Abstract

Reinforced soil structures offer economic advantages over conventional mass gravity wall systems as the wall height increases. Different forms of soil reinforcement like grids, meshes and strips used for mechanical stabilization of soil are generally either metallic or polymeric. The innovative concept of Composite Soil Reinforcement System (CSRS) discussed in this paper deals with the possibility to combine high strength geogrids and steel mesh together to build very high reinforced soil walls or slopes. The origin of this concept stems from the need to analyze how a more efficient use of different reinforcements will contribute to the overall project’s economy, which is primarily a function of the material cost only. When structures achieve relevant heights (say above 10 m), there is a large potential for cost effectiveness by using Composite Soil Reinforcement System, in place of a 100% Geogrid or a 100% steel mesh reinforcement solution only. This paper also presents the experience on two high CSRS walls in Europe where the combined use of different products like Terramesh System™ / Green Terramesh™ (as facia and secondary reinforcement) and high strength geogrid ParaLink™ (as primary soil reinforcement) resulted in overall technical & economic benefits for the project.

1.0 Introduction

Reinforced soil is a composite material formed by the friction or passive resistance between soil and reinforcement. By means of friction or passive resistance, soil transfers to the reinforcement the forces built up in the earth mass. They offer economic advantages over conventional mass gravity wall systems as the wall height increases. Generally either of two types namely metallic or polymeric forms soil reinforcement are adopted which takes different shapes like grids, meshes and strips. The concept of Composite Soil Reinforcement System (CSRS) discussed in this paper deals with the possibility to combine high strength geogrids and steel mesh together to build very high
reinforced soil walls or slopes, thereby achieving reduction in cost. The high strength geogrid acts as primary reinforcement which offers major contribution to the stability of structure. Double twist hexagonal mesh acts both as secondary reinforcement and a modular facia unit, which contributes also to improve compaction and prevents sloughing failure near facia. As the height of structures increase certain limit, there is always potential scope for achieving cost effectiveness by adopting Composite Soil Reinforcement System, in place of a 100% Geogrid or a 100% steel mesh reinforcement solution only. This paper also presents the experience on two high CSRS walls in Europe where the combined use of different products like high strength geogrids and double twisted hexagonal mesh resulted in overall technical & economic benefits for the project.

2.0 Mechanism and advantages of CSRS structures

The mechanism of working of CSRS is illustrated in figure 1. For a normal structure with one type of soil reinforcement only, all reinforcements are required in stabilizing against potential failure surfaces. This is generally achieved by using relatively lower strength reinforcements provided at lower vertical spacing. As the height of the structure increases beyond certain limit (say 10m), this system become quite uneconomical in terms of material coats and constructability. In case of CSRS structure, high strength soil reinforcement is provided at higher vertical spacing to achieve stability again the main disturbing forces, whereas low strength material is used only for a limited length near to facia to function as facia and secondary reinforcement. The second purpose for using reinforcement is at the edges of a compacted fill slope to provide lateral resistance during compaction. The increased lateral resistance allows for an increase in compacted soil density over that normally achieved and provides increased lateral confinement for the soil at the face. Even modest amounts of reinforcement in compacted slopes have been found to prevent sloughing and reduce slope erosion. Edge reinforcement also allows compaction equipment to operate more safely near the edge of the slope.

Generally, CSRS structures offers advantages like reduction in overall cost of project, quick supply of components possible to site (since primary & secondary reinforcements are separate) and flexibility in spacing, lift thicknesses, modular facia system and geogrids.

![Figure-1: Stabilization mechanism in normal structures and CSRS structures](image-url)
3.0 Components of CSRS structures

3.1 Primary soil reinforcement (ParaLink™)

ParaLink™ geogrids are planar structure consisting of a mono-axial array of composite geosynthetic strips. Each single longitudinal strip has a core of high tenacity polyester yarns tendons encased in a polyethylene sheath. These single strips are connected by non-resisting cross laid polyethylene strip which give a grid like shape to the composite, as shown in below figure.

![ParaLink Details](image1)

Figure-2 & Photo-1: ParaLink details

3.2 Facia and secondary reinforcement

3.2.1 Green Terramesh™

Green Terramesh units are made of mechanically woven double twisted steel wire mesh with reinforcing steel rods, a biodegradable erosion control blanket and a welded mesh panel with loose steel tie rods. These tie rods are fixed at top to welded mesh panel and shall be connected at bottom to steel rod passing through secondary reinforcement while installation in job site to form the required slope angle. They are made of heavily galvanized and PVC coated soft type steel wire. Attached to the inside facing is a biodegradable 100% coconut fiber biomat, in order to prevent soil erosion at facia allow vegetation growth.

![Green Terramesh Details](image2)

Figure-3 & Photo-2: Green Terramesh details
3.2. 2 Terramesh System™

Terramesh system is fabricated from soft flexible heavily galvanized and PVC coated double twisted steel woven wire mesh units. The facing section of the unit is formed by connecting the back panel and a diaphragm to the main unit. This creates rectangular shaped cells used for stone confinement. Terramesh units are manufactured with all components mechanically connected at the production facility. The external face, reinforcing panel, and lid of the unit shall be woven into a single unit. The ends, back, and diaphragm shall be factory connected to the base. All perimeter edges of the mesh forming the basket shall be selvedge with wire having a larger diameter. The facing element of a Terramesh unit is divided into two cells by means of a diaphragm positioned at approximately 1 m centres. The diaphragm shall be secured in position to the base so that no additional lacing is necessary at the job-site.

![Image of Terramesh System™](image)

Figure-4 & Photo-3: Terramesh System™ details

4.0 Types of CSRS structures

Where space is highly restricted, a vertical structure as shown in figure-5 is provided. This system

![Image of vertical CSRS structure](image)

Figure-5: Details of vertical CSRS structure with Terramesh System™ and ParaLink™
is also adopted for water front structures and also if a culvert has to go through the CSRS structure. If space is not critical, a sloped structure as illustrated in figure-6 is provided. This system is also preferred when a green facia is a project requirement.

![Diagram of CSRS structure with Green Terramesh ™ and ParaLink™](image)

Figure-7: Details of a medium sloped CSRS structure with Terramesh System™, Green Terramesh ™ and ParaLink™

### 5.0 Case References

#### 5.1 CSRS Wall for Retail Park project in Leiria, Portugal

<table>
<thead>
<tr>
<th>Products Used</th>
<th>Terramesh System™, Green Terramesh™ and ParaLink™</th>
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</thead>
<tbody>
<tr>
<td>Client</td>
<td>Retail Park, Leiria, Portugal</td>
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<tr>
<td>Wall Height</td>
<td>29m</td>
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<td>Date of Construction</td>
<td>August 2001.</td>
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<tr>
<td>Bill of Quantity</td>
<td>3300sqm wall/slope facia</td>
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A reinforced soil wall was planned to extend the parking space in the Retail Park in Leiria, Portugal. The wall in this case reached a maximum height of 29.2 m. CSRS structure was considered due to the relevant heights and the limited space available at the toe.

Based on the field experience, the estimated cost of the designed section using combined reinforcements, assuming the material supply and the installation costs (labor, equipment and backfill compaction) was estimated approximately 15 % lower than the equivalent section designed with geogrids reinforcements only.

The project was designed in April 2001. The wall construction (3,300 m² of wall face) started in May 2001 and ended in August 2001. The hydro seeding treatment was made in October 2001. The
lower portion of the walls required a free-draining facing system. This was achieved by using Terramesh system which has got a free draining gabion facia. The main contractor of the project confirmed the preliminary expectation, which is that the overall project construction time was lower than what had been experienced with conventional reinforced soil systems.

From the contractor’s perspective, the possibility to combine a modular ready-to-use facing and secondary reinforcement system (steel mesh) able to allow vegetation growth, with the “easy to handle” geogrid material to simply roll out and cut to the required length, was a very effective and innovative concept. This was found to hold true for wall sections of relevant height (above 10m). In these circumstances, in fact, a solution with a uniform geogrid reinforcement system using the wrapped-around face would require frameworks and care to ensure a proper shaping of the outer slope. Along the same line, in high walls or slopes (10m and above) a uniform steel mesh reinforcement solution may require different lengths for each layer that could not result cost effective when supplied pre-cut to the required sizes. Another interesting feature highlighted was about the easier handling operations and quality control during the construction, due to the lesser number of different reinforcement sizes (rolls of one or two grades of high strength geogrid and one-size standard steel mesh reinforcements supplied in bundles).

### Photo (4 & 5): Completed CSRS Structure
5.2 CSRS Wall for Retail Park project at Loreto, Aprutino, Italy.

<table>
<thead>
<tr>
<th>Products Used</th>
<th>Terramesh System™, Green Terramesh™ and ParaLink™</th>
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</thead>
<tbody>
<tr>
<td>Client</td>
<td>Roads Authority of Italy (ANAS)</td>
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<tr>
<td>Wall Height</td>
<td>19m</td>
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<td>Date of Construction</td>
<td>September 2000</td>
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<td>Bill of Quantity</td>
<td>1800sqm wall/slope facia</td>
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This project consisted of construction of an embankment along SS151, as part of the main roadway rehabilitation project connecting the city of Pescara and Loreto Aprutino, in Italy. Due to the morphology of the territory, hilly and mountainous in this area, the original design included the construction of a viaduct to provide a better roadway alignment. The engineers at the Road Authority (ANAS) looked at other alternative designs, and eventually decided for a solution that could permit vegetation on the facia for a 70º sloped reinforced soil embankment. The cross section at the highest point of the structure reached a height of 19 m from bottom to the top elevation.

The heaviest loading condition was assumed with a horizontal seismic coefficient of 0.07 and no surcharge load acting concurrently. The design solution adopted in the design was a reinforced soil slope using combined primary geogrids widely spaced between secondary shorter layers of steel mesh reinforcements, also used to provide a modular facing system.

Based on the field experience, the installed cost of the design section using combined reinforcements, assuming the material supply and installation costs (labor, equipment and backfill compaction) was estimated approximately 10 to 12% lower than the equivalent section designed with geogrids reinforcements only. This project was designed in October 1998. The structure, consisting of 1,800 m2 of wall face, was built between June & September 2000.

Photo (6 & 7): Completed CSRS Structure
6.0 Conclusions

Composite soil reinforcement system combines high strength geogrid as primary soil reinforcement and heavily galvanized and PVC coated steel wire mesh panels as secondary reinforcement. The stability to potential slip circles are provided by main primary geogrid reinforcement whereas secondary reinforcement contributes to necessary face stability. As the height of structures increase certain limit, there is always potential scope for achieving cost effectiveness by adopting Composite Soil Reinforcement System, in place of a 100% Geogrid or a 100% steel mesh reinforcement solution only. Based on space availability and other constraints like presence of water or culvert, different type of CSRS structures like vertical, sloped or semi sloped structures are possible. The experience on the two existing projects has shown that there is a potential for cost effectiveness that may be further exploited for very high reinforced soil walls.

References


