



Geogrid Stabilizers for Clay Soil Improvement: A Review

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ABSTRACT

Geogrid reinforcement represents a foundational practice in geotechnical engineering, wherein soil and other earthy substances are meticulously incorporated with polymer-based net-like structures to significantly increase their intrinsic strength and general stability. This approach has become indispensable within modern civil engineering, particularly in the construction of roads, embankments, retaining walls, slopes and foundation on weak clay soil, where it serves to prevent soil displacement and structural failure. Clayey soils often exhibit low strength and high plasticity, challenging soil stability and prompting the search for sustainable stabilization solutions. The efficacy of geogrids lies in their unique geometry, which fosters a secure mechanical interlock with surrounding soil particles. As the soil becomes compressed across the grid, the material's tensile capacity actively resists deformation under load, thereby improving the distribution of stresses, minimizing settlement, and extending the service life of infrastructure. In an era marked by rapid urbanization and expanding infrastructural demands, the thoughtful implementation of geogrid reinforcement has grown increasingly vital to ensuring both the safety and long-term sustainability of engineering projects. Looking ahead, continued innovation in geogrid materials consisting of the development of ecological and recyclable alternatives holds promise for broadening the impact and applicability of this essential technology.

1. Introduction

Soil stability plays a fundamental role in structural engineering, as it directly influences the safety and longevity of constructed facilities. The capacity of soil to maintain its cohesion and resist disintegration under external forces such as water, wind, or mechanical loading is essential in assessing its suitability for supporting structural loads [1]. Stable soil demonstrates increased resistance to erosion and enhanced infiltration capacity, contributing to improved geotechnical performance and overall soil health [2]. In the evolving landscape of geotechnical

engineering, a variety of ground improvement methods continue to be advanced to enhance the stability and performance of underlying soil deposits. Among these approaches, reinforcing the soil beneath foundations stands as a well-established and widely accepted practice [3-4]. This technique involves the strategic placement of materials such as strips, bars, sheets, or grids within the soil mass to impart additional strength. When subjected to load, the integrated reinforcement actively resists the tensile stresses that develop throughout the soil structure, thereby contributing to greater overall integrity and durability [5-6]. Among the array of ground improvement methods, the

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geogrid stands as a notable example a net-like polymer structure engineered to integrate with and reinforce soil through mechanical interlocking. By embedding these grids within earthen layers, engineers can substantially improve the soil's inherent capacity to bear loads, maintain stability, and resist deformation [7-8]. This innovation has profoundly transformed practices in slope stabilization, road construction, and numerous further civil and geotechnical endeavours. This assessment, we examine the development of geogrid technology over the last forty years, tracing scientific advances in its development while exploring the underlying mechanisms that enable geogrids to strengthen soil, the diversity of geogrid types now available, and their expanding role in contemporary engineering projects [9-10].

2. Geogrid

Geogrids are polymeric planar structures designed as an open, grid-like network, where interconnected tensile elements are joined at their intersections to form a cohesive unit [11]. During manufacturing, extruded geogrids are typically categorized according to the directional stretching applied to the polymer sheet. Uniaxial geogrids, for instance, are stretched longitudinally, which grants them significantly greater tensile strength along that axis compared to the transverse direction. In contrast, biaxial geogrids undergo stretching in both longitudinal and transverse directions, resulting in balanced tensile properties in these two orientations. Finally, triaxial geogrids are engineered to distribute tensile strength multidirectional, achieving near-uniform resistance across approximately 360 degrees while interacting effectively with soil and which considered one of the best types [12]. The distinguishing features of these geogrid types are further illustrated in Figure 1.

2.1 Advantages

Geogrid materials present a compelling array of benefits for erosion control and soil stabilization, beginning with their capacity to substantially improve bearing strength. This is achieved through enhanced frictional

resistance, which effectively restricts lateral movement within the subgrade and promotes greater structural integrity. A further significant advantage lies in the material's long-term environmental durability, ensuring reliable performance over extended periods. From an economic perspective, geogrid offers a notably cost-effective solution by providing a stable synthetic alternative to the frequent and expensive replacement of failed or eroded soil. Its design also affords considerable landscape flexibility, as it can be seamlessly adapted to varied topographies, including sloped or uneven surfaces. Ultimately, the use of geogrid addresses a paramount concern for any property: safety. By preventing the gradual degradation and instability caused by soil erosion, which can devalue land and create hazardous conditions such as tripping or slipping, geogrid helps safeguard both the physical asset and the well-being of those who use it.

2.2 Disadvantages

The enduring performance of the formulated resin used in geogrid manufacturing must be ensured through the careful incorporation of appropriate additives, such as antioxidants, ultraviolet screeners, and fillers. As a polymeric material, the service life of geogrid is notably reduced when exposed, compared to when it is protected within a soil backfill. Furthermore, the design process must contend with the potential for clogging or bioclogging in geosynthetics, including geotextiles, geonets, geopipes, and geocomposites, which presents a particular challenge in specific soil conditions or unusual environments. Problematic scenarios include fine cohesionless soils, loose soils, and liquids with turbid and a high microbiological content, such as agricultural runoff, all of which require specific testing and assessment. It is also essential that rigorous quality control and quality assurance protocols govern every stage of handling, storage, transport, and installation. Fundamentally, the geogrid serves to enhance the properties of geotechnical materials by providing reinforcement and stabilization. Accordingly, and as reflected in the literature, its essential properties are broadly categorized into three

groups: physical, mechanical, and endurance characteristics [13].

3. Literature review

The academic investigation into the stabilization of clay soils using geosynthetic reinforcement has developed through a series of methodical studies, each contributing to a more comprehensive understanding of its mechanisms and efficacy. Studies selected in this research are arranged according to the time period specified above. Early model tests by Mandal and Sah (1991) established foundational principles, demonstrating that the horizontal placement of geogrids could enhance bearing capacity, with an optimal depth of 0.175 times the foundation width yielding a capacity factor of 1.36, while also achieving settlement reductions of up to 45% at a depth of 0.25 times the foundation width. This concept was further validated by Adams and Collin (1997), whose work on large model footings confirmed that a single reinforcement layer could increase the pressure required for a specific settlement by up to 119% compared to unreinforced soil, thereby substantiating the dual benefit of increased strength and reduced deformation.

Subsequent research refined these insights by exploring critical interface behaviors and practical application parameters. The work of Abu-Farsakh et al. (2007) crucially highlighted the sensitivity of the soil-geogrid interface to environmental conditions, showing that increased moisture content and decreased density significantly weaken the interfacial bond, a finding that underscored the necessity of considering compaction control in design. This focus on implementation was echoed by Manoj and Premalatha (2008), who developed an innovative in-situ technique using cellular geogrid cages pushed into soft clay, noting that both the width and depth of reinforcement contributed to increased load capacity through improved bearing surface and adhesive shear resistance. Analytical validation followed, with Sharma et al. (2009) present a method for estimating the ultimate bearing capacity of reinforced silty clay, confirming strong

agreement between theoretical predictions and experimental results.

Further experimental work broadened the scope to include specific performance indicators like the California Bearing Ratio (CBR). Researchers such as Naeini and Moayed (2009) and Tiwari and Vyas (2017) systematically demonstrated that geogrid reinforcement could improve CBR values by 35% to 40% in both soaked and unsoaked conditions, identifying an optimal placement depth typically near 0.2 times the sample height from the top. This theme of optimization was continued by Sarika and Valunjkar (2011) and Pradeep (2012), who investigated the effects of varying geogrid percentages and placement strategies, consistently finding that strategic reinforcement leads to significant gains in subgrade strength.

Concurrently, sophisticated laboratory testing advanced the fundamental mechanics of soil-reinforcement interaction. Khoury et al. (2011) and Esmaili et al. (2014) explored unsaturated interface mechanics, revealing that soil suction enhances interface shear strength and apparent cohesion, while also developing practical moisture reduction factors for design. Zhang et al. (2012) further clarified that while increased moisture content drastically reduces interface cohesion, the friction angle remains relatively constant, providing key parameters for stability calculations.

Modern studies have integrated these findings through numerical analysis and scaled model tests to explain the underlying mechanisms. Payam et al. (2017) identified four primary reinforcing mechanisms: prevention of local shear, improved load distribution, shear stress reorientation, and the tensioned membrane effect. This was complemented by the work of Shahin et al. (2017), which emphasized that reinforcement effectiveness is maximized when layers are placed at a critical depth and their ends are fixed, highlighting the importance of both position and interfacial friction.

The cumulative evidence strongly supports the practical and economic viability of geogrid reinforcement. Research from Madhu et al. (2018), Correa et al. (2020), and Navale et al. (2025) has consistently shown that

reinforcement can reduce pavement thickness, enable the use of more economical shallow foundations, and drastically cut settlement by as much as 70% in some plate load tests. Recent investigations by Reyaz and Anuj (2022), Qais et al. (2023), and Sahib et al. (2025) have reinforced these conclusions, demonstrating a more than doubling of load-bearing capacity in some cases and a consistently strong bonding ratio ($\eta > 1$) at the interface between subgrade and subbase layers. Finally, the synthesis by Edrian et al. (2025) positions geogrids as a sustainable and cost-effective remediation strategy, effectively enhancing the structural reliability of foundations on weak clay soils and confirming their role as a practicable solution in modern geotechnical engineering.

4. Conclusion

Geogrids represent a significant advancement in geotechnical engineering, with practical applications extending across diverse projects including landfills, pavements, embankments, and retaining structures. Their functional versatility in providing reinforcement and separation allows them to be employed more effectively and low cost in many scenarios than traditional materials such as cement, lime, or fly ash. Based on a review of treatment methods for soft soils using geogrids, several meaningful conclusions emerge.

- Research consistently indicates that incorporating geogrids substantially enhances key soil properties, including liquid and plastic limits, compaction characteristics, shear strength, and California Bearing Ratio values.
- Geogrid installation mitigates lateral aggregate displacement, thereby reducing induced stresses within the soil matrix.
- The inherent frictional resistance of geogrids restrains lateral transition of the soil, leading to enhanced bearing capacity and diminished settlement through the development of beneficial inward stresses.

- Published results also demonstrate that the ratio of reinforced to unreinforced shear strength typically exceeds unity, reflecting a strong and effective interfacial bond between the subgrade soil and the geogrid. This demonstrates that the composite interaction between the reinforcement and soil matrix exceeds the intrinsic shear strength of the soil separately.

5. Recommendations

While prior research has successfully studied the usage of several geogrid materials to improve soft soils for highway building and other civil engineering applications, several important avenues remain open for further exploration. Future studies would benefit from considering a wider range of environmental conditions and integrating more sustainable material alternatives to advance both the efficacy and the ecological responsibility of ground improvement techniques.

- A mixture of several kinds of geosynthetic material with additions such as waste glass powder, crum rubber, fly-ash, RAB and Rice husk should be applied for soil stability.
- The application of finite element modeling (FEM) has to be employed as it assists in forecasting the efficiency of payment and it delivers a cycle of cost analysis which is advantageous.
- Installation of the proper geosynthetic and the effective depth in the soil has a key impact in the effectiveness of geosynthetic technology.

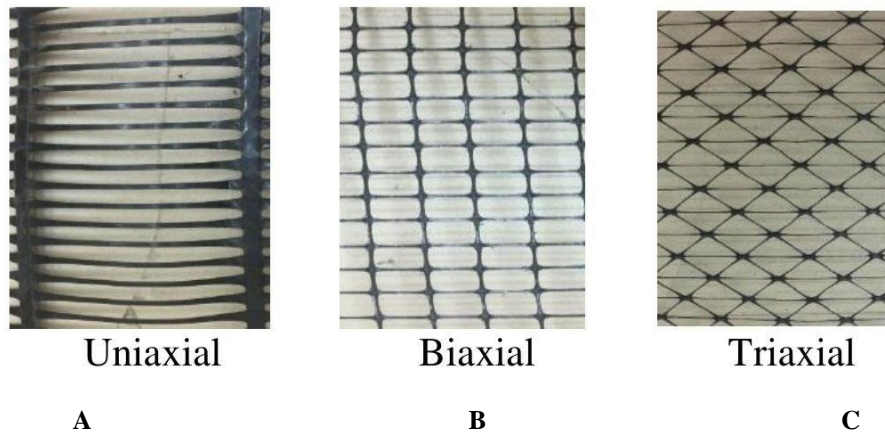


Figure 1. Types of geogrid materials.

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