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Application of Reinforced Gabion Walls in Roadbed Slope Engineering

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ABSTRACT: Since the beginning of the 21st century, with the advancement of the times, people have increasingly emphasized ecological factors such as environmental protection, ecological restoration, and landscape construction. The ecological function and stability of slopes have become equally important. Ecological slope protection technologies have attracted increasing attention. Reinforced gabion walls, as a new type of flexible retaining structure, possess characteristics like flexibility, permeability, durability, earthquake resistance, cost-effectiveness, and being conducive to vegetation growth, making them promising for widespread application.

KEYWORDS: Reinforced Gabion; Permeability; Application.

I. INTRODUCTION

A gabion is a hexagonal double-twisted steel wire mesh box made from specially treated low-carbon steel wire woven by machinery. Gabion walls refer to a type of retaining and protective structure formed by filling the gabion box with stones of a particle size that meets design requirements and constructing it layer by layer. Fundamentally, gabion walls belong to a category of gravity retaining walls. Their basic stability principle is akin to that of mortared rubble walls, concrete retaining walls, and the like, relying on the wall's inherent weight to ensure its stability, thereby forming a protective retaining structure. Due to its advantages over traditional methods, such as flexibility, permeability, durability, seismic resistance, cost-effectiveness, and being conducive to vegetation growth, it has been widely used in recent years in China's water conservancy, navigation, highways, railways, mining, geological disasters, airports, and other construction projects.

II. STRUCTURAL FEATURES

Since the introduction of reinforced soil technology in the 1970s, its extensive application in the field of civil engineering has highlighted its growing superiority. Compared to traditional retaining wall structures, the following points can be summarized:

(1) The most significant feature is that it can be constructed as very tall vertical fill slopes, thereby reducing the land occupation. This has enormous economic significance, especially in areas where fill material is scarce, where sloping of fill is challenging, cities' outskirts, and regions where land is precious.

(2) The structure is flexible, allowing it to adapt to substantial uneven deformations in the foundation.

(3) Construction is straightforward. The components of reinforced soil (panels, reinforcing materials, kerb stones, etc.) can be prefabricated. Apart from the need for compaction machinery, other machinery is generally not required during construction, making it easy to master. Concurrently, the construction efficiency is high, reducing the construction period and saving labor.

(4) Excellent seismic performance. Due to the flexibility of the structure, it can absorb the energy of earthquakes, giving it seismic performance that rigid structures cannot match.

(5) Aesthetically pleasing designs. Wall panels can be designed and shaped according to needs and stress characteristics, assembling them into aesthetically appealing structures and enhancing road landscapes.

(6) Cost-effective. With thin wall panels and small foundation dimensions, compared to gravity walls, it can save up to 95%-97% on masonry work. Costs can be reduced by 10%-60% or more compared to mortared stone walls and reinforced concrete walls. The higher the retaining wall, the more funds saved.

Apart from the general advantages listed above for reinforced soil walls, the reinforced gabion wall system, when compared to precast block panel systems and metal-panel reinforced soil systems, has the following unique features:

(1) Gabion box panels and reinforcing mesh are continuously produced, ensuring seamless

connections. This avoids the weakness of traditional reinforced soil walls where the connection points between the reinforcing material and panels become weak structural links.
(2) Gabion panels have excellent self-drainage performance, not only saving costs on drainage facilities but also avoiding the risk of entire structure collapse due to poor drainage seen in traditional metal and precast concrete block panel reinforced soil structures.
(3) Gabion panels are of a porous structure, offering excellent vegetation-friendly properties, truly achieving harmony with the surrounding natural environment.
(4) Reinforced gabions have strong anti-scour performance.
(5) Depending on the geotechnical conditions and project characteristics at the construction site, reinforcing materials can be metallic mesh sheets or geogrids.

III. CONSTRUCTION PROCESS

3.1 Gabion Assembly

(1) The delivered reinforced gabion components are unpacked on a relatively spacious and flat site. The folded individual reinforced gabions taken from the bundles are spread out and assembled according to the folding lines. Its front panel, side panels, partitions, and back panels should all be placed vertically.
(2) All connecting edges of the panels are intertwined with specialized binding wire at intervals of 10-15cm in a single-loop wrap and double-loop locked twist.

3.2 Foundation Work

(1) Excavate the foundation to the required load-bearing layer and then conduct a foundation inspection.
(2) Clear the foundation surface of loose soil, stagnant water, debris, etc., and compact the soil that was disturbed during excavation.

3.3 Component Installation

(1) Place the pre-assembled reinforced gabion components at the specified locations. All adjacent edges of the wall of adjacent reinforced gabions are intertwined and connected, using the 10-15cm single-loop wrap and double-loop locked twist method to make the wall a continuous whole.
(2) The rear reinforcing mesh of the reinforced gabion must be fully stretched and fixed at the end at intervals of 1m with small wooden stakes (or steel bars). Adjacent mesh panels are connected using the binding wire at intervals of 1 meter.
(3) For curved and cornered walls:
Concave curve: The walls are closely placed, with the reinforcing mesh offset at the rear. Adjacent wall units must be tightly connected with wire.
Convex curve: The walls are closely placed with the reinforcing mesh overlapping at the back. There are mainly two forms of curves.

3.4 Wall Stone Filling

(1) Stone material requirements: The strength of stones used for filling the reinforced gabion walls should not be less than MU30, weather-resistant, and non-hydrolyzing. Stone sizes between 100mm and 300mm are suitable and should have a certain grading.
(2) During stone filling, ensure coordinated filling progress. The height difference of stones filled in adjacent gabions should not exceed 0.3m during the process to prevent side squeezing deformation, leading to misalignment during the subsequent installation of the lid.
(3) For a 1m high gabion unit, add reinforcement wires between the front and back panels every third of the filled height. The horizontal distance is about 40cm (i.e., 4 wires for a 2m width gabion) to limit wall deformation and ensure wall flatness.
(4) Once a layer of stones is filled, arrange them manually to minimize the void ratio. The stones on the outer surface of the wall should be placed manually, placing the relatively flat stone faces outward to minimize voids and enhance aesthetics. The stone filling rate should be no less than 70%.
(5) Each layer of filled stone should exceed the top by 3-5cm to account for some stone settling. The lid should be aligned with the top edge of the gabion cage, with protruding wires on the lid wrapped around the side panel's protruding wires for two rounds.
(6) Before twisting the lid, check if the stones are filled sufficiently and whether the top surface is flat. Check the gabion's external outline and correct any bending deformations or uneven surfaces.
(7) For adjacent gabions, the lid should be intertwined together, and the remaining edge wires should be folded into the finished gabion interior.
(8) All adjacent edges between two layers of reinforced gabions should be intertwined with binding wire at intervals of 10-15cm using a single-loop wrap and double-loop locked twist method.
(9) During wall stone filling, use temporary supports (like wooden molds, scaffolds) to restrict deformation, ensuring a regular and flat appearance after construction.

3.5 Installation of Drainage Mat, Geogrid, and Geotextile

(1) Drainage Mat Construction

Lay the drainage mat along the interface between the road base and the structural backfill. The edge of the mat should overlap by at least 60mm. The overlap area should be anchored with U-shaped nails. U-shaped metal anchors made of Φ8 steel bars are used to fix the drainage mat to the interface. The drainage mat should extend to the inner side of the retaining wall, positioned above the ground level, and anchored through the wire mesh into the structural backfill.

(2) Geogrid Construction

Install the geogrid according to the standards and design requirements. The overlap width should not be less than the design requirements, with the higher end pressed on the lower end. U-shaped nails should fix the joints of the geogrid at 1.0m intervals. Before laying the geogrid, manually spread a 10cm thick sand cushion layer, compact it, and remove any sharp debris that might pierce the geogrid. The geogrid should be laid out smoothly, straightened, and tensioned without creases or damage.

During structural backfilling, fill the sides first and then the middle to avoid displacing the sand surface and loosening the geosynthetic material. Start compacting with a light roller from both sides, moving towards the center. After 3-4 passes, switch to a heavy roller until the desired compaction is achieved.

(3) Geotextile Construction

The geotextile is laid between the gabion wall's back and the backfill layer. To ensure the geotextile is securely placed, its width folded into the compacted soil at both the top and bottom should be no less than 300mm.

3.6 Structural Backfill

(1) The type and quality indicators of the structural backfill soil should be determined during the preliminary preparation phase through tests. The maximum dry density, optimum moisture content, and compaction method should all be acquired during the technical preparation phase before construction. The fill used for construction should be approved by the supervisor and should be executed strictly according to the parameters verified by tests.

(2) Before the fill is spread over the reinforcement mesh, vehicles, material transport machinery, paving machinery, and compaction machinery are strictly prohibited from operating on the exposed reinforcement mesh. For heavy machinery operating in the reinforced area, the fill on the reinforcement mesh should be at least 20cm thick. Even with protective fill on the mesh, paving and compaction machinery should move slowly and avoid sudden turns or abrupt stops to prevent mesh displacement.

(3) Fill Spreading

The fill must be spread in layers and compacted. Each layer should ideally be 30cm thick when loosely spread. The spread thickness should be uniform, and the surface should be level after compaction. The spreading should start from the wall and move towards the end of the reinforcement mesh.

(4) Filling and compaction should not be done on rainy days to prevent uncontrollable moisture content and failure to meet the required compaction standards.

(5) After leveling the spread fill, a light roller should be used for the initial pass. If the roller on-site is a vibratory roller, the first pass should be done without vibration. Reinforced areas should not be compacted using a sheepsfoot roller.

(6) Within 1m of the wall, compaction should be done manually or with light machinery. Heavy compaction machinery should not operate within 1m of the wall to avoid damaging the gabion wall.

(7) During compaction, start from the halfway point of the reinforcement strip length, move towards the strip end, then back from the halfway point to the wall side. The roller should move perpendicular to the mesh length. The overlap between consecutive passes should be at least 1/3 of the wheel width. The first pass should be gentle to avoid displacing the reinforcement strips. Subsequent passes can be faster and more forceful. Each pass should cover the entire width before starting the next pass. The number of passes is determined by the process tests and controlled by on-site inspections.

(8)Standard for Compaction Quality of Structural Backfill: The compaction of cohesive backfill material should not be less than 90%. The relative density Dr of non-cohesive backfill should be ≥0.65. It should also meet the compaction requirements specified for that depth. After each layer in the reinforced body is rolled, compaction checks should be carried out. At least three check points should be set up for every 500 ㎡ or every 50m long section. The check points should be staggered, randomly selected, and at least one should be within 1m behind the panel (for every 50 ㎡ or 50m length).

IV. SOLUTIONS

(1) If a rigid structure is used to support a submerged road embankment, the foundation will inevitably settle under the long-term effect of water flow. Even with timely and preemptive treatment of

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the foundation, this cannot be avoided. The flexible support technology addresses this issue head-on. Flexible supporting structures can not only bear the pressure from the earth but also allow for certain deformations in the soil. Furthermore, they have excellent adaptability to the non-uniform settlement of foundations within allowable ranges, effectively resolving the stability issues of submerged road embankments.

(2) The pore water in the reinforced Maccaferri mat provides conditions for water flow, enabling a natural exchange between water and soil. This facilitates the natural growth of vegetation. Over time, the structure harmoniously merges with nature, allowing the reinforced retaining wall to integrate into the surrounding environment, thereby playing a role in environmental protection and improvement.

(3) Compared with traditional retaining walls, the use of reinforced gabion retaining walls can increase the design slope of the embankment, saving project land and reducing the occupied area.

(4) The factory production process yields semi-finished products. On the construction site, assembly and shaping are carried out according to design drawings. This process is simple to operate, minimally affected by weather, and suitable for mechanized operations. It not only ensures construction quality but also accelerates project progress.

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