

Performance of Geosynthetics in Reinforcing Soft Ground for Construction

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ABSTRACT - The use of geosynthetics to reinforce soft ground is crucial in addressing the challenges posed by soft soils, including their low shear strength, high compressibility, and inadequate drainage. These challenging soil conditions, frequently found in regions like Malaysia, present major obstacles to infrastructure development. This research examines how geosynthetic materials such as geogrids, geotextiles, and vertical drains can offer innovative solutions to enhance soil stability and load capacity. By reviewing three case studies, the study illustrates how geogrids reduced settlement in a railway project, geotextiles stabilized road embankments on soft ground, and vertical drains sped up soil consolidation. These cases show that geosynthetics improve stability, shorten construction time, and support durable infrastructure on soft soils. This study examines the use of geosynthetics, including geogrids for high-speed railway embankments in Malaysia, geotextiles for road stabilization in Indonesia, and prefabricated vertical drains for ground improvement in Egypt. The findings highlight the practical advantages of geosynthetics in improving construction efficiency, promoting sustainability, and enhancing resilience in soft soil conditions. Ultimately, this paper adds to the expanding body of knowledge on advanced geotechnical methods, emphasizing the crucial role of geosynthetics in modern construction practices.

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1. INTRODUCTION

Soft soils consist of fine clay particles combined with a high-water content in their pores, which results in low shear strength and poor bearing capacity. Furthermore, these soils pose significant engineering challenges, as their high compressibility and porosity lead to excessive settlement during and after construction [1]. Soil improvement techniques play a vital role in improving soil properties like bearing capacity, shear strength, and resistance to settlement, which are necessary for maintaining the stability of structures such as buildings, highways, and bridges. The application of these methods is crucial for mitigating problems related to ground subsidence, liquefaction in seismically active zones, and the instability of slopes [2]. Soil reinforcement is one such technique used to improve the strength of the soil [3]. The practice of soil reinforcement in construction entails the enhancement of soil engineering characteristics by utilizing a range of reinforcement components, such as synthetic fibers and plastic waste. This strategy is designed to enhance mechanical properties, with a particular focus on strength, ultimately leading to increased efficiency and stability in geotechnical applications [4].

Geosynthetics are synthetic products designed from either natural or artificial components to improve the engineering performance of soil. The term "geosynthetics" is formed from two elements: "geo," indicating the earth, and "synthetics," signifying human-made materials. As such, the term geosynthetics is used to describe these materials collectively [5]. Among the various geosynthetic materials widely used are geotextiles, geomembranes, geogrids, geocells, geonets, and geocomposites [6], [7]. Weak or soft soils, including peat, clay, and silty clay, are often associated with low shear strength and high compressibility, which can result in problems such as excessive settlement and instability. To mitigate these effects, geosynthetics, including geogrids and geotextiles, are employed to bolster soil strength and ensure a more even distribution of loads, which enhances both the bearing capacity and the overall stability of the soil structure [8]. Expansive soils, known for their tendency to expand when saturated and contract when dried, present considerable difficulties in construction due to their inherent volume instability. The implementation of geosynthetic reinforcements, such as geogrids, has been shown to effectively regulate the swell-shrink behavior of expansive soils, thereby lessening the likelihood of structural damage associated with these foundations [9].

Soft soil specifically, have numerous challenge due to their high compressibility, which greatly affects the stability of construction projects and infrastructure. This issue arises from the soil's fragile structure and high-water content, causing considerable settlement when loads are applied. The compressible nature of soft soils leads to extended consolidation periods, during which water is gradually released from the soil structure, resulting in slow deformation and uneven settling. This process delays construction schedules and increases the risk of structural instability and damage over time

[10]. Another critical challenge is the poor drainage capacity of soft soils, which extensively impacts their engineering properties and construction viability. Inadequate drainage results in elevated water content, diminishing the soil's shear strength and increasing its compressibility. This can lead to significant settlement of structures under applied loads, rendering the soil inherently unstable. Additionally, the inability to effectively release pore water pressure during loading raises the risk of soil liquefaction, especially in earthquake-prone areas [11].

Soft soils are also defined by their low bearing capacity, which poses major obstacles for construction and infrastructure projects. Their high porosity and low shear strength make them ill-suited to supporting heavy loads, such as those from high-rise buildings and other large structures. This challenge is compounded by their ability to retain significant amounts of water, which acts as a lubricant, diminishing soil resistance and increasing vulnerability to compression under pressure. Consequently, structures built on untreated soft soils are at risk of subsidence and eventual failure. As a result, structures constructed on untreated soft soils are susceptible to subsidence and potential failure [12]. Finally, soft soils present considerable problems due to their tendency to undergo excessive settlement, which can cause serious structural difficulties. Their high compressibility makes them prone to significant deformation when subjected to applied loads. This characteristic is especially troublesome for structures such as buildings, embankments, and roadways. Excessive settlement can lead to uneven surfaces, structural instability, and damage to infrastructure [13].

Eventually, this review paper presents three case studies that showcase creative geotechnical solutions for managing challenges of soft soils in infrastructure development. Each case highlights the application of geosynthetic materials to enhance soil stability, limit settlement, and ensure the structural durability over time.

First case study: investigates the use of geogrids and geotextiles in construction of high-speed railway project in Malaysia. The project tackled geotechnical challenges associated with soft and compressible soils through the strategic application of geogrid-reinforced piled embankments. This innovative approach ensured the railway infrastructure met stringent performance criteria, enabling long-term stability and efficient construction in complex soil conditions.

Second case study: explores utilization of geotextile reinforcement for stabilizing soft and swampy soils in road embankment construction in South Kalimantan, Indonesia. By integrating local soil with geotextile layers, the project achieved enhanced settlement control and durability while reducing environmental impact and construction costs. The study underscores the viability of geotextiles as a sustainable solution for infrastructure development in challenging terrains.

Third case study: examines the implementation of prefabricated vertical drains (PVD) and surcharge techniques to improve soft silty and clayey soils in a ground improvement project in northern Egypt. By accelerating soil consolidation and enhancing bearing capacity, the project demonstrated the effectiveness of PVD-surcharge combinations in addressing settlement and stability challenges for large-scale construction.

2. RELATED WORK

This section reviews the aspects related to problematic soils in Malaysia, the application of geosynthetic materials for soil stabilization, and relevant case studies that provide practical insights into their application. Problematic soils, such as soft clays and peat, are prevalent in Malaysia and pose significant challenges to construction projects due to their low shear strength, high compressibility, and poor drainage properties. Understanding the characteristics and behavior of these soils is essential for developing effective stabilization and construction techniques. Geosynthetic materials, including geogrids, geotextiles, and vertical drains, have been widely implemented in Malaysia as innovative solutions to mitigate the issues associated with problematic soils. Geogrids enhance soil stability by distributing loads and reducing settlement, while geotextiles provide separation, filtration, and reinforcement. Vertical drains accelerate the consolidation process in soft soils, reducing the time required for settlement. The review also investigates case studies that document the use of geosynthetics in Malaysian construction projects. These studies highlight the practical applications, challenges, and outcomes of executing geosynthetic solutions in different situations, such as road construction, embankment stabilization, and flood control measures. A comparison of these case studies will provide a deeper understanding of the effectiveness and limitations of each technique in addressing specific soil problems.

3. PROBLEMATIC SOILS IN MALAYSIA

Common problematic soils in Malaysia include organic soils like peat, soft soil, and residual soils [14]. It is estimated that there are approximately 1 billion acres of peat land worldwide, making up 4.5% of the total land surface. A global chart of total peat deposits shows that Malaysia has the 9th largest area of peat soil in the world, which covers around 2.56 million of the country's total land area [15], [16]. Peat is expected to be a part of the soil foundations for development considering the world's rising urbanisation. The decomposition of different plant materials in a wet environment such as marshes, bogs, and swamps are what produces peat [17], [18]. Peat exemplifies an extreme form of soft soil, categorized as organic because it contains over 75% organic matter. The organic composition of peat primarily arises from plant fibres, where the rate of accumulation surpasses the rate of decomposition. The fiber content within peat varies across different locations, influenced by factors such as the source of the fibres, temperature, and humidity levels [19], [20]. Peat has been labelled as one among the main types of soil in Malaysia [21]. Peat is identified by its coloration, which ranges from black to dark brown, and is noted for its spongy texture and organic smell. It is often perceived as a problematic

geological formation due to its unfavourable geotechnical properties, frequently requiring stabilization to adequately support any structures or infrastructures constructed on its surface [22]. Several properties are commonly found in peat soil, including low specific gravity, high moisture content and water retention. It also has high compressibility, poor bearing capacity and medium-to-low permeability [23].



Figure 1. Geographical distribution of peat soil regions within Malaysia

In Malaysia, soft soils present notable geotechnical challenges that complicate various construction and development projects. These soils are primarily located in the coastal and lowland regions and are characterized by their low shear strength, high compressibility, and poor drainage capabilities, which make them particularly prone to deformation under applied stress. A key issue associated with these soils is differential settlement, which can occur between pile-supported structures and adjacent areas that lack such support, such as car porches or roadways. This can lead to structural instability, disconnection of platforms, and long-term serviceability concerns. Furthermore, excessive settlement both elastic and consolidatory can significantly impact infrastructure, particularly when ground treatment is either inadequate or improperly executed. Embankment instability is yet another issue. Because of inadequate stability analysis, the strain incompatibility of reinforcement, and the limited lateral resistance of supporting piles, embankments over soft soils are vulnerable to cracking, sliding, and overall failure. A lack of appropriate countermeasures, including reinforcing or suitable drainage systems, or poor building methods frequently make these failures worse [24], [25].

Bridge approaches and foundations can have significant problems. For example, "humps" that compromise driving comfort and structural integrity are caused by differential settlement between hard abutments and nearby flexible embankments. The safety of transport networks is further threatened by the potential for slip failures in bridge foundations due to the underlying instability of soft soils. One significant challenge faced by expressways constructed on soft ground is the development of uneven surfaces, often termed "mushrooms." This situation is primarily attributed to inadequate load distribution mechanisms within piled embankments. Additionally, utilities and other infrastructure are not exempt from these issues, as the settlement of untreated soft soil surrounding piled utilities can cause surface cracks, bumps, and persistent maintenance difficulties. The failure to implement proper ground treatment continues to be a critical issue, with insufficient consolidation periods often leading to further settlement after the completion of construction [26].

Laterite soils found in Malaysia pose various challenges that hinder their application in construction, agriculture, and infrastructure projects. A significant concern is their low fertility, which is exacerbated by nutrient leaching resulting from the region's substantial rainfall. This characteristic renders laterite largely ineffective for agricultural use unless substantial soil amendments are applied. Furthermore, the high clay content inherent in laterite contributes to issues of shrinkage and swelling, which adversely affect its load-bearing capacity and stability, potentially leading to structural complications in both buildings and roadways. These problems are made worse by the soil's high plasticity, which makes it more likely to fracture under pressure or traffic loads. This frequently results in subgrade failures during road construction and expensive restorations. Additionally, laterite soils are prone to erosion, especially in regions with steep slopes and high rainfall, which causes topsoil loss and deposition in water bodies [27], [28].

One of the primary challenges is the durability of soil, especially in Malaysia's tropical climate, which is defined by frequent cycles of wetting and drying. These cycles accelerate the formation of cracks and the deterioration of laterite soils over time, compromising their structural integrity in infrastructure applications. Moreover, the substantial iron and aluminium content in laterite soils leads to difficulties in workability for construction, as these soils harden excessively upon exposure to air, making excavation and shaping particularly challenging. It is more difficult to standardise and apply laterite properties in geotechnical projects because of their diversity, especially across small distances. It is also becoming more and more difficult to meet the demand for dependable materials due to the declining supply of standard-quality laterite soils that are appropriate for road construction [29].

4. GEOGRID AS SOIL REINFORCEMENT

The Geogrids are a category of geosynthetic materials that find widespread application in the reinforcement of soil within civil engineering and construction endeavors. These materials are generally produced from polymers, including polyester, polypropylene, or polyethylene, and are distinguished by their grid configuration, which features openings that facilitate interlocking with soil particles [30], [31]. Main types of geogrids are uniaxial, biaxial, and triaxial geogrids. Each type is designed to specific reinforcement needs in civil engineering and construction. Uniaxial Geogrids are engineered to support loads predominantly in one direction, usually aligned with the machine direction. They are primarily utilized in mechanically stabilized earth (MSE) structures, such as walls and slopes, where there is a significant requirement for tensile strength along a singular axis [32], [33], [34].

These geogrids possess superior stiffness and strength in the intended direction, making them particularly effective for reinforcing embankments and retaining walls subjected to significant lateral forces. Biaxial geogrids provide tensile strength across both longitudinal and transverse directions. This capability makes them well-suited for applications in soil stabilization and reinforcement, particularly in areas where stresses are distributed in two orthogonal planes, such as under pavements or base layers. Nonetheless, their strength may diminish when exposed to stresses at oblique angles, particularly around 45 degrees relative to the primary ribs, which can restrict their performance in situations involving multi-directional loads. Triaxial geogrids signify a significant progression in geogrid technology, characterized by their triangular openings that facilitate uniform load distribution across multiple directions. This quasi-isotropic nature significantly boosts their performance in environments subjected to multi-directional stresses, particularly in applications involving roadways and railways. Furthermore, triaxial geogrids improve the distribution of stress, thereby reducing soil deformation and enhancing support for soft subgrades. Their flexibility and improved mechanical properties have made them a popular choice for sophisticated geotechnical applications [35], [36], [37].

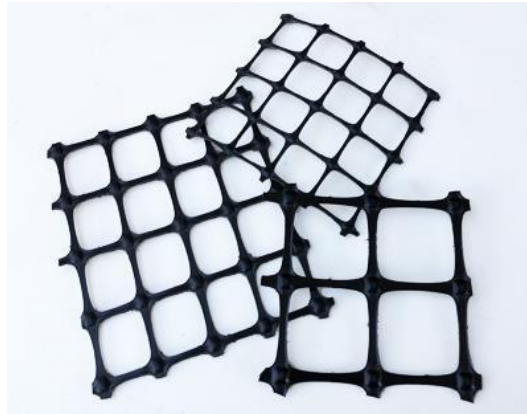


Figure 2. Example of biaxial geogrid used for railway embankment reinforcement in Malaysia

5. GEOTEXTILE AS SOIL REINFORCEMENT

The Geotextiles are highly adaptable materials that are widely utilized in applications related to soil reinforcement, offering innovative approaches in geotechnical engineering. Composed of synthetic fibers such as polypropylene or polyester, these permeable sheets are produced through various methods, including weaving, knitting, needle punching, or thermal bonding. Their primary roles involve separation, filtration, drainage, reinforcement, and erosion control, which are essential for the successful execution of infrastructure projects like roads, pavements, and embankments. Through soil stabilization, geotextiles increase the poor soils' ability to support loads, allowing for more affordable building on difficult terrain. The lifespan of pavements is extended, and structural integrity is preserved by geotextiles, which stop subgrade and base materials from mixing. For example, research indicates that the addition of non-woven geotextiles to subgrades causes a significant improvement in California Bearing Ratio (CBR) values, which indicates more strength and less deformation. Due to the constant dynamic loads on roads and airport runways, geotextiles are very useful in these settings [38], [39].

Moreover, geotextiles are advantageous from an environmental perspective, as they minimize the need for excavating and transporting soil from external sources. They enhance drainage efficiency by dissipating excess pore water pressure and reducing the risk of soil erosion. This dual capability of reinforcement and filtration offers sustainable solutions for infrastructure initiatives, thereby lowering both construction and maintenance costs while enhancing durability. Advance geotextiles, which comprise woven and non-woven varieties, offer advantages in various applications. Woven geotextiles are noted for their high tensile strength, making them suitable for reinforcement applications. In contrast, non-woven geotextiles are particularly effective in filtration and drainage applications, attributed to their permeable structure. The integration of these materials into composite forms is becoming more prevalent, thereby augmenting their functional performance across various geotechnical applications [40], [41], [42].



Figure 3. Geotextile material at site

6. VERTICAL DRAINS AS SOIL REINFORCEMENT

Vertical drains, commonly known as prefabricated vertical drains (PVDs), represent a prevalent technique for soil reinforcement that facilitates the rapid consolidation of soft and compressible soils. This technique is particularly effective in low-permeability soils, such as clay and silty deposits, where traditional drainage methods do not suffice. Typically, vertical drains are constructed from synthetic materials, such as geotextiles or geosynthetics, which provide both high permeability and significant mechanical strength. They are installed in the soil in a grid or radial pattern, allowing excess pore water pressure to dissipate more rapidly, thus accelerating the settlement process and improving soil strength [43], [44].

The notable benefit of employing vertical drains as a method for soil reinforcement lies in their capacity to expedite the consolidation process in soft, compressible soils. This advantage is especially relevant for projects that involve clay or peat soils characterized by low permeability, where natural drainage may require several decades. By shortening the drainage path for pore water, vertical drains facilitate the rapid dissipation of excess pore pressures induced by applied loads, such as those from embankments or structures. This expedited consolidation not only enhances soil stability but also significantly decreases construction duration and related expenses. Furthermore, vertical drains play a crucial role in mitigating liquefaction risks and managing residual settlements in both greenfield and brownfield developments, thereby improving the overall performance and durability of infrastructure [45], [46]. However, issues including the effects of soil smears, clogged drains, and fluctuating field conditions need to be carefully considered during the design and implementation phases. To forecast and assess the functionality of vertical drain systems, sophisticated numerical modelling methods and field monitoring are frequently used. Optimising drain spacing, enhancing material qualities, and minimising possible disadvantages remain the main goals of future study [47].

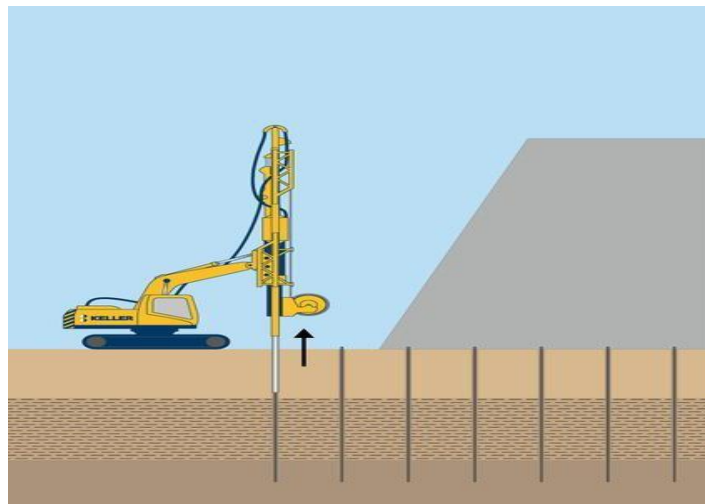


Figure 4. Prefabricated vertical drains

7. RELATED CASE STUDIES

7.1 Case study 1: Application of Geogrid in High-Speed Railways

7.1.1 Project Background

A high-speed railway project in Malaysia was completed years ago, featuring trains traveling at speeds of 160–180 km/h. The project spanned a length of 110 kilometers and required significant geotechnical enhancements due to variable and challenging soil conditions, including very soft silts, clays, and loose sands to depths of 30 meters. High strength geosynthetics, including biaxial geogrids and geotextiles, were extensively used for separation, filtration, and

reinforcement. This advanced engineering solution was crucial to meeting strict performance criteria, such as limiting post-construction settlement to 25 mm over six months and ensuring a minimum 90% degree of consolidation [48].

7.1.2 Problem and Its Causes

The primary challenge in this project stemmed from the geotechnical instability of the terrain. The existing soils were highly compressible and prone to settlement under load, particularly in areas with high embankments and bridge transitions. Without intervention, these conditions would lead to excessive deformation, differential settlement, and potential structural instability of the railway infrastructure. The traditional methods of soil improvement, such as preloading and soil replacement, were insufficient or infeasible due to time constraints, cost implications, and environmental concerns.

7.1.2 Solution

The solution involved the use of geogrid-reinforced pile embankments with individual pile caps, which addressed the issues of settlement and stability. Geogrids served as load transfer platforms, effectively distributing stresses and preventing lateral soil movement. The system utilized end-bearing piles capped with high-strength geogrids, which were further reinforced with layers of crusher run and sand blankets. This approach allowed for rapid construction and minimized environmental disruption. Additionally, woven and non-woven geotextiles were employed for various applications, including cement column reinforcement, drainage, filtration, and slope protection. The strategic design ensured optimal load distribution, reduced differential settlement, and extended the lifespan of the railway infrastructure.

7.2 Case study 2: Application of Geotextile for Stabilizing Local Soil as Backfill in Road Embankment

7.2.1 Project Background

In regions with soft and swampy soils, constructing stable road embankments is a persistent challenge. Such soils, due to their low bearing capacity, often lead to excessive settlement and instability when used as backfill without appropriate reinforcement. Using geotextiles for soil stabilization offers a viable solution to improve soil strength and minimize deformation. A full-scale investigation in the Tapin region of South Kalimantan, Indonesia, evaluated the use of local soil as backfill material, reinforced with geotextile layers. The study focused on vertical settlement, horizontal displacement, and road performance over an extended period under traffic and environmental stresses [49].

7.2.2 Problem and Its Causes

The main problem in constructing road embankments in swampy areas is the inability of soft soil to support heavy loads. This results in excessive settlement, lateral displacement, and frequent structural failures. Conventional backfill materials often exacerbate these issues due to their incompatibility with the underlying soil properties, requiring higher volumes and costs. Additionally, rainfall penetration and ground movement further compromise road integrity, leading to puddles and rapid degradation. These challenges necessitate innovative and sustainable stabilization techniques to reduce environmental impact and ensure the durability of the embankments.

7.2.3 Solution

Geotextile reinforcement was employed to stabilize the local soil used as backfill material. Geotextiles were layered strategically within the embankment to distribute loads evenly, minimize settlement, and enhance horizontal stability. The design included woven and non-woven geotextiles, ensuring compatibility with the local soil's physical and mechanical properties. Field tests demonstrated that the embankment using geotextile-reinforced local soil exhibited better long-term stability compared to the traditional method. Numerical analyses using the finite element method supported these findings, showing consistent improvements in settlement control and safety factors. The approach also reduced reliance on expensive, imported materials, making it economically viable and environmentally sustainable.

7.3 Case study 3: Application of Vertical Drains on Soft Soil

7.3 Project Background

The case study involves a significant ground improvement project in northern Egypt, utilizing prefabricated vertical drains (PVD) and surcharge. The site's upper 15 meters consist of soft silty clay to silty sand, underlain by a 35-meter layer of very soft clay. This challenging soil composition posed risks for stability and excessive settlement. To predict the soil behavior and ensure the project's success, a trial area equipped with advanced instrumentation was established. Field and lab tests were conducted to develop a numerical model capable of analyzing both short- and long-term impacts of the improvement strategy [50].

7.3.1 Problem and Its Causes

The primary issue at the project site was the soft soil's low bearing capacity and high compressibility. Without intervention, these conditions would lead to substantial settlement and instability of any constructed structures. The problem stemmed from the high-water content and weak structural integrity of the soil layers, which prevented adequate load distribution. Traditional soil stabilization methods were insufficient for such extreme conditions, necessitating an innovative and efficient approach.

7.3.2 Solution

The project employed a combination of prefabricated vertical drains (PVD) and surcharge loading to accelerate soil consolidation and improve its properties. Vertical drains were installed to shorten the water drainage path, enabling faster dissipation of excess pore water pressure. This method significantly increased soil stiffness and reduced long-term settlements. A surcharge of 6.5 meters was applied for nine months to preload the soil. During this period, settlements were monitored using ground measurement points and piezometers, revealing that consolidation was predominantly confined to the top 25 meters of the soil. A numerical model was developed and validated with field data to predict settlement behavior, demonstrating the effectiveness of the PVD-surcharge combination in mitigating soil settlement challenges.

8. COMPARATIVE ANALYSIS

Table 1. Comparison of geogrid, geotextile, and vertical drain applications in soft soil case studies

Aspect	Case Study 1: Geogrid in High-Speed Railways	Case Study 2: Geotextile for Road Embankments	Case Study 3: Vertical Drains on Soft Soil
Method	Geogrid-reinforced piled embankments with pile caps, biaxial geogrids, geotextiles, crusher run, and sand blankets	Woven and non-woven geotextile layers to stabilize local soil used as backfill	Prefabricated vertical drains (PVDs) with surcharge loading
Mechanism	<ul style="list-style-type: none"> • Load transfer platform • Lateral restraint • Filtration and separation 	<ul style="list-style-type: none"> • Load distribution • Drainage enhancement • Horizontal stability 	<ul style="list-style-type: none"> • Accelerated consolidation • Pore pressure dissipation • Preloading
Effectiveness & Outcome	<ul style="list-style-type: none"> • ≤ 25 mm settlement over 6 months • Supports 160–180 km/h speed • Fast, environmentally friendly construction 	<ul style="list-style-type: none"> • Reduced settlement and displacement • Cost-effective use of local materials • Proven durability under stress 	<ul style="list-style-type: none"> • Improved stiffness • Accelerated settlement • Validated by numerical models
Environmental Impact	Minimal disruption; avoided traditional mass excavation or replacement	Reduced footprint; minimized extraction through use of local soil	Temporary disruption during installation; less invasive overall
Economic Impact	Higher initial cost; long-term savings via low maintenance and durability	Cost savings due to local soil use; sustainable material sourcing	High upfront investment; cost-effective over lifecycle due to reduced maintenance

Table 2. Summary of geosynthetics and their functions in soft soil reinforcement

Geosynthetic Type	Primary Functions	Typical Applications	Benefits
Geogrids	Reinforcement, load distribution	Railway embankments, retaining walls	Reduces settlement, increases bearing capacity
Geotextiles	Separation, filtration, reinforcement	Road embankments, drainage	Controls settlement, improves stability
Vertical drains (PVD)	Accelerated consolidation, drainage	Soft clay ground improvement	Speeds up settlement, increases soil stiffness

8. CONCLUSION

Use of geosynthetics in stabilizing soft ground has become crucial in modern geotechnical engineering. Soils like peat and clay present considerable challenges due to their high compressibility, low shear strength, and inadequate drainage, all of which threaten the stability and durability of infrastructure projects. Innovative materials such as geogrids, geotextiles, and vertical drains have proven to be effective solutions, enhancing soil properties while boosting construction efficiency. The case studies analyzed underscore the successful use of geosynthetics in various real-world applications, such as railway construction, road embankments, and large-scale soil consolidation projects. These examples demonstrate the ability of geosynthetics to reduce settlement, enhance bearing capacity, and provide lasting structural stability, even in complex soil environments. Their adaptability across a wide range of engineering situations, coupled with their cost-efficiency, highlights their critical role in addressing soil-related construction challenges.

In summary, geosynthetics play an essential role in soil stabilization and improvement, effectively addressing the inherent limitations of problematic soils. Their use facilitates the development of sustainable and long-lasting infrastructure, especially in areas with challenging soft soil conditions, such as Malaysia. Ongoing research and innovation in this field will continue to improve their performance and expand their applications, enabling the resolution of increasingly complex geotechnical challenges.

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