 No)	
6	Tolerance in size of gabion box	Length and Width...±5 percent; Height≤0.3 m.....±10 percent	

* ID/OD - Internal diameter/Outer diameter of Polymer coated wire

e) Tests and Standard of Acceptance

Gabion and revert mattress mesh and materials shall be tested in accordance with procedure outline below and IS 16014 and shall meet prescribed criteria mentioned in **Table 5**.

Tensile Strength of Wire Mesh Panel

The wire mesh specimens shall be representative of proper field construction as to materials, mesh geometry, and workmanship, and shall be as large as practical to minimize the effect of variations. The tests shall be run with the load applied parallel to the axis of the twist and repeated on a separate test specimen with the load applied perpendicular to the axis of the twist.

Place the mesh into the machine grips such that the gripped mesh will be maintained in the mesh geometry characteristic of field use. The specimen of approximately 0.8 m width and 0.5 m height shall be tested. The effective width to be considered for test specimen shall be the distance between two extreme gripping points. The specimen should extend by at least one mesh repetition beyond the extreme gripping points on either side. However, specimen should not extend more than two mesh repetitions beyond extreme gripping points. The mesh shall be pre-loaded to 10% of the specified minimum strength and machine head travel stopped. The mesh gauge dimensions shall be recorded at this time and taken as the initial dimensions of the specimen where such dimensions are required. If the sample slips at any of the gripping point during the test, such a test shall be discarded and a new sample shall be taken. The loading shall then continue uniformly maintaining the displacement rate of 75 to 100 mm per minute, until first fracture or unwrapping of an individual wire in the system occurs. The distortion of the mesh or changes in gauge length shall be measured to accuracy consistent with reporting the percentage elongation to the nearest 0.5%.

Punch Test

The punch test could be done using two different apparatus.

1) Pre-Tensioned Punch Test

An uncut section of 1.82 m in length (unselvedged) and not less than 0.91 m in width shall have the ends securely clamped for 0.91 m along the width of the sample. When the width of the section under test exceeds 0.91 m, the clamps shall be cantered along the width and the excess width will be allowed to fall free on each side of the clamped section. The sample shall then be subjected to tension sufficient to cause 10% elongation of the sample section between the clamps. After elongation and while clamped as described above (and otherwise unsupported), the section shall be subjected to a load over 960 cm² of area applied to the approximate center of the sample section between the clamps and in a direction perpendicular to the direction of the tension force.

2) Secured Punch Test

An uncut section of 1.24 m in length and not less than 0.9 m in width (selvedged), including all selvedge bindings, shall have the sides and the ends securely clamped at every mesh opening to a rigid frame. After being secured as described above, the section shall be subjected to a load over 960 cm² applied to the approximate center of the sample section between the clamps and in a direction perpendicular to the direction of the tension force.

The sample shall withstand, without rupture of any strand or opening of any mesh fastening, an actual load applied by means of a circular ram at a uniform rate not to exceed 220 N/s equalling or exceeding the values shown in **Table 5**. The ram head used in the test shall be circular with a 350 mm diameter and have its edges bevelled or rounded to prevent cutting of the wire strands.

Pull-Apart Resistance Test

A set of two identical rectangular gabion panels, each with a width about 10½ mesh openings along a selvedge wire, shall be joined by properly installed wire fasteners along the two selvedge wires so that each fastener confines two selvedge and two mesh wires. If the fasteners are also to be used to join two individual empty gabion baskets, two additional selvedge wires that are each mechanically wrapped with mesh wires shall be included so that each fastener confines four selvedge and four mesh wires. The set of the jointed panels shall be subject to pull-apart resistance test. The specimen shall be mounted on a loading machine with grips or clamps such that the panels are uniformly secured along the full width. The grips or clamps shall be designed to only transmit tension forces. The load will then be applied at a uniform rate not to exceed 220 N/s until failure occurs. The failure is defined as when the maximum load is reached and a drop of strength is observed with subsequent loading or alternately the opening between any two closest selvedge wires, applicable to a fastener confining either two or four selvedge wires, becomes greater than 50 mm at any place along the panel width. The strength requirements of the jointed panels at failure shall be as shown in **Table 5**.

Table 5 Minimum Strength Requirements of Mesh and Connections

Mesh Type	10x12			8x10		6x8	
Characteristics	Only Zn / Zn Al alloy		Zn / Zn Al alloy + Poly coated	Only Zn / Zn Al alloy	Zn / Zn Al alloy + Poly coated	Only Zn / Zn Al alloy	Zn / Zn Al alloy + Poly coated
Wire Mesh Dia (mm)	2.7	3.0	2.7	3.0	2.7	2.2	2.2
Tensile strength parallel to twist (kN/m)	32.0	40.0	32.0	51.1	42.3	33.6	33.6
Tensile strength perpendicular to twist (kN/m)	15.4	20.5	15.4	26.3	20.4	13.1	13.1
Connection to selvages (kN/m)	10.2	11.22	10.2	20.4	16.32	10.2	10.2
Panel to panel connection using lacing wire or fasteners (kN/m)	10.2	11.22	10.2	20.4	16.32	10.2	10.2
Punch strength (kN)	17.8	19.58	17.8	26.7	21.36	17.8	17.8

f) Fabrication

Gabions shall be manufactured with all components mechanically connected at the production facility. The front, base, back and lid of the gabions shall be woven into a single unit. The ends and diaphragm(s) shall be factory connected to the base. The lid may be a separate piece made of the same type mesh as the basket. All perimeter edges of the mesh forming the basket and top, or lid, shall be mechanically selvaged with wire having a larger diameter.

Gabion is divided into cells by means of diaphragms positioned at approximately 1m centres. The diaphragms shall be secured in position to the base so that no additional lacing is necessary at the jobsite.

4.2 Rocks for Filling the Gabion

An unweathered (sound) naturally occurring angular or crushed hard rock material can be used for filling. Stone for the Gabion facia shall be hard, angular to round, durable and of such quality that they shall not disintegrate on exposure to water or weathering during the life of the structure. The minimum size of the rock to be filled in the boxes is governed by the mesh opening "D" in the mesh as shown in **Fig. 2b**. The minimum and maximum size of the stone used for filling shall be 1.5 to 2.5 times the mesh opening. Each range of sizes may allow for a variation of 5% oversize rock by number of particles, or 5% undersize rock by number of particles, or both. The rock pieces should be properly hand-placed and packed with their larger dimensions in the horizontal position. The size of any oversize rock shall allow for the placement of minimum of three layers of rock must be achieved when filling the 1 m high units and a minimum of two layers for the 0.50 m high gabion units and 0.3m thick gabion mattress.

Table 6 Properties of Rock to be fill in Gabion

Sr No.	Properties of Rockfill	Values
1	Minimum and Maximum size of stone	1.5 to 2.5 times mesh opening
2	Tolerance on size of stone	± 5%.
3	Minimum density	22kN/m ³
4	Los Angeles abrasion value	Not more than 45

Minimum density and Los Angeles abrasion can be changed by designer based on availability of the rock in the area. In places where stones are not available alternate material having good characteristics can be used.

8 INSTALLATION METHODOLOGY OF GABION

Gabions are delivered at the work site in bundles along with the lacing wire. Bundles must be unloaded using any available machine and stored close to the site where they are to be installed. While unloading care shall be taken that Gabion bundles are not damaged. Maximum 4 bundles shall be stacked over each other. Gabion bundles shall be stacked on a leveled ground with wooden rafters/sleepers in between them for easy in handling and preventing any damage to the mesh and other components like the selvedge wire. Storage can be outdoors as long as the bundles are not laid over abrasive or chemically aggressive surfaces (corrugated asphalt, oils, grease, chemicals, etc.).

The following are the steps in the basic procedure for erection and installation of structures. At the work site bundles should be opened and gabions assembled according to the following instructions:

- 1) Excavate the formation to the required level as shown in the drawings. If good bearing stratum is not observed after the excavation up to mentioned levels then, the same should be brought to the notice of Engineer-in-charge for further advice. The surface of formation should be free from any deleterious material and unwanted foreign objects. Loose pockets if any, should be excavated and filled with suitable granular or backfill material.
- 2) The place should be cleared of standing water to ensure proper placement of gabions. In case dewatering is not possible then gabions shall be installed underwater.
- 3) Compact the formation using Vibro-roller of 8 to 10 tonnes capacity. Density of compacted formation should be greater than or equal to 95% of the modified Proctor value.
- 4) The outer alignment of the gabion facia should be marked by the survey team as per the requirements in the drawings.
- 5) The gabions are unfolded and laid over an even, level and hard surface (compact ground). One or two persons may be deployed for the straightening of mesh panel activity depending on the size of gabions. The gabions should be properly assembled and wired together, so that all four corners match and form an exact rectangular shape and size as designed (**Fig. 30a and b**).

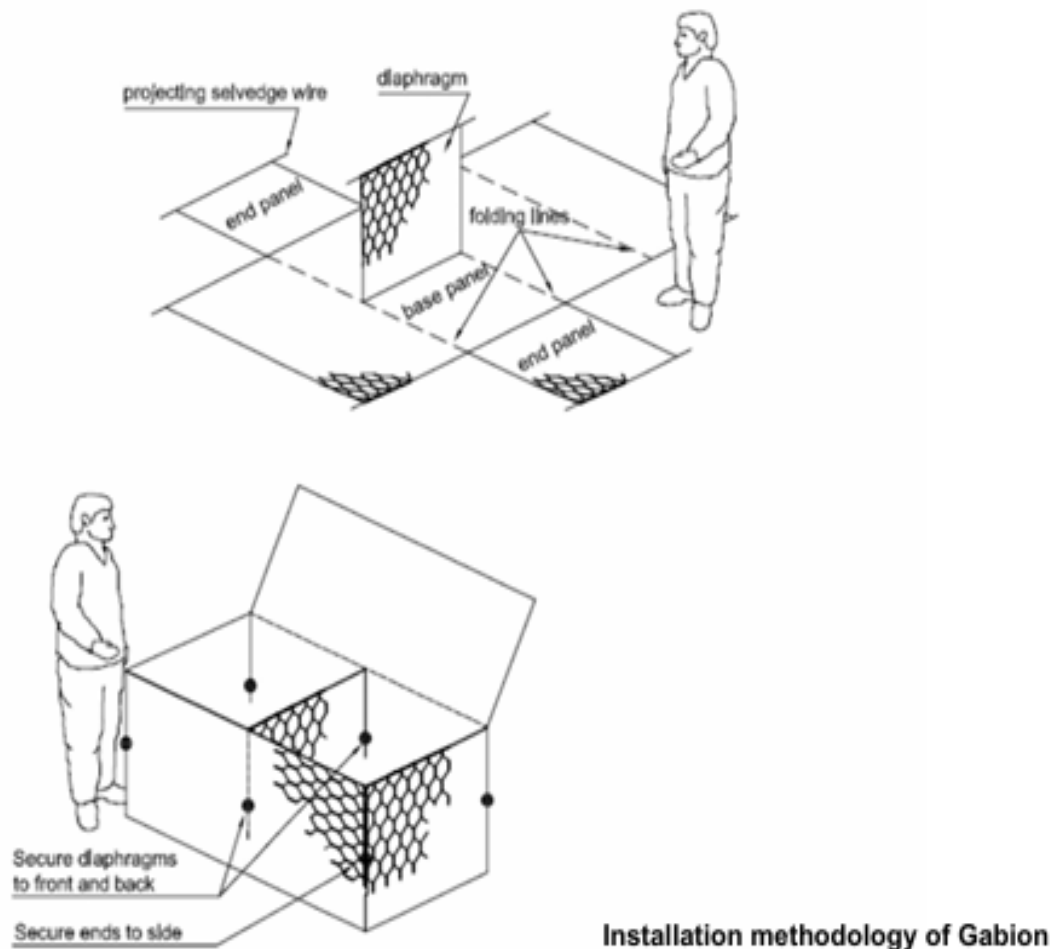


Fig. 30a and 30 b: Gabion Installation Steps

- 6) The side panels are opened up to form a box by tying the upper corner of each pair of side panels using the thick selvedge wires (**Fig. 31a**).
- 7) The edges are laced together, starting from top corner, in a continuous operation using alternate single and double loop at the spacing of one mesh length i.e., 100 mm to 125 mm. The ends of the lacing wire are secured at each corner and turned into the gabions. Individual ties of lacing wire should not be used. Alternatively, steel rings mentioned IS16014 can be used which are attached using mechanical tool (**Fig. 31a** and **31b**).
- 8) Similarly all the other sides are tied up and the box structure made, with the top end open to fill the boxes.

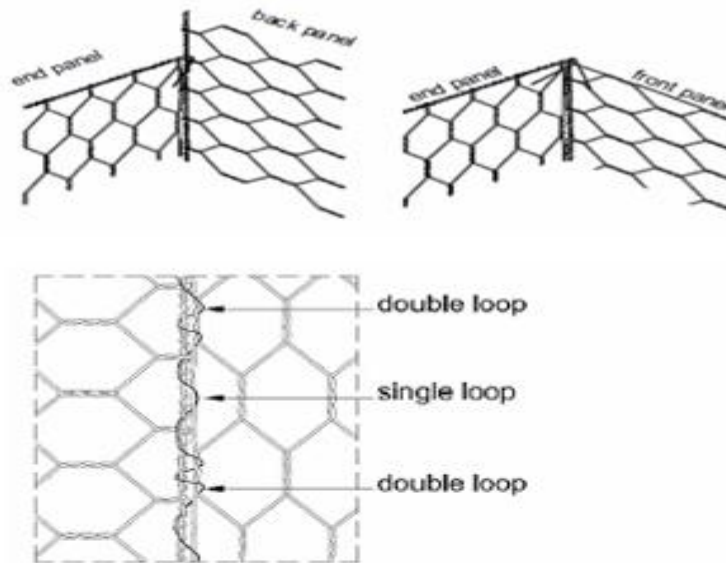


Fig. 31a: Assembling details with Lacing Wire



Fig. 31b: Assembling details with C-rings

- 9) The filling is then carried out with stones of dimensions larger than that of the mesh opening making sure that there are minimum voids. For better finish the stone fill to the front face is selected and placed carefully to give the best appearance. When using quarried/crushed rock, rock shall be selected in such a way that at least one face is flat-shaped. This will not be applicable when using rounded stone from rivers. Front loader or back loaders or excavator can be used to fill gabions maintaining porosity. For

a better alignment of the face, it is advisable to include internal tie wires while filling the gabions. This horizontal tie wires prevent gabion deformation during the filling stage.

Porosity check

The average porosity of the Gabion boxes can be found out by weighing the filled boxes. The weight of the box can be compared with calculated weight of box.

Let us assume the density of the stone (γ_s) = 26 kN/cum.

In general porosity of the filled Gabion box shall be around (n) 30-40%.

Density of gabion would be $\gamma_g = \gamma_s * (1 - n)$ ignoring air voids

Assuming 35% porosity the density of gabion = 16.9 kN /cum.

Hence, weight of 1.5 x 1 x 1 m Gabion box = 1.5 x 16.9 = 25.35 kN ~ 2.5 ton

The weight of the filled gabion box should be approximately equal to the calculated weight.

8.1 Some Causes of Failure of Gabion Retaining Walls

As explained earlier that the Gabion structure is flexible and permeable. While the settlements cannot be avoided, the gabions can adjust to the settled/deformed profile. Development of pore pressure at the back of the wall may be negligible.

There have been some causes of failure of the gabion walls due to improper wrong data, improper design, poor workmanship at site and/or material failure. Some of such failures include:

- 1) Insufficient data collection required to improper design and hence the final performance is affected.
- 2) While these structures can be constructed with local labours including skilled and unskilled labour, minimum machinery and equipment, construction of Gabion wall is highly quality conscious. It needs to be constructed as monolithic structure with simultaneous backfilling and compaction which is often not followed at site due to poor workmanship.
- 3) Improper galvanisation of the wires (mesh, fastening, lacing, stiffening etc.). Improper galvanising leads to the premature degradation of wires/gabions, causing the failure of the structure.
- 4) Improper foundation and placing of gabion layers without the required preparation can lead to excessive settlements and thereby deformation of the structure.
- 5) Use of improper graded aggregate or rock and improper filling may lead to post construction deformations of the boxes and settlements.

Note: Besides the gabion work/item, the latest CPWD specifications may be followed for all other items.
