Ground Improvement using Geosynthetics: A Review

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Abstract- Ground improvement with Geosynthetics is an innovative solution for difficult ground conditions. It is a sustainable solution for ground improvement, as it utilizes locally available materials, can employ unskilled labour, and is easy to install. This paper shows a review study of the recent development in ground improvement techniques, using geosynthetics, focusing on drainage application of geosynthetics. Various functions of Geosynthetics for ground improvement are Drainage, Filtration, surface erosion Control, Barrier (fluid), Protection, Reinforcement, Separation, etc. Different types of Geosynthetics serve various purposes, such as erosion control, canal lining, landfill lining, tunnel lining, accelerating the consolidation rate, soil confinement, sub-base support for road bases, construction of steep slopes, railway tracks, container yards, etc. The most recent trends in ground improvement feature vacuum consolidation, encased stone columns, and electrokinetic geosynthetics.

Keywords– Ground improvement, Geosynthetics, sustainable solution, drainage

1. INTRODUCTION

Geosynthetics are progressively used in geotechnical constructions. These are available in natural and artificial form. Indraratna, B. et al. [1] present the use of prefabricated vertical drains (PVDs) to enhance the performance of tracks and analysed them to control and prevent mud pumping.

Carlos, D.M. et al. [2] investigate the improvement in the penetration resistance of two local site-won soils (coarse and fine), the influence of several parameters is analysed, using geosynthetic in laboratory CBR tests.

Mach, A. and Wałach, D. [3] highlighted the promising potential of new, eco-friendly materials in sustainable geoengineering and emphasized the need for comprehensive tools to evaluate their sustainability.

Gupta, S. and Kumar, S., [4] analyzed bearing capacity, settlement performance, and failure patterns through modeling and testing, soft soils stabilized with deep soil mix (DSM) columns.

Almeida MD et al. [5] described various techniques involving prefabricated vertical drains (PVD), such as vacuum preloading; combining PVD with rigid inclusions like CPR grouting; purely column-like elements such as piled embankments (including those constructed with the deep mixing technique, DSM); combining column-like elements with drainage functions, such as stone columns and geosynthetic-encased columns; and using cementitious binders in shallow soil mixing.

Andrade et al. [6] carried out laboratory experiments using balloon tests on normally consolidated kaolin samples to study their behavior during and after the expansion of the balloon.

Deshpande, T.D. et al. [7] proposed that for the failed railway embankment, the study of geosynthetic-encased stone columns (ESC) is a chosen ground improvement technique.

Verma et al. [8] present a review of the recent development in ground improvement techniques, using chemical stabilizers. He discussed that chemical methods have several advantages over mechanical soil stabilization methods, such as not producing noise and vibrations like dynamic compaction.

Mohammed et al. [9] discussed for replacing soil stabilization materials that result in significant CO_2 emissions.

Shrivastava et al. [10] measure the viability of the modified grout mix (prepared by using dolomite mine overburden as a partial replacement for cement), the research investigates its fresh-state properties as well as its hardened-state properties.

Singh, M. [11] evaluates the life-cycle performance of mitigation methods, which can enhance sustainability and efficacy in the railway industry for ground-borne noise and vibration mitigation.

King, D.J [12] outlined the numerical modeling used to assess the serviceability behavior of a

GRCSE, with a focus on horizontal deformation. He emphasized the importance of recognizing the limitations of traditional FEM software in describing the effects of column installation and the associated geotechnical mechanisms.

The history of geosynthetics and their applications in various infrastructure construction projects was well defined by Karpurapu, R. [13]. The limitations in soil strength were effectively addressed using techniques such as the sandwich method and geocell confinement, among others.

Qurishee [14] focused on reducing the thickness of the base course by using geogrid material, maintaining the load-carrying capacity and performance of the pavement.

Hosseinpour et al. [15] examined the settlement beneath embankments, horizontal displacement of the soft foundation, and excess pore pressures within the soft clay layer for evaluation of the effectiveness of encased granular columns. Their research demonstrated that these columns significantly decreased both the maximum settlement beneath the embankment and the maximum horizontal displacement in the clay foundation. Additionally, at the same settlement level, the load-carrying capacity of the reinforced foundation was found to be approximately 2.5 times greater than that of the unreinforced foundation. The performance of clay beds reinforced with bamboo cells and bamboo grids is compared to that of clay beds reinforced with geocells and geogrids and observed that the bearing capacity of the clay bed increased sixfold when a combination of geocells and geogrids was used [16].

Nimbalkar et al. [17] conducted a five-year performance study of an instrumented railway track under operational conditions, including tamping activities. They installed four types of geosynthetics and a shock mat beneath the ballast layer in specific sections of the track, which was built on three different subgrades: soft alluvial clay, hard rock, and a concrete bridge. The observed stress-deformation response showed that the geosynthetics effectively managed both long-term and transient strains in the ballast layer, resulting in a significant reduction in maintenance costs.

Dutta et al. [18] depict the application of the geocell mattress and geofoam as reinforcements for ground modification.

Christopher B.R. [19] highlights the cost savings achieved by using geosynthetics in civil construction projects, noting their contribution to improved long-term performance and sustainability.

Flutcher et al. [20] review demonstrates that geogrids are particularly effective as sub-pavement reinforcement. Geosynthetics as interlayers should only be incorporated when a pavement's primary failure mode is fatigue or age cracking, and their use should be carefully considered based on economic factors.

M.B.D. Elsawy [21] indicates that stone columns in Bremerhaven clay enhance bearing capacity and expedite the reduction of excess pore water pressure in the foundation by analyzing the behavior of full-scale unreinforced and reinforced Bremerhaven clay using conventional and geogrid-encased stone columns under embankment loads through numerical simulations.

2. Types and Application of Geosynthetics

2.1 Geotextiles

These are engineered sheet-like products crafted from natural or synthetic materials, offered in both woven and non-woven varieties. They serve various functions, including separation, drainage, filtration, erosion control, and reinforcement. Rajagopalaiah, S. [22] has reviewed the performance of coir geotextile as a reinforcement in various soil conditions and concluded that natural fiber products hold promise for rural road construction over soft clay.

Woven non-woven

Figure 1: Woven and non-woven Geotextiles [23]

Figure 2: Geotextile layer applied below railway track [23]

2.2 Geogrids

Sheet-like products with open apertures facilitate excellent interlocking with soil. These high-strength materials are utilized for reinforcement purposes. Uniaxial products serve as reinforcement layers in retaining walls and embankments, while biaxial products are employed in road bases, beneath rail tracks, and for ground reinforcement.

Figure 3: Geogrid reinforcement in pavements [23]

2.3 Geonets

Geonets are also planar products with ribs oriented in two directions at different planes. The thickness of geonets is greater than that of geogrids.

It provides:

Erosion control – To reduce the risk of erosion caused by surface runoff, ribs function as small check dams.

Drainage layers – The thick geonet allows water to flow along it.

Figure 4: Boulder net laid on Konkan railway line [23]

2.4 Geomembrane

These are 0.5 mm to 3 mm thick plastic sheets used for landfill lining, canal lining, and tunnel lining.

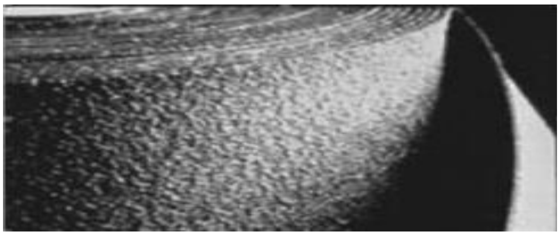

Figure 5: Textured Geomembrane [24]

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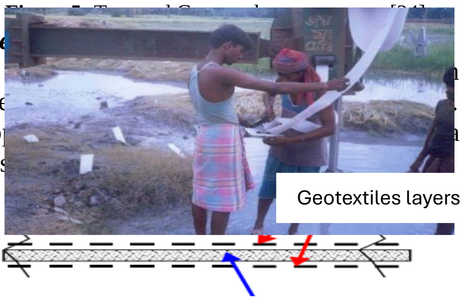

Figure 6: Geosynthe

2.6 Geocells (3-d confinement)

It is easy to transport, any fill material used for all-round confinement to soil. It provides exceptional support even under cyclic loads. Sub-base support is provided for Road bases, Railway tracks, and Container yards through Geocells.

Figure 7: Geocells used for the construction of steep slopes [23]

2.7 Geocomposites & Geo-others

The combination of two different types of geosynthetics allows for the benefits of each to be utilized. Geoothers include geodrains, geotextile bags and soil encapsulation, gabions, geosynthetic-encased stone columns, and more.

Figure 8: Gabions filled with sandbags [23]

Figure 9: Gabions filled with sandbags at Ocean [23]

2.8 Pre-fabricated vertical drains (PVD)

These are useful in reducing the flow path length to accelerate the rate of consolidation.

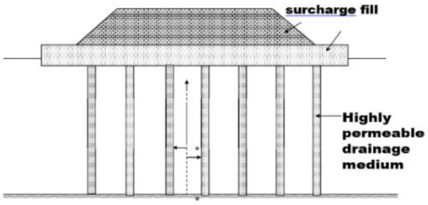

Figure 11: Connection of PVD with the anchor Plate at construction site [23]

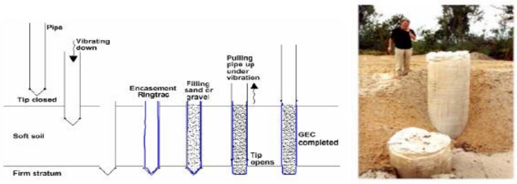

Figure 12: Construction of Encased Stone Column [24]

3. DRAINAGE

When incorporated into drainage systems, geotextiles enhance water flow management. They can be combined with gravel or aggregate layers to form efficient drainage pathways, effectively managing excess water and alleviating hydrostatic pressure.

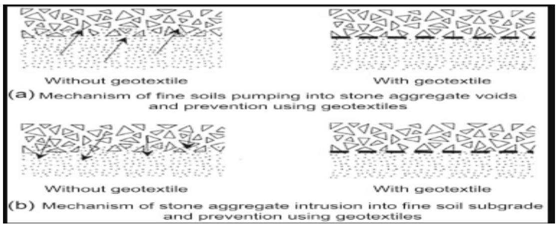

Figure 13: Different physical mechanisms in the use of geotextiles involved in separation function [25]

Designed to manage surface water runoff along the edges of pavements, these drains help prevent water accumulation and reduce the risk of pavement damage.

By capturing surface runoff and subsurface water, interceptor trenches help stabilize slopes and prevent erosion. Essential for maintaining the integrity of bridges and retaining walls, this drainage system alleviates hydrostatic pressure by allowing water to drain away from the structure.

Installed around buried structures, such as foundations and tanks, these drainage systems relieve hydrostatic pressure, protecting against potential damage from water infiltration.

Modern geocomposite drains can effectively replace traditional drainage systems. They provide enhanced performance, often requiring less space and offering improved flow capacity.

Commonly used in landfills, this system collects leachate liquid that has percolated through waste and allows for the venting of gases.

Drainage mats are installed under roofing systems to facilitate drainage, preventing water accumulation and promoting proper moisture management.

Prefabricated vertical drains (PVDs) are used to expedite the consolidation process in clay soils by providing a pathway for pore water to escape. This application is vital in construction projects requiring quick stabilization of soft soils.

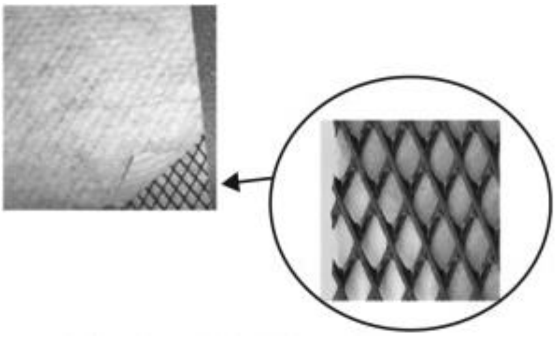

Figure 14: Drainage Geocomposites for drainage and geotextile filter [27]

Figure 15: Geonet having a large thickness as drainage medium [23]

4. CONCLUSION

Using geosynthetics is a great method to consider sustainability and lessen the need for natural building materials like soil aggregate. It promotes rural development with the use of natural Geosynthetics. The majority of roadway projects may have their carbon footprint decreased by using geosynthetics. The husk of the coconut is used to make coir fibers via a process called retting, which is mostly carried out by semi-skilled manual labor. During their 100 days of development, one hectare of jute plants can absorb around 15 metric tons of CO2 from the atmosphere and release 11 metric tons of O2. The ability to retain moisture and the surface roughness of natural geosynthetics are highly advantageous properties for successful applications. Numerous tests are conducted to evaluate the physical, mechanical, hydraulic, endurance, and degradation properties of geosynthetic materials in order to ensure quality control during the construction process. When choosing a geotextile for drainage, it is important to consider properties such as soil retention, clogging, and flow capacity [26].

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