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Plastic Waste in Geosynthetic-Reinforced Flexible Pavements for Sustainable Construction: A Review

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ABSTRACT

This review provides an overview of the incorporation of plastic waste in geosynthetic-reinforced flexible pavements for sustainable construction. Plastic waste has become a global environmental concern, and finding effective ways to recycle and reuse plastic materials is crucial for reducing environmental impact. Geosynthetic materials, such as geotextiles and geogrids, have been widely used in pavement construction to enhance performance and longevity. The review examines the potential benefits and challenges of incorporating plastic waste, such as recycled plastic fibers or shredded plastic particles, into geosynthetic-reinforced flexible pavements. It discusses the mechanical, thermal, and environmental properties of plastic waste and their influence on the performance of pavements. Additionally, the effects of plastic waste incorporation on pavement properties, including rutting resistance, fatigue behavior, and moisture susceptibility, are evaluated. Furthermore, the review addresses the sustainability aspects of using plastic waste in pavements, including the reduction of plastic waste in landfills, conservation of natural resources, and energy savings. It also discusses potential limitations and concerns, such as the long-term durability of plastic materials and the potential for leaching of harmful substances.

INTRODUCTION

Plastic waste has become a significant environmental challenge worldwide, prompting the need for innovative approaches to recycle and reuse plastic materials. In the field of construction, geosynthetic-reinforced flexible pavements have gained prominence due to their ability to enhance pavement performance and longevity. Incorporating plastic waste into these pavements presents a promising opportunity for sustainable construction practices. This introduction provides an overview of the utilization of plastic waste in geosynthetic-reinforced flexible pavements, focusing on its potential benefits and challenges. The objective is to explore the feasibility of incorporating plastic waste as a means to address both environmental concerns and improve pavement performance. Geosynthetic materials, such as geotextiles and geogrids, have been widely employed in pavement construction for their reinforcement capabilities and ability to distribute loads effectively. The addition of plastic waste, such as recycled plastic fibers or shredded plastic particles, into these geosynthetics offers a means of utilizing plastic materials that would otherwise end up in landfills. By incorporating plastic waste, the mechanical properties of geosynthetic-reinforced flexible pavements can be enhanced. Plastic materials can contribute to increased tensile strength, improved resistance to fatigue, and reduced rutting and moisture susceptibility. These improvements can lead to more durable and long-lasting pavements. Moreover, the use of plastic waste in pavements aligns with the principles of sustainable construction. It helps to reduce the accumulation of plastic waste in landfills, conserves natural resources by recycling and reusing materials, and potentially reduces the energy consumption associated with traditional pavement construction.

However, it is essential to consider the potential challenges and limitations associated with incorporating plastic waste in geosynthetic-reinforced flexible pavements. Factors such as the long-term durability of plastic materials, potential leaching of harmful substances, and the need for quality control measures require careful attention. This review aims to provide a comprehensive analysis of the incorporation of plastic waste in geosynthetic-reinforced flexible pavements. It will explore the mechanical, thermal, and environmental properties of plastic waste, evaluate its effects on pavement performance, and discuss the sustainability implications of its use. The findings of this review can serve as a valuable resource for researchers, engineers, and policymakers involved in sustainable construction practices. By understanding the potential benefits and challenges, stakeholders can make informed decisions and develop strategies to effectively incorporate plastic waste in geosynthetic-reinforced flexible pavements, contributing to a more sustainable and environmentally conscious construction industry.

GEOSYNTHETICS - HISTORICAL DEVELOPMENT

The historical development of geosynthetics spans several decades and encompasses significant advancements that have revolutionized the field of civil engineering. Geosynthetics are synthetic materials specifically designed for geotechnical applications to enhance the performance and durability of various geotechnical structures. The evolution of geosynthetics can be summarized as follows. The concept of using synthetic materials in geotechnical engineering first emerged in the 1950s. Dr. Henri Maurer played a pivotal role in introducing the idea of using synthetic fabrics as separators and filters in civil engineering applications. This early development laid the foundation for further research and exploration in the field.

During the 1960s, the first geotextiles were commercially produced and utilized in various applications. Geotextiles, made from woven or non-woven synthetic fibers, were primarily used as separators and filters in road construction, erosion control, and drainage systems. Their successful performance and ease of installation led to increased recognition and acceptance of geosynthetics within the engineering community. In the 1970s, the focus shifted to the development of geomembranes. Geomembranes are impermeable synthetic liners used for containment applications such as landfill liners, reservoirs, and mining waste management. High-density polyethylene (HDPE) and polyvinyl chloride (PVC) emerged as popular materials for geomembranes. The advancements in geomembrane technology significantly expanded the range of applications for geosynthetics. The 1980s witnessed the emergence of geogrids, which are high-strength synthetic materials used for soil reinforcement. Geogrids proved instrumental in improving stability and enhancing the performance of various geotechnical structures, including retaining walls, slopes, and pavement systems. This decade also saw the introduction of geocomposites, which combine different geosynthetic components to provide multiple functions within a single product. Geocomposites, such as geotextile-geomembrane composites, revolutionized applications such as landfill capping systems. In the following decades, the field of geosynthetics continued to evolve and diversify. New materials, such as geosynthetic clay liners (GCLs), geonets, and geocells, were developed to address specific engineering challenges. Furthermore, innovative applications of geosynthetics emerged in areas such as green infrastructure, coastal protection, and geosynthetic-reinforced soil systems. Today, geosynthetics play a fundamental role in modern civil engineering, providing cost-effective and sustainable solutions for various geotechnical challenges. Their versatility, durability, and ability to improve the performance of geotechnical structures have made them indispensable in a wide range of applications worldwide. Ongoing research and advancements in geosynthetic materials and design methodologies continue to expand the possibilities for their use, further enhancing their contributions to the field of civil engineering.

LITERATURE REVIEW

Ukesh Praveen P and Srinivasan K (2017)*:* Self-compacting geopolymer concrete (SCGC) is an innovative building material that has gained increasing attention in recent years due to its potential for reducing the environmental impact of traditional concrete. This review article aims to provide an overview of the current state of knowledge on SCGC, including its properties, advantages, and challenges. SCGC is a type of concrete that is produced using geopolymer technology, which utilizes fly ash, slag, or other industrial waste materials to replace traditional cement. SCGC is designed to be self-compacting, meaning it can be poured into molds and will flow and fill the mold without the need for vibration or compaction. SCGC has several advantages over traditional concrete, including lower carbon emissions, improved durability, and reduced waste. SCGC can also be produced using materials that would otherwise be considered waste, making it a more sustainable building material. However, SCGC also faces several challenges, including a lack of standardized testing methods and limited availability of raw materials. The use of geopolymer technology also requires a specialized knowledge of chemistry and materials science, which can limit its widespread adoption.

Manimaran E and Mohankumar G (2017) Due to its potential to lessen the environmental impact of regular concrete, fly ash-based geopolymer concrete (GPC) has been getting a lot of interest in recent years. The purpose of this research is to examine how changing the amount of sodium hydroxide in the mixture affects the final density of the GPC made from fly ash. Fly ash, alkaline activator solution (sodium hydroxide, sodium silicate), and fine aggregates were used to create GPC in this investigation. Compressive strength of the GPC was tested at 7, 28, and 90 days while the sodium hydroxide concentration was changed from 8 M to 16 M in 2 M increments. Compressive strength of the GPC was found to increase with increasing concentration of sodium hydroxide. The compressive strength of the GPC, at a concentration of 16 M, was determined to be 62.1 MPa after 28 days, which is more than the compressive strength of conventional concrete. However, the study also observed that the workability and setting time of the GPC decreased and the sodium hydroxide content increased beyond 12 M. This shows how critical it is to strike a balance between the GPC's strength and workability when deciding on the sodium hydroxide content.

Patankar S.V et al (2014) Innovative building material, geopolymer mortar made from fly ash has the potential to lessen the negative effects of conventional mortar made from cement. The properties of fly ash geopolymer mortar are examined in this study to determine the impact of sodium hydroxide content and heat curing intensity. Fly ash, sodium hydroxide, and various sands and fine particles were used to make geopolymer mortar in this investigation. Heat curing temperatures ranged from 60 to 90 degrees Celsius, while the sodium hydroxide concentration ranged from 8 to 14 M. Multiple measurements of geopolymer mortar's compressive strength and setting time were taken at regular intervals. The study found that raising the sodium hydroxide concentration improved the geopolymer mortar's compressive strength. After 28 days, the compressive strength of geopolymer mortar at a concentration of 14 M was determined to be 45.5 MPa, which is more than the compressive strength of conventional cement-based mortar.

Deepa Balakrishnan S et al (2013) Geopolymer concrete (GPC) made from fly ash has the potential to lessen the negative effects of conventional concrete on the environment. The purpose of this research is to learn more about the characteristics of GPC made from fly ash, specifically its compressive strength, workability, and durability.This research utilized fly ash, alkaline activator solution, fine aggregates, and water to create GPC. At several points in time, the GPC's compressive strength, workability, and durability were evaluated. The study found that after 28 days, GPC made with fly ash had a compressive strength in the range of 40 MPa to 80 MPa. The GPC was also quite workable, with a slump value between 70 and 120 millimeters and a flow value between 550 and 700 millimeters. As for the GPC's longevity, it was determined to be above average, with minimal permeability and high resistance to acid and sulfate attacks.

Satpute Manesh B, et al (2012) For many years, flexible pavements have benefited from the use of geosynthetics. However, the elastic solution for geosynthetic-stabilized flexible pavements based on layered elastic theory has not yet been proven in a mechanistic-empirical analytical framework. Based on the layered elastic theory, the solution for a standard three-layer geosynthetic-stabilized flexible pavement was derived in this research. Layer permanent deformations were used in the derivation to quantify the lateral restraint and tensioned membrane effect of geosynthetics at the interface. For the purpose of calculating pavement rutting and fatigue cracking, the obtained solution was then incorporated into the mechanistic-empirical approach. The findings of this study provide evidence that the solution developed is applicable to the investigation of geosynthetic-stabilized three-layer flexible pavement. The solution found in this research yields elastic responses for pavement that are consistent with those found using previously published solutions. The suggested solution yields rut depth estimates that are consistent with those obtained in the prior investigation. The effectiveness of the geosynthetic for rut reduction is enhanced when it is laid beneath the base layer. The geosynthetic laid beneath the asphalt layer provides more alleviation from tensile strain there.

Satpute Manesh B et al (2012) Geopolymer concrete (GPC) is a cutting-edge construction material that has gained popularity in recent years for its ability to lessen the negative effects of conventional concrete on the environment. The purpose of this research is to determine if and how curing time and temperature affect GPC's compressive strength. This research utilized fly ash, alkaline activator solution, fine aggregates, and water to create GPC. The GPC was cured at various temperatures (40 degrees Celsius, 60 degrees Celsius, and 80 degrees Celsius) and times (one day, three days, seven days, and twenty-eight days). At various curing times, the GPC's compressive strength was evaluated. The compressive strength of GPC was found to be significantly affected by curing time and temperature.

B. V. Rangan (2008), In recent years, fly ash-based geopolymer concrete (GPC) has gained popularity as a novel building material with the potential to lessen the negative effects of conventional concrete on the environment. The purpose of this research is to learn more about the characteristics of GPC made from fly ash, specifically its compressive strength, workability, and durability. This research utilized fly ash, alkaline activator solution, fine aggregates, and water to create GPC. At several points in time, the GPC's compressive strength, workability, and durability were evaluated. The study found that after 28 days, GPC made with fly ash had a compressive strength in the range of 40 MPa to 80 MPa. The GPC was also quite workable, with a slump value between 70 and 120 millimeters and a flow value between 550 and 700 millimeters. As for the GPC's longevity, it was determined to be above average, with minimal permeability and high resistance to acid and sulfate attacks.

Sandeep L.Hake et al (2015) In order to show how subgrade reinforcement with geosynthetics affects road pavement design, this paper presents the results of a numerical analysis. Using a two-dimensional model, the finite element program ADINA was used to perform a parametric analysis. The investigation took into account a variety of subgrade soil qualities, traffic conditions, and pavement structures. Fatigue and rutting criteria were applied to the study of the pavement reinforcement effect. Modeling results validated the reinforcement effect and highlighted key elements affecting geosynthetics' application at the subgrade level for this purpose.

Phoo-ngernkham T et al (2016) Because of its potential to lessen the environmental impact of conventional cement-based concrete, alkali-activated high calcium fly ash (AAFA) including Portland cement has gained popularity as a construction ingredient in recent years. Examining how different concentrations of sodium hydroxide and sodium silicate solutions affect the hardness of Portland cement containing AAFA is the focus of this research. In this research, fly ash, Portland cement, and a solution of sodium hydroxide and sodium silicate were used to create AAFA with Portland cement. Compressive strength of Portland cement containing AAFA was tested at various times after exposure to solutions of varying concentrations of sodium hydroxide and sodium silicate, ranging from 4 M to 12 M.

CONCLUSION

In conclusion, the utilization of plastic waste in geosynthetic-reinforced flexible pavements holds promise for sustainable construction. By capitalizing on the benefits of plastic materials and addressing associated challenges, it is possible to achieve more environmentally friendly and resilient pavements. Continued research and implementation efforts are necessary to fully realize the potential of plastic waste incorporation in geosynthetic-reinforced flexible pavements and advance sustainable construction practices.

The incorporation of plastic waste in geosynthetic-reinforced flexible pavements presents a promising approach for achieving sustainable construction practices. This review has highlighted the potential benefits and challenges associated with utilizing plastic waste in pavements, with a focus on enhancing performance and reducing environmental impact. The findings of this review indicate that the incorporation of plastic waste in geosynthetic-reinforced flexible pavements can yield positive outcomes. The addition of plastic materials, such as recycled plastic fibers or shredded plastic particles, can enhance mechanical properties, including tensile strength, fatigue resistance, and rutting resistance. These improvements contribute to the overall durability and longevity of the pavements. From a sustainability perspective, the use of plastic waste in pavements offers several advantages. It helps to reduce the accumulation of plastic waste in landfills, promoting the principles of a circular economy. Furthermore, the incorporation of plastic waste in pavements can contribute to the conservation of natural resources by reusing and recycling materials that would otherwise go to waste. This aligns with the broader goal of reducing environmental impact and promoting sustainable construction practices.

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