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WATER PROOFING SYSTEM FOR A TECHNICAL BUILDING WITH SANDY OVERHEAD FILL USING GEOSYNTHETICS

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ABSTRACT

A unique dome shaped structure of 36m diameter and 6 to 8m height needed a complete water proof system giving complete protection against seepage of water . Further, the structure was required to have a green mound on top . This work required an impermeable cut off surface over the roof slab against water seepage, stabilisation of the sandy soil cover to avoid possible local shear failure and slump of sand fill and covering of the sandy overhead fill with micro reinforced green vegetation for erosion control. This paper discusses the design, construction and specification aspects.

INTRODUCTION

Geosynthetics as a family of products has a wide range primary among them are Geogrids, Geotextiles, Geomembranes and Geocomposites. These products can provide techno economic solutions to diverse problems, starting from restrainment and reinforcement applications to containment of municipal waste, surface protection, permeation cut off, river bank protection, coastal protection etc. Such solutions are not only economically viable but the construction procedure takes less time as compared to conventional alternatives. The project is located of the eastern coast, on an island where only fine silty sand is available as construction material. The site is subjected to heavy rainfall .and strong windy conditions. Thus area is subjected to erosion due to wind and rainfall. A traverse has been constructed using Geosynthetic material around and above the dome shaped building.

THE PROBLEM

It was required to construct a suitable protection measure over the roof top and wall joints with the roof slab of the Block House, in order to prevent seepage of water from the vegetated sand cover on top. This work required an impermeable cut off surface over the roof slab against water seepage, stabilisation of the sandy soil cover to avoid possible local shear failure and slump of sand fill and covering the sandy overhead fill with micro reinforced green vegetation as an erosion protection measure.

THE SOLUTION

The development of the scheme evolved from a feasibility analysis and geotechnical requirements of the proposed structure. The envisaged scheme comprises the following three parts:

a. Impermeable Geomembrane liner
b. Bi oriented Geogrid as slope reinforcement
c. Micro reinforced green vegetation cover on the sand cover canopy

Impermeable Geomembrane Liner

A permanent green vegetated sand canopy cover was suggested over the circular roof top of the building, thus, an impermeable cut off surface was placed between the sand fill and the roof surface, against water seepage. The Geomembrane liner has been placed over the roof slab and the ends extend beyond the edge of the roof in order to avoid any seepage through the roof slab and wall joints junction.

Slope Reinforcement

In the second phase sand slope around the building has been stabilised using Bi oriented Geogrid reinforcement on slope. The sand slope is confined at toe by a periphery toe wall of 1m all round the building at a distance of 12m from the building. The sand slope is continued upto a height of 7m as shown in fig.1. The sand slope is stabilised by placing horizontal layers of bi oriented geogrid placed intervals of 1.5m c/c and 2.0m tail length . The horizontal layers of reinforcement have been designed with a view so to prevent the occurance of local shear failure and provide an additional confinement by providing pseudo cohesion in sand fill and prevent slump in soil. The geogrid layer interlocks with the adjoining soil layer adjacent to it and avoids formation of any potential slip surface.

The provision of oriented Geogrid reinforcement close to the face of the shoulder of any sandy soil embankment permits better compaction of the slope up to the edge. As a result and by virtue of pseudo cohesion developed due to reinforcement the shearing resistance of the soil increases significantly. Thus, the overall stability of the soil embankment is increased.

The angle of proposed slope is about 24°, four layers of Bi oriented Geogrid were placed. The provision of these reinforcing layers all along the face of the circular embankment stabilises the sandy soil at the face by improving its stability against local shear/ slump failure and need for localised confinement of sand.

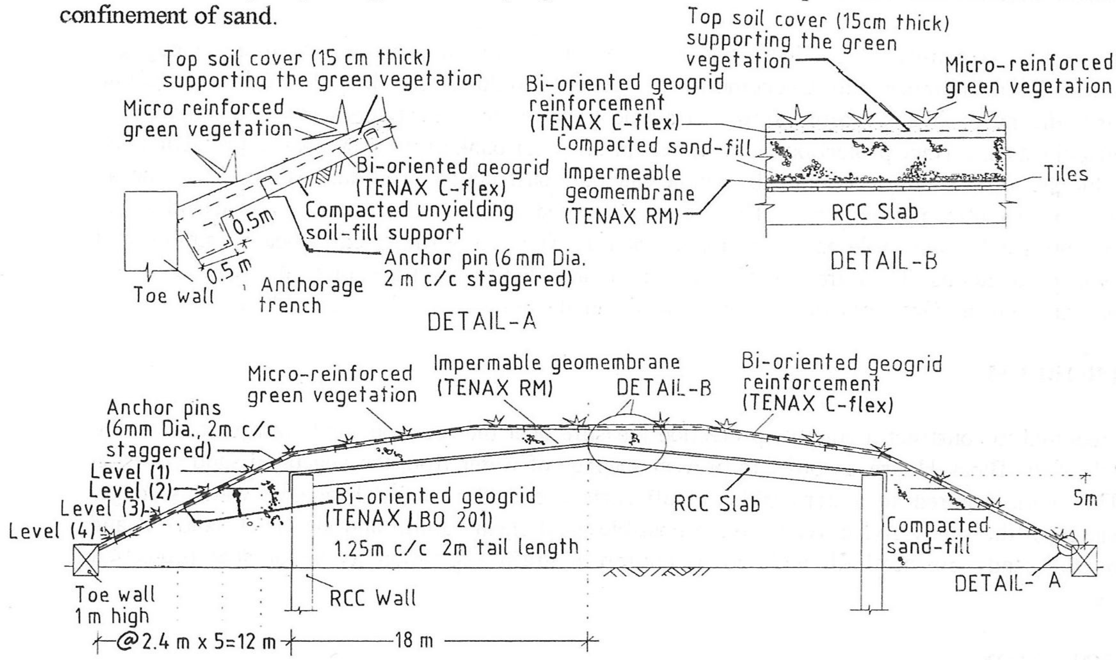

FIG.1 DRAWING SHOWING TYPICAL DETAILS OF THE PROJECT

NOT TO SCALE

Micro Reinforced Induced Vegetation

The sandy overhead fill needs to be protected against rainfall runoff down the slope, attracting likely chances of erosion. It needs protection against denudation due to rain splash and resulting sand flow. This is achieved by providing a micro reinforced green vegetation cover over the sandy soil fill. The micro reinforcement shall be provided with a 15cm thick top soil cover, which shall allow the roots of vegetation to establish permanently over the sandy soil embankment slope. The above ground biomass of grass provides adequate canopy interception to the falling rain drops, mitigates soil erosion due to surface water flow as well as splash of rain water.

Using a light weight bi oriented geogrids acting as root reinforcement, extremely high density of grass growth can be achieved. The retardation of surface water flow by using polymer Geogrids and its effect on root reinforcement can be understood from the study of Lopez-Tello,1977(2). They reported a 33% increase of Factor of Safety for a 10m high cut slope in clay laid in 1:1, when covered with vegetation, having root density of 500kg/ha. The geogrids are used extensively to prevent mass migration of soil particles. The use of polymer geogrids provides a permanent protection as it is not bio degradable, non corrosive and are chemically inert to naturally occuring salts, acids and alkalies in buried condition.

DESIGN METHODOLOGY

Reinforced soil technique consists of an association of soil and reinforcement in such a manner that soil's engineering characteristics are enhanced by adding tensile resistant reinforcing material, Geogrids. Soil exhibits very low tensile strength, mostly becoming nil as it tends to granular nature. In reinforced soil, owing to the internal friction of the soil, the transfer of stress/strain from the soil to the reinforcing element occurs by way of mutual interaction. In this particular case the soil available at site used for construction of the slope is loose silty fine sand. It was imperative to induce pseudo cohesion as the soil had negligible cohesion, which makes the slope critical to local shear failure.

The design of a geogrid reinforced soil slope is obtained once the geometry of the slope is defined, the surcharge load is fixed, the geotechnical characteristics of the soil known and the long term design strength P of the Geogrid is known. Based on these parameters, the number, the vertical spacing required and the length of the reinforcing layers required to provide equilibrium for every possible failure mechanism is determined.

The modes of failure considered for steep slope design are

a. Local equilibrium of a single reinforcement layer

Each reinforcement layer must provide a sufficient force to support the horizontal stresses in the zone of soil of its competence, caused by the thrusts of the unreinforced soil behind. Refer Fig2, the vertical spacing Sv shall satisfy the condition:

$P > Sv.\sigma_h$, where $\sigma_h = Ka.\ \sigma v$

Ka = coeff. of active earth pressure

b. Insufficient reinforcement length near the slope crest

Near the slope crest the geogrid length must support the whole design strength P. If the upper layers have an insufficient length, the lower layers must resist greater loads, that could become excessive and dangerous. The anchorage length at the top shall be sufficient to avoid the pull out of the geogrid when subjected to a tensile force equal to the design strength (fig.3).

c. **Sliding at the soil-geogrid interface**

Insufficient length of geogrid at the slope base would lead to gross outward sliding of the reinforced zone (fig.4). The length of the geogrid at the base shall be sufficient to avoid direct sliding along any geogrid layer.

d. **Equilibrium of the reinforcement zone, acting as a rigid block**

The reinforcement zone, acting as a rigid block should be sufficiently wide to resist the outward thrust (fig.5).

e. **Two parts wedge mechanism**

The distribution of the reinforcement layers must satisfy the equilibrium for every possible failure mechanism which might be planar, multiwedge, circular or logarithmic.

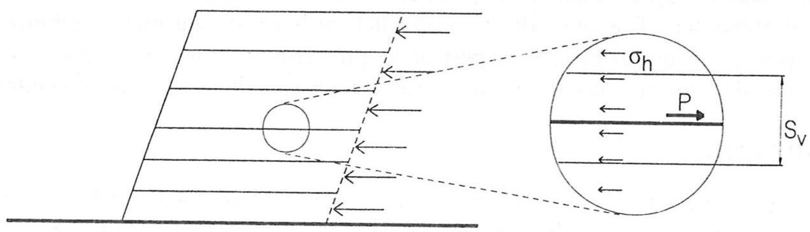

Fig. 2 - Local equilibrium of a single reinforcement layer

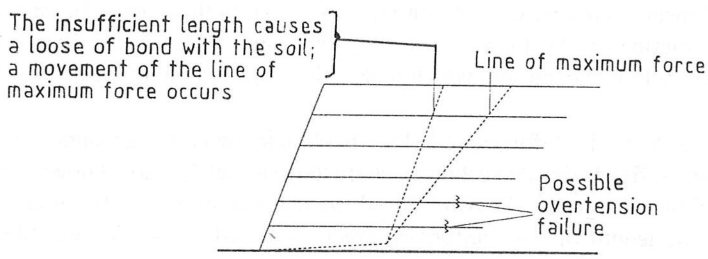

Fig. 3 - Insufficient reinforcement length near the slope crest

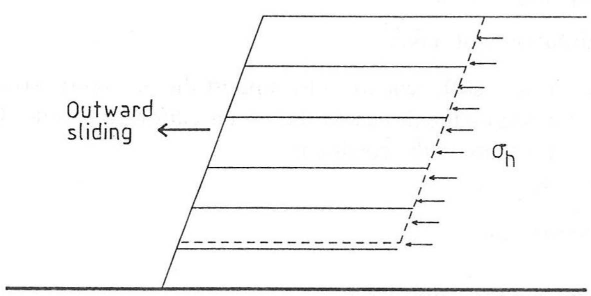

Fig. 4 - Sliding at the soil-geogrid interface

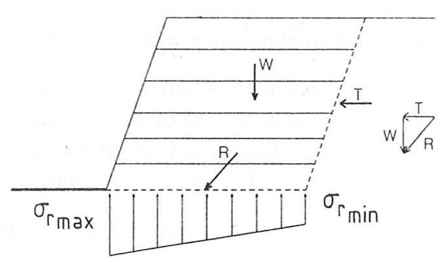

Fig. 5 - Equilibrium of the reinforcement zone, acting as a rigid block

The design has been done keeping in mind the above factors in mind. The reinforced soil slope using Geogrid is designed with limit equilibrium analysis, both external and internal stabilities have been considered.

Cohesion concept in slope stability

It is known that provision of a reinforcement like Geogrid induces an anisotropic or pseudo-cohesion (c') which is a function of reinforcement spacing and it's tensile strength, refer Schlosser,F. & Long, et.al(4).
The strength of the reinforced soil is given by,

$$\sigma_1 = \sigma_3 N_\phi + 2c' \sqrt{N_\phi}$$

where, $N_\phi = \tan^2 (45° + \phi/2)$

The pseudo-cohesion c' is computed from a force equilibrium analysis of a reinforced composite, as per following expression:

Horizontal reinforcement in $c' = (R_T \Delta_H) \times (\sqrt{N_\phi}/2)$

where, R_T = Force per unit width of reinforcement

Δ_H = Spacing between reinforcement

From above on simplifying:

$$c' = (\Delta\sigma_3/2)\sqrt{N_\phi} \qquad \text{and} \qquad \Delta\sigma_3 = R_T/\Delta_H$$

To determine the induction of pseudo cohesion in the mentioned project site, the calculation follows:

$\Delta\sigma_3 = R_T/\Delta_H$,

$\Delta\sigma_3 = 15.0/1.25 = 12.0$ KN/m ,

Using LBO 201 Geogrids, R_t =15.0 KN/m (tensile strength at 5% strain)

& Δ_H at a spacing of 1.25m c/c.

$c' = (\Delta\sigma_3/2)\sqrt{N_\phi}$

$c' = 12.0/2 \sqrt{2.77} = 10$KN/m where $\phi = 28°$ (fine sand)

Thus, the geogrid induces a pseudo cohesion greater than required, hence the design is safe.

Veneer Stability

To safeguard the sandy soil slope which is vulnerable to erosion due to rain and wind and keeping its long term performance in mind, the micro reinforced vegetation has been suggested on the slope. Veneer stability is of great importance when the geogrid system is placed on slope.

Giroud and Beech ,1989 (3) proposed a design method based on limit equilibrium method. A two part wedge failure mechanism with vertical inter-wedge surface was used. The thickness of the cover soil was assumed to be uniform. The effect of soil cohesion was not included. The maximum height of the cover soil, or the required reinforcing tension when the actual height is larger than the maximum was formulated. Koerner and Hwu ,1991 (5) developed a similar design method, but allowing one to determine the safety factor at any cover soil height.

The design parameters of the veneer stability is as follows:

Slope height h	5.5m
Slope angle β	23.75°
Slope length l	13.65m
Soil cover thickness z	0.15m
Unit density of soil γ	18.0 KN/m³
Required factor of safety f.s.	1.25

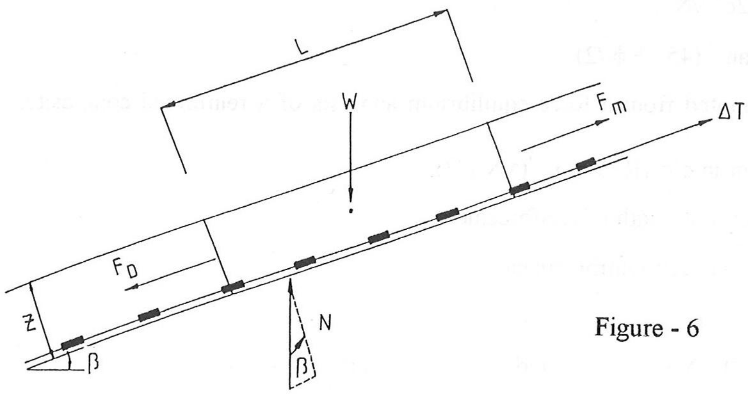

Figure - 6

In the design, rigid body analysis has been assumed and that the entire normal force is resisted on side slopes and cohesion is zero at critical interface. The force analysis is shown in fig.6

$F_d = (zl\gamma) \sin\beta$, where F_d is the driving force

$= 14.85$ KN/m

$F_r = zl\gamma \cos\beta \tan\phi_c + \Delta T$ where F_r is the resistance force

$\phi_c = 25.57°$ is the critical angle of interface friction between geogrid and the fine silty sand layer below

$\Delta T = 2.4$KN/m is the design geogrid tensile force

$= 18.52$KN/m

$F.S. = F_r / F_d = 1.248 \cong 1.25$

$\Delta T = zl\gamma\,(f.s. \sin\beta - \cos\beta \tan\phi_c) = 2.395 \cong 2.4$ KN/m, hence design is safe

SPECIFICATION

The geomembrane liner specified as a cut off between the roof slab and the soil is a reinforced flexible membrane having resistance against naturally occuring acids, alkalis and tear and is ultra violet radiation stabilised. The impermeable geomembrane suggested is a polyethylene film reinforced with a orientated polypropylene net. The specifications of the Geomembrane are shown in table 1.

Table 1

TECHNICAL DATA	UNIT	RM	
TEST DIRECTION		MD	TD
PEAK TENSILE STRENGTH	kN/m	3.0	7.0
YIELD POINT/BREAK ELONGATION	%	25.0	10.0

The bi oriented geogrid used for slope reinforcement are chemically inert, with homogenous and uniform characteristics, are bi-dimensional structures manufactured from HDPE. They are manufactured by an integral extrusion process and then stretched longitudinally and transversely.

Table 2

TECHNICAL DATA	UNIT	LBO 201 SAMP		C FLEX	
TEST DIRECTION		MD	TD	MD	TD
PEAK TENSILE STRENGTH	kN/m	14.5	20 .5	5.0	7.0
YIELD POINT/BREAK ELONGATION	%	16.0	13.0	15.0	10.0

INSTALLATION

Once the construction of the dome shaped structure was completed, the construction of the Geosynthetic traverse for the surroundings commenced. A toe wall of height one meter has been constructed all round at a distance of 12m from the edge of the building to avoid any possible toe erosion. The first layer of Bi oriented Geogrid is placed at a level of 1.25m above the top of the toe wall. The soil upto this level is placed duly compacted in layers not exceeding 20cm each by using suitable hand held vibro-plate compactor. The dressing and preparation of side slopes is done for each layer and adequate amount of watering is carried out to achieve a proctors compaction of 85%.

The geogrid layers are placed at vertical intervals of 1.25m, c/c all along the traverse. The sand layers are compacted with a vibro compactor. The reinforced slope is raised in stages with sand being compacted in layers of 20cm, watered and well rammed. Compaction is carried out till the edge of the slope. Dressing and compaction of side slopes of each layer should also be done adequately.

The impermeable geomembrane liner was placed on the RCC roof slab of the building, after cleaning thoroughly, so that there are no sharp projections. The Reinforced membrane is available in roll form, hence laying could be done easily with unskilled labour. Only care was needed to ensure proper sealing at the transverse and longitudinal joints. The membrane liner was placed upto a metre beyound the roof slab, to ensure that no leakage occurred at the joint between the roof slab and the wall joint. The minimum overlap of 10cm has been kept between two adjacent layers. After placing the geomembrane the balance of the sandy soil fill is placed and compacted

Once the sand slope has been stabilized with horizontal layers of geogrid reinforcement, prior to laying, the site was dressed. The Geogrid is placed in such a manner on the slope so that surface contact is ensured at all points to enable maximum protection. 6mm dia mild steel bars of 400mm length serve as anchor pins placed staggered at a distance of 2m, c/c. The grid is anchored well in trenches near the toe and then stretched to the other end and anchored to provide additional protection against incidental damage/slip. With regular watering and implantation of grass seed/turf, the root established quickly. Turf sod transplanted from adjoining grassed area over the grid laid on slope was found most suitable. Once the seedlings establish root and intertwine with the net aperture, and after occasional initial care, they did not require any maintenance. Attached plate no.1 shows the details of micro reinforced vegetation growth at site.

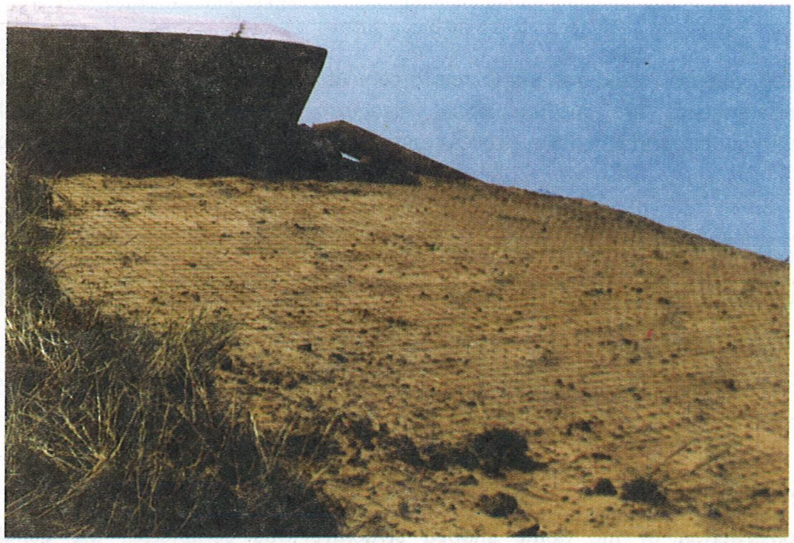

Plate no.1

CONCLUSION

Conventional methods of providing a solution in this project would be tedious as well as expensive. Adoption of Geosynthetics for the project ensured complete impermeability to the building and a green vegetated stabilized slope. The construction was completed with ease using available local unskilled labour and construction equipment available at site. Geosynthetics has provided an eco friendly solution while using locally available sand to construct the canopy. Application of Geosynthetics in important public structures finds wide application in developed nations of the world.The Indian technical community is slowly accepting the merits of Geosynthetics. Structures of the like constructed in the above project show that the Indian community accepts the merits of this technology.

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