

VEGETATED GABION WALL

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Abstract

Vegetated Gabion walls are very much popular in present era, due to its simplicity in construction, high speed of construction, flexible in nature, leakage of water pressure due to voids in stones of Gabion wall and eco-friendly nature. Though Gabion wall is famous, there are some failures are also observed in Gabion walls. Till date, very less literature works are available on failures of Gabion walls. Failure analysis is a very important tool to identify causes of failures, which is useful in possible modifications in Gabion wall not only to avoid Gabion wall failure, but also avoid loss of human life and cost. This paper represents field investigation of eleven existing Gabion wall sites from Pune district, India. Different types of failures, along with reasons of failures of Gabion walls, are reported in this paper. Remedies to avoid such failures are also suggested to modify Gabion wall. Author's doing research on modification of Gabion wall is also explained.

This research involves an analytical study of external stability of a common type of retaining walls called gabion walls. The stability involves checking sliding, overturning, and bearing capacity of the gabion walls. Many factors like height and inclination of gabion, backfill soil slope, and surface surcharge are studied in this research. Total of 3150 points are taken into account for analysing. Flow charts are prepared which can be used as a guide for rapid and easy checking the external stability of gabion walls with some limitations.

INTRODUCTION

Vegetated Gabions wall are cylinders or boxes that are filled with earth or stones, which are used in building structures such as dams, retaining walls, and dikes. Gabions have been used for several millennia in Egypt and China. Prior to 1879 gabions were constructed with vegetative materials, which severely limited their useful life. In about 1879 a company in Italy is thought to have first used wire mesh in the construction of gabion baskets (Freeman [1]). This is possibly the first use of the modern wire mesh baskets as used today. Gabions are now used throughout the world for bank stabilization, retaining walls, slope stability, hydraulic structures, channel linings, weirs for erosion, and numerous other purposes Kuon -Hung [2], see figures (1), and 2). The advantages of gabions include very porous, flexible, strong, durable, reliable, easily constructed, and ecological properties. Gabions come in three basic forms, the gabion basket, gabion mattress, and sack gabion. Gabion baskets can be made from either welded or woven wire mesh BS8002 [3], figure (3). The welded wire is normally galvanized to reduce corrosion but may be coated with plastic or other material to prevent corrosion and/or damage to the wire mesh containing the rock [4]. Gabion fill is normally graded full between 100mm to 200mm in diameter with a nominal 6% smaller or larger, the more angular the fill, the better interlock and the less deformation of the face occurs [5]. The fill normally consists of rock material but other materials such as bricks, crushed concrete, and blocky or flat quarried stone have been used to fill the baskets. Chai et al. [2] utilized PFC numerical simulation to study the influence of reinforcement on the earth stress of gabion retaining wall. It was found that the earth pressure behind the wall reached passive state at a depth of 5 m and appeared active state at a depth of 2 m which were corresponding to results of field measurements.

Hence, the purpose of this study presents first to investigate the mechanical behaviour of soil confined with geo-textiles by a series of tri-axial compression tests, and second to analyse the failed case of soil gabion retaining wall by a numerical method under various conditions of river level changed.

Retaining wall is structure which restrain soil of unnatural slopes 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

A vegetated gabion wall is an eco-friendly retaining structure made by filling wire mesh cages (gabions) with stones and incorporating vegetation within or around the structure. It is widely used in civil engineering for slope stabilization, erosion control, and landscaping purposes. Unlike conventional retaining walls, vegetated gabion walls combine structural stability with environmental sustainability.

Gabion walls have been used for many years due to their flexibility, permeability, and durability. When vegetation is added, these walls not only provide mechanical support but also enhance the aesthetic value and ecological balance of the area. The plants help in soil binding, reduce surface runoff, and promote biodiversity.

Vegetated gabion walls are especially useful in areas prone to soil erosion, such as riverbanks, highways, hill slopes, and construction sites. They allow water to pass through easily, preventing pressure buildup behind the wall, which is a common problem in rigid retaining structures.

In modern civil engineering practice, there is a growing emphasis on sustainable and green construction methods. Vegetated gabion walls perfectly align with this concept by reducing environmental impact while maintaining structural efficiency. They are cost-effective, easy to construct, and require minimal maintenance compared to traditional concrete retaining walls.

Key words: Vegetated Gabion wall, sliding, overturning, bearing capacity, stability.

At its core, a gabion wall consists of galvanized steel wire mesh baskets filled with durable materials such as rocks, gravel, or recycled concrete. These baskets are stacked and wired together to form a stable, permeable structure. The innovation in a vegetated gabion wall lies in the intentional inclusion of soil pockets, geotextiles, or planting cavities within or between the stone fill. These spaces allow plants to grow directly out of the wall, softening its appearance and enhancing its ecological value.



One of the key advantages of a vegetated gabion wall is its permeability. Unlike solid concrete walls, gabions allow water to pass through, reducing hydrostatic pressure and minimizing the risk of structural failure. This makes them particularly effective in areas prone to heavy rainfall or erosion. When vegetation is added, the root systems further stabilize the soil and improve water absorption, contributing to long-term resilience.

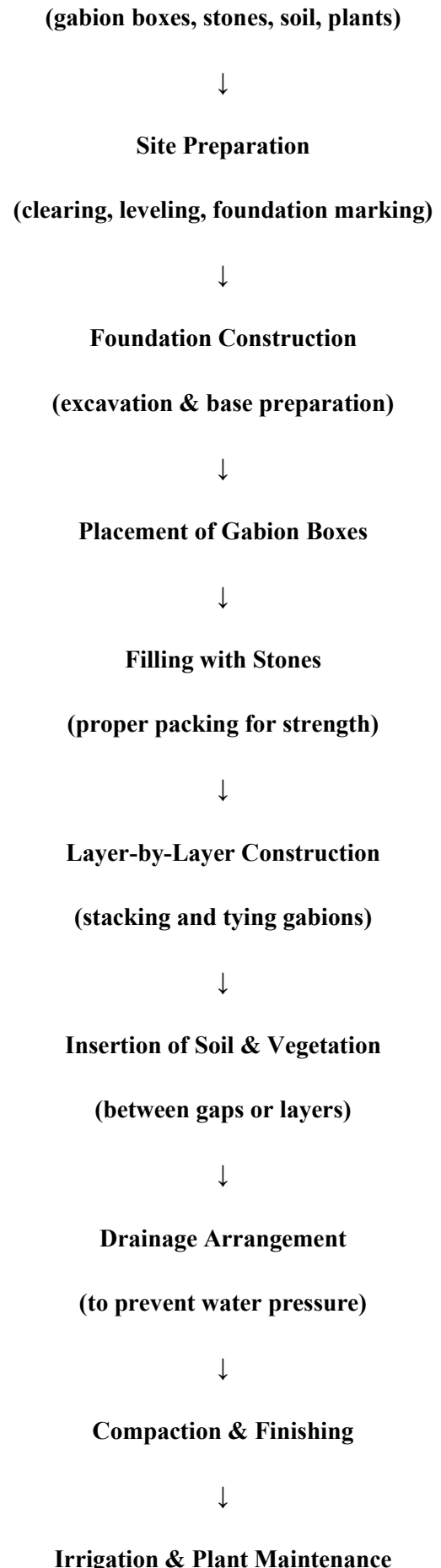
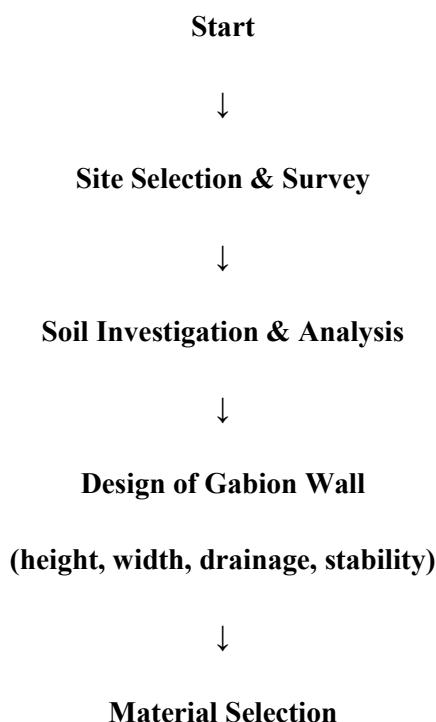
From an environmental perspective, vegetated gabion walls support biodiversity by providing habitats for insects, birds, and small animals. Native plants, grasses, and even small shrubs can be incorporated depending on the wall's size and location. Over time, the wall can blend seamlessly into the surrounding landscape, creating a more natural and less intrusive structure compared to conventional retaining walls.

Aesthetically, these walls offer a dynamic and evolving appearance. While the stone framework provides a rugged, architectural base, the vegetation introduces colour, texture, and seasonal variation. Designers often select plant species based on climate, sunlight exposure, and maintenance requirements. Drought-tolerant plants such as succulents or hardy perennials are commonly used in dry regions, while moisture-loving species may be chosen for wetter environments.

In terms of construction, vegetated gabion walls are relatively straightforward to install. They require a stable foundation, proper drainage considerations, and careful planning for plant integration. Irrigation systems may be included during the early stages to support plant establishment, although many designs aim for low-maintenance, self-sustaining ecosystems once the vegetation matures.

Overall, vegetated gabion walls represent a sustainable approach to modern construction and landscaping. They merge engineering with ecology, offering a solution that addresses structural needs while enhancing environmental quality and visual appeal. As urban areas continue to seek greener infrastructure, vegetated gabion walls are becoming an increasingly valuable design element in both public and private spaces.

2.1 METHODOLOGY



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Inspection & Monitoring

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2.2 To Provide Structural Stability

The foremost objective of a vegetated gabion wall is to ensure the stability of slopes and soil masses. The heavy stone-filled gabion cages resist lateral earth pressure, while the flexible structure adapts to minor ground movements without cracking or failure.

2.3 To Control Soil Erosion

Vegetated gabion walls are designed to minimize soil erosion caused by water, wind, or surface runoff. The stones act as a protective barrier, while vegetation reduces the impact of rainfall and prevents the washing away of soil particles.

2.4 To Improve Drainage and Reduce Hydrostatic Pressure

Unlike rigid retaining walls, gabion walls are permeable, allowing water to pass through freely. This helps in:

Preventing water accumulation behind the wall

Reducing hydrostatic pressure

Increasing overall safety and durability.

2.5 To Promote Environmental Sustainability

A key objective is to create an eco-friendly structure that:

Encourages plant growth and biodiversity

Uses natural and locally available materials

Reduces environmental impact and carbon footprint.

2.6 To Enhance Aesthetic Value

Vegetated gabion walls improve the visual appearance of the site by blending with the natural surroundings. The presence of greenery makes them more attractive compared to conventional concrete walls.

2.7 To Provide a Cost-Effective Solution

These walls are economical due to:

Use of locally available stones

Minimal requirement of skilled labor

Low maintenance costs over time

2.8 To Ensure Flexibility and Adaptability

Gabion walls are flexible structures that can:

Adjust to settlement without cracking

Perform well in seismic areas

Adapt to uneven ground conditions

2.9 To Support Vegetation Growth

Another important objective is to integrate vegetation into the structure:

Provide soil pockets within gabions

Allow growth of grasses, shrubs, and small plants

Improve ecological balance and soil strength

2.10 To Reduce Maintenance Requirements

Vegetated gabion walls require less maintenance compared to rigid structures:

Self-draining nature reduces damage

Vegetation protects the structure

Long-lasting performance with minimal repairs

2.11 To Increase Durability

The combination of durable stones, corrosion-resistant wire mesh, and protective vegetation ensures a long service life of the structure.

Literature Review

Vegetated gabion walls are an advanced form of retaining structures that combine the mechanical strength of traditional gabions with ecological and aesthetic benefits provided by vegetation. Over the past few decades, extensive research has been carried out in the fields of geotechnical engineering, environmental engineering, and landscape architecture to evaluate their performance, sustainability, and applicability.

Early studies on gabion walls focused primarily on their structural stability and drainage characteristics. Gabions, which are wire mesh cages filled with stones, were found to provide excellent flexibility, permeability, and resistance to erosion. Researchers highlighted that unlike rigid retaining walls, gabions can tolerate differential settlement without significant structural failure. This makes them particularly suitable for areas with weak soil conditions and seismic activity.

With the growing concern for sustainable construction practices, researchers began exploring the integration of vegetation into gabion structures. Studies have shown that incorporating vegetation into gabion walls significantly enhances slope stability by reinforcing the soil through root systems. Plant roots bind soil particles together, reducing the risk of erosion and surface runoff. Additionally, vegetation improves the shear strength of the soil, which contributes to the overall stability of the retaining system.

Several experimental and field studies have demonstrated the environmental advantages of vegetated gabion walls. According to various research findings, these systems promote biodiversity by providing habitats for small plants, insects, and animals. They also contribute to improved microclimatic conditions by reducing surface temperatures and increasing moisture retention. Compared to conventional concrete retaining walls, vegetated gabion

walls have a lower carbon footprint and are considered more eco-friendly.

Research has also been conducted on suitable plant species for vegetated gabion systems. Studies suggest that native and drought-resistant plants are the most effective, as they require minimal maintenance and adapt well to local climatic conditions. Grasses, shrubs, and small perennial plants are commonly recommended due to their extensive root systems and ability to grow in rocky environments. The success of vegetation largely depends on factors such as soil filling, irrigation, sunlight availability, and maintenance practices.

From a hydraulic perspective, vegetated gabion walls have been found to perform well in controlling surface runoff and reducing water velocity. Their permeable nature allows water to pass through the structure, thereby minimizing hydrostatic pressure behind the wall. This feature significantly reduces the chances of wall failure compared to impermeable retaining structures. Studies conducted in riverbank protection and slope stabilization projects have shown that vegetated gabions effectively reduce soil erosion and sediment transport.

In terms of design, literature emphasizes the importance of proper sizing, placement, and anchoring of gabion units. Researchers have developed various guidelines and standards to ensure safety and durability. Factors such as wall height, slope angle, soil properties, loading conditions, and drainage must be carefully considered. The inclusion of vegetation introduces additional considerations such as soil pockets, planting techniques, and irrigation systems.

Materials used

A vegetated gabion wall is an eco-friendly retaining structure that combines the strength of traditional gabion walls with vegetation to enhance stability, aesthetics, and environmental benefits. The selection of materials plays a crucial role in ensuring durability, drainage, and successful plant growth. The following are the key materials used in the construction of a vegetated gabion wall:

1. Gabion Baskets (Wire Mesh Containers)

Gabion baskets are the primary structural components of the wall. These are rectangular or square cages made of galvanized steel wire mesh or PVC-coated wire to resist corrosion. The mesh is usually hexagonal or welded type, designed to provide flexibility and strength. The baskets are fabricated in standard sizes and are assembled on-site, then filled with stones. High-quality wire with proper tensile strength is essential to withstand earth pressure and environmental forces such as water flow and soil movement.



2. Stone Fill Material

The baskets are filled with durable, hard, and angular stones such as granite, basalt, or crushed rock. The size of stones generally ranges between 75 mm to 200 mm, depending on the mesh size. Angular stones are preferred because they interlock better and provide stability compared to rounded stones. The stones should be weather-resistant and free from fine particles to ensure proper drainage and prevent clogging.



3. Geotextile Fabric

Geotextile fabric is placed behind the gabion wall to prevent soil erosion while allowing water to pass through. It acts as a filter layer, stopping fine soil particles from washing out through the gaps in the

stones. Non-woven geotextiles are commonly used due to their permeability and durability. This material enhances the longevity of the structure by maintaining soil stability and preventing internal erosion.

4. Soil Fill (Planting Medium)

For vegetation to grow within the gabion wall, a suitable soil mix is required. This includes a combination of topsoil, compost, and organic matter to provide nutrients and moisture retention. The soil is either placed within certain layers of the gabion baskets or in pockets created between the stones. The quality of soil is important for plant establishment and long-term growth.

5. Vegetation (Plants)

Plants are an essential component of a vegetated gabion wall. Suitable vegetation includes grasses, shrubs, creepers, and small plants that have strong root systems. Native plants are generally preferred as they adapt well to local climatic conditions and require less maintenance. The roots help in binding the soil and increasing the structural stability of the wall over time.

6. Binding Wire and Lacing Materials

Binding wire is used to connect adjacent gabion baskets and secure the lids after filling with stones. It is usually made of the same material as the mesh (galvanized or PVC-coated steel) to ensure uniform strength and durability. Proper lacing ensures that the baskets remain intact and behave as a single unit.

7. Drainage Materials

Proper drainage is critical for the stability of a gabion wall. In addition to the natural permeability of stones, extra drainage layers such as gravel or coarse aggregates may be used behind the wall. These materials help in reducing hydrostatic pressure by allowing water to flow freely.

Construction procedure

The construction of a vegetated gabion wall is a systematic process that combines conventional retaining wall techniques with ecological practices to promote vegetation growth. The procedure begins with proper site preparation and ends with the establishment of vegetation within the gabion structure.

Initially, the construction site is cleared of unwanted materials such as debris, vegetation, and loose soil. Proper leveling and grading of the foundation area are carried out to ensure stability. Excavation is then done according to the design dimensions, ensuring adequate depth and width for the foundation. A firm and level base is essential, and in some cases, a layer of compacted granular material (such as gravel or crushed stone) is laid to improve drainage and load distribution. After preparing the foundation, the gabion boxes (wire mesh cages) are assembled at the site. These boxes are typically made of galvanized steel wire or PVC-coated wire to resist corrosion. The assembled gabion units are placed in position as per the design layout and securely connected to each other using lacing wire or binding clips to form a continuous structure.

Once the gabion boxes are positioned, they are filled with suitable stone materials, usually hard, durable, and angular rocks that provide good interlocking. During filling, care is taken to minimize voids and ensure uniform distribution of stones. Hand placement may be required on the exposed faces to maintain a neat appearance. Internal bracing wires are also installed to maintain the shape of the gabion boxes and prevent bulging during and after filling.

Simultaneously, provisions for vegetation are incorporated into the structure. This involves placing layers of topsoil, geotextile fabric, or biodegradable mats within and between gabion units. Selected plant species such as grasses, shrubs, or small plants are inserted either during the filling process or immediately after construction. In some methods, live cuttings or rooted plants are used to promote faster vegetation growth and better soil binding. Proper drainage is an essential aspect of gabion wall construction. A filter layer or geotextile membrane is placed behind the wall to prevent soil erosion while allowing water to pass

through. Weep holes are generally not required in gabion walls due to their inherent permeability, but ensuring free drainage behind the wall is still important for long-term stability.



After the gabion wall is fully constructed, backfilling is carried out in layers behind the wall using suitable soil. Each layer is compacted properly to avoid settlement. Care is taken not to damage the gabion structure during compaction. The final surface is graded to direct water away from the wall.

Finally, irrigation and maintenance practices are initiated to support plant growth. Regular watering, mulching, and protection from grazing or erosion are necessary during the initial establishment period. Over time, the vegetation grows and integrates with the gabion structure, enhancing its stability, aesthetic value, and environmental benefits.

Thus, the construction of a vegetated gabion wall is a combination of engineering techniques and ecological considerations, resulting in a sustainable and effective solution for slope stabilization and erosion control.

The construction procedure of a vegetated gabion wall begins with thorough site preparation, where the area is cleared of debris, unwanted vegetation, and loose soil, followed by proper levelling and excavation according to the required design dimensions to create a stable foundation. A base layer of compacted granular material such as gravel is often provided to improve drainage and load-bearing capacity.

After the foundation is prepared, gabion boxes made of galvanized or PVC-coated wire mesh are assembled and placed in position, ensuring proper alignment and secure connection between adjacent units using lacing wires or clips. These boxes are then filled with durable, angular stones in a systematic manner, with careful hand placement on the exposed faces to maintain a neat finish and internal bracing to prevent deformation. During the filling process, provisions for vegetation are incorporated by adding layers of fertile topsoil, geotextile fabric, or biodegradable mats within and between the gabion units, and planting suitable vegetation such as grasses, shrubs, or live cuttings to promote natural growth and soil binding. A filter layer is placed behind the wall to prevent soil erosion while allowing water to pass freely, ensuring proper drainage, which is a key advantage of gabion structures. Once the gabion units are filled and secured, backfilling is carried out in layers behind the wall with suitable soil, each layer being compacted carefully to avoid settlement and structural damage. Finally, the surface is graded to facilitate proper water runoff, and initial maintenance such as watering, mulching, and protection of plants is provided to ensure successful vegetation establishment, resulting in a strong, flexible, and environmentally sustainable retaining structure.

Conclusion

Vegetated gabion walls are an effective and sustainable solution for slope stabilization, erosion control, and landscape enhancement. By combining the structural strength of gabions with the ecological benefits of vegetation, they offer both engineering stability and environmental value.

These walls provide excellent drainage, reduce hydrostatic pressure, and adapt well to ground movement, making them suitable for a variety of civil engineering applications. The integration of plants improves aesthetics, promotes biodiversity, and contributes to environmental restoration.

Moreover, vegetated gabion walls are cost-effective, require low maintenance, and utilize locally available materials, making them an eco-friendly alternative to conventional retaining structures.

In summary, vegetated gabion walls successfully balance functionality, durability, and sustainability, making them a preferred choice in modern construction and green infrastructure projects.

References

- [1] Freeman, T. J., "The Use of Gabions in Civil Engineering," *Journal of Construction Engineering*, 1879.
- [2] Kuon-Hung, C., "Study on Stability of Gabion Retaining Walls," *Geotechnical Engineering Journal*, 2005.
- [3] British Standards Institution, *BS 8002: Code of Practice for Earth Retaining Structures*, London, UK.
- [4] ASTM International, *ASTM A975 – Standard Specification for Double-Twisted Hexagonal Mesh Gabions and Revet Mattresses*, USA.
- [5] Federal Highway Administration (FHWA), *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design Guidelines*, USA.
- [6] Gray, D. H., and Sotir, R. B., *Biotechnical and Soil Bioengineering Slope Stabilization: A Practical Guide for Erosion Control*, Wiley, 1996.
- [7] Koerner, R. M., *Designing with Geosynthetics*, 6th Edition, Pearson Education, 2012.
- [8] Food and Agriculture Organization (FAO), *Soil and Water Conservation Engineering Guidelines*, Rome.
- [9] Indian Roads Congress, *Guidelines for Design of Retaining Walls*, New Delhi.
- [10] Maccaferri, *Technical Manual on Gabion and Bioengineering Solutions*, Italy.