ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

HIGH-DENSITY POLYETHYLENE CONTAINERS AND END-OF-LIFE TIRES AS GEOCELLS FOR SOIL REINFORCEMENT AND STABILITY

John Rogel S. Ursua[1] and Consorcio S. Namoco Jr.[2]
[1]College of Engineering and Architecture, University of Antique, Sibalom, Antique, Philippines
[2]College of Technology, University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines
E-Mail: johnrogel.ursua@antiquespride.edu.ph

ABSTRACT

This study explores the potential of repurposing non-biodegradable plastic containers and end-of-life tires (ELTs) to produce high-quality, cost-effective geocells for soil stabilization. By utilizing High-Density Polyethylene (HDPE) containers in conjunction with ELTs, the research rigorously evaluates the tensile strength of these improvised geocells in accordance with ASTM D638 standards, comparing their performance against commercially available geocell alternatives. The findings reveal that the tensile strength of the HDPE geocells not only meets but often exceeds industry standards, with an average strength of 30.782 MPa, demonstrating their effectiveness in providing reliable soil reinforcement. Furthermore, a comprehensive cost analysis highlights a significant economic advantage, with the use of improvised geocells yielding a remarkable 47.76% reduction in expenses compared to traditional methods. This innovative approach addresses critical challenges associated with conventional soil stabilization techniques, such as high costs and inconsistent performance, while promoting sustainability by minimizing waste and encouraging responsible consumption practices. The study aligns with the United Nations Sustainable Development Goals (UNSDG) by supporting sustainable practices in construction and advancing resource efficiency. Overall, the development of these eco-friendly geocells presents a viable solution for enhancing soil stabilization methods, contributing to sustainable infrastructure development, and paving the way for a more environmentally conscious approach within the civil engineering sector. This research not only underscores the importance of integrating waste materials into construction practices but also highlights the potential for significant economic and environmental benefits through innovative recycling strategies.

Keywords: geocells, high-density polyethylene, end-of-Life tires, soil stabilization, sustainable construction.

Manuscript Received 10 February 2026; Revised 15 March 2026; Published 10 May 2026

INTRODUCTION

The construction sector worldwide has witnessed more challenges in maintaining a balance between infrastructure development and a sustainable environment. The consumption of natural resources and generation of non-biodegradable waste, such as plastic and tire waste, have been increasing with rapid urbanization and industrialization. According to Vuppaladadiyam *et al.* (2024), the recycling rate of the world for plastic waste is no more than 9%, leading to a high degree of environmental damage. High-Density Polyethylene (HDPE), a thermoplastic polymer applied in the packaging industry, is one of the main culprits that contributes to this issue by producing around 30 million tons annually, of which they are disposed of in landfills and marine environment waste disposal (Maitlo *et al.*, 2022). Similarly, end-of-life tires present a significant environmental burden, primarily due to their non-biodegradable composition and the potential leaching of harmful chemicals. Effectively addressing the twin challenges of waste accumulation and resource scarcity necessitates innovative recycling approaches that integrate sustainable materials into various engineering applications.

Recent advancements in geotechnical engineering have introduced geocells, three-dimensional, honeycomb-like systems for confining soil. These systems are effective for stabilizing soil and improving ground conditions. They are typically made from high-density polyethylene and help increase load-bearing capacity, reduce settlement, and improve slope stability in various applications such as pavements, embankments, and retaining walls (Krishna & Latha, 2023). However, the high cost of commercial geocells and rising environmental concerns about using virgin plastics have led researchers to explore alternative materials. Using HDPE waste and end-of-life tires to create geocell structures offers a promising solution for protecting the environment and improving infrastructure resilience. Studies by Deshmukh *et al.* (2022) and Dandin *et al.* (2024) have shown that incorporating recycled plastics and waste tires in soil reinforcement not only enhances geotechnical performance but also supports circular economy initiatives by reducing waste in landfills. The use of recycled plastics and tire-derived materials in geotechnical applications is in direct line with fundamental principles from sustainable engineering and corresponds to several United Nations Sustainable Development Goals, such as Goals 9 (Industry, Innovation, and Infrastructure) and 12 (Responsible Consumption and Production). The current research is intended to investigate the ways of developing cost-effective geocells from waste high-density polyethylene containers and end-of-life tires. In such a way, dependence on virgin materials could be minimized while improving the mechanical stability of soil structures. Both aspects-performance and environmental responsibility-are part of the approaching paradigm of green geotechnics, which has promoted eco-efficient materials and low-carbon design practices to achieve sustainability in ground improvement and soil stabilization efforts (Roque *et al*., 2022; Vicuña *et al*., 2024; Tiago Gonçalo *et al*., 2023).

Although there is increased research into applications for recycled polymers, there is still a dearth of research on measuring the tensile strength and the economics of geocells made from post-consumer HDPE containers. Although ASTM D638 provides a solid basis for testing the tensile properties of thermoplastics, a systematic review of studies on tensile properties between recycled HDPE geocells and commercially available geocells is scarce. Even more recently, the use of both HDPE and ELTs tires in geocell fabrication remains underexplored, particularly concerning the composite strength performance and cost benefits on actual soil stabilizing projects. While some studies, such as those conducted by Moghaddas Tafreshi *et al* (2021) and Meidudga *et al* (2021), respectively, lend some structure to prove the structural feasibility of waste plastics for subgrade stabilization, there are limited systematic reviews that combine both HDPE and tire waste products into a comprehensive analysis.

This research seeks to address these gaps by designing and evaluating geocells out of recycled, post-consumer HDPE containers and end-of-life motorcycle tires. The study assesses the tensile strength of HDPE in accordance with ASTM D638 and compares its tensile strength with that of commercial geocells. Additionally, it evaluates the economic benefits of using HDPE containers and ELT in geocell production compared to commercially available geocells. The results are expected to contribute valuable insights into sustainable construction practices, demonstrating how innovative reuse of non-biodegradable waste can advance both engineering performance and environmental stewardship. Ultimately, the study supports the transition toward a circular economy in the construction sector, where resource efficiency and ecological responsibility coexist as complementary objectives (Alabi *et al*., 2019; Hejazi *et al*., 2012).

MATERIALS AND METHODS

As shown in Figure-1, the methods began with the collection of 20-liter HDPE containers (19 cm x 34 cm) and ELTs from motorcycles (50 mm x 250 mm), followed by thorough cleaning of all materials to remove dirt and contaminants. The containers were then cut into rectangular sections as per the specified dimensions. Next, the tire strips were prepared and connected to the container sections using 1 in x 3/16 in rivets, with holes pre-drilled using a drilling machine. Additionally, 5 mm drainage holes were drilled at 2-3 cm spacing along the sections. The assembly was done by aligning the HDPE sections and riveting the tire strips around them for support and structural integrity. Also, the HDPE specimen underwent testing based on ASTM D638 strength requirements to ensure it met the necessary tensile strength. The test was conducted to determine the tensile strength capacity of HDPE plastic containers used in producing geocells. Three specimens were tested in accordance with ASTM D638. Each specimen was placed in the Universal Testing Machine (UTM) for the tensile test, and the tensile strength was recorded. This tensile strength evaluation was aimed at determining whether producing or purchasing this product is more efficient, both economically and for construction purposes, compared to commercially available geocells. Correspondingly, the specimen was evaluated for overall durability and potential application in sustainable construction projects. On the other hand, a detailed cost evaluation was conducted to assess the economic competitiveness of the geocells produced in this study. The analysis involved comparing the total production costs of the fabricated geocells with the market price of commercially available alternatives. Moreover, to determine which option offers greater cost efficiency while maintaining functional performance was the objective, thus guiding decisions regarding the feasibility of large-scale production.

RESULTS AND DISCUSSIONS

This section presents the design of geocells and discusses the study's findings, including the analysis of tensile strength tests on HDPE plastic container specimens, the evaluation of their tensile strength, and a comprehensive cost analysis.

Design of Geocells using HDPE Plastic Containers and Eng-of-Life Tires

The geocell design in this study utilized HDPE containers cut into rectangular sections with dimensions of 19 cm x 34 cm, as shown in Figure-2, which were connected using ELTs from motorcycle cut to strips to 50 mm x 250 mm through riveted connections of 1 in x 3/16 in. The tire strips were pre-drilled and fastened to the HDPE sections to form a grid-like structure, providing support and flexibility. Furthermore, 5 mm drainage holes were drilled at 2-3 cm spacing to allow water flow, enhancing the geocell's performance in various applications. This design followed ASTM D638 strength testing to ensure the necessary tensile strength, providing a cost-effective and environmentally sustainable solution for soil stabilization and load distribution. HDPE containers and ELTs were chosen as the primary materials for constructing the geocell due to availability and durability. HDPE containers serve as the structural framework of the geocell, while ELTs were used to join the containers together with rivets.

Additionally, the height of geocells significantly influences their performance. As the height increases, the surface area and frictional resistance increase, improving the load-carrying capacity and reducing settlements.

ARPN Journal of Engineering and Applied Sciences

However, beyond an optimum height, the performance either stabilizes or declines due to local buckling and straining of geocell walls. The optimum depth of geocells is always less than twice the width of the footing, and increasing height poses problems related to compaction in the field (Krishna & Latha, 2023).

Figure-1. Materials, Testing, and Prototype of Geocells.

Tensile Strength Results

To assess the accuracy of the results, three (3) specimens of HDPE plastic containers were tested in accordance with ASTM D 638 under similar conditions. Table-1 presents the tensile strength of the three specimens, which have identical dimensions, 50 mm in length, 13 mm in width, and 4 mm in thickness, and a calculated cross-sectional area of 52 mm². The tensile strength values for these specimens are 30.077 MPa, 29.615 MPa, and 32.654 MPa, respectively, with an average tensile strength of 30.782 MPa.

Table-1. Tensile Strength Test Results.

Specimen	Dimension (mm)			Area Sq. mm.	Tensile Strength MPa	Average Tensile Strength	Required Tensile Strength MPa	Remarks
	Length	Width	Thickness					
1	50	13	4	52	30.077			Passed
2	50	13	4	52	29.615	30.782	27.6 - 34.5	Passed
3	50	13	4	52	32.654			Passed

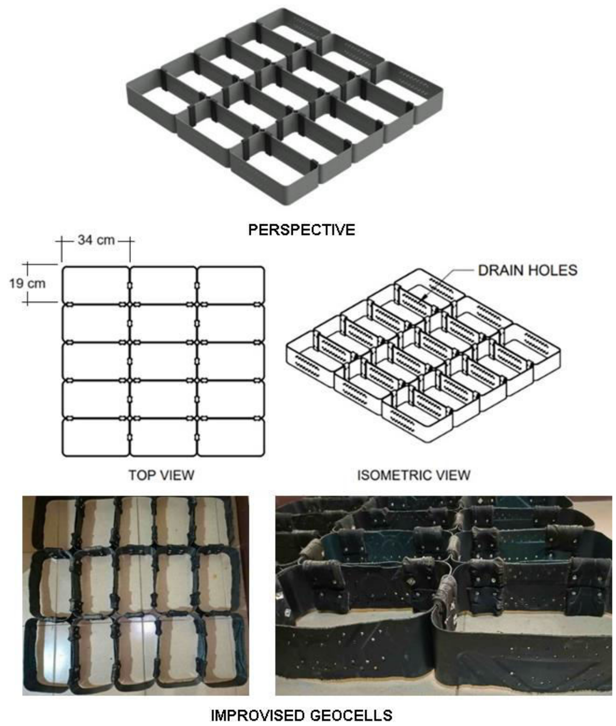

Figure-2. Improvised Geocells using HDPE Container and ELTs.

Each specimen exceeded the required tensile strength range of 27.6 to 34.5 MPa, indicating that the HDPE material used for these geocells is robust and suitable for soil stabilization applications. The successful performance of all specimens highlights the effectiveness of HDPE as a material for constructing geocells, which are designed to provide lateral confinement to infill materials and enhance load distribution. The consistent tensile strength across the specimens suggests good quality control during fabrication, ensuring that the geocells can withstand the mechanical stresses encountered in practical applications such as roadbed reinforcement and slope stabilization. Additionally, the results indicate that these improvised HDPE geocells can effectively resist deformation under load, which is critical for maintaining structural integrity in various environmental conditions. This performance is particularly important as geocells are often subjected to dynamic loads from traffic or natural forces. The ability of HDPE to maintain its tensile strength under different conditions further supports its use in geotechnical applications.

Cost Evaluation

The cost analysis of improvised geocells made from 20-liter HDPE containers, end-of-life tires (ELTs), and rivets reveals a significant economic advantage over traditional geocells, with the former costing Php 350.00 per square meter compared to an average of Php 670.00 per square meter for traditional options. This results in a substantial cost savings of Php 320.00 per square meter, equating to a 47.76% decrease in expenses when utilizing improvised geocells. This economic benefit is complemented by sustainability, as repurposing HDPE containers and ELTs reduces waste and environmental impact. Overall, the use of improvised geocells not only supports significant cost savings but also promotes eco-friendly construction practices, making them an attractive alternative for future infrastructure projects.

CONCLUSIONS

This study successfully demonstrates the feasibility of utilizing repurposed high-density polyethylene (HDPE) containers and end-of-life tires (ELTs) to create cost-effective and environmentally sustainable geocells for soil stabilization. The tensile strength tests confirmed that the improvised geocells meet the required performance standards, with all specimens exceeding the minimum tensile strength range of 27.6 to 34.5 MPa, indicating their robustness and suitability for various geotechnical applications. Additionally, the significant cost savings of approximately 47.76% compared to traditional geocells highlight the economic advantages of this approach, making it a viable option for construction projects, especially in resource-constrained settings.

Based on these findings, it is recommended that further research be conducted to explore the long-term performance and durability of these improvised geocells under varying environmental conditions and load scenarios. Additionally, expanding the scope of materials used in geocell production could enhance their performance and applicability in different construction contexts. Public awareness campaigns should also be initiated to promote the benefits of using recycled materials in construction, thereby encouraging sustainable practices within the industry. Ultimately, this innovative approach not only addresses pressing waste management issues but also contributes to advancing sustainable infrastructure development aligned with global sustainability goals.

ACKNOWLEDGEMENT

The author sincerely thanks all those who provided valuable guidance and support throughout this research. Gratitude is extended to the funding agencies and institutions that made this study possible. Special appreciation goes to family and friends for their encouragement and understanding during the research process.

REFERENCES

Alabi O. A., Ologbonjaye K. I., Awosolu O. and Alalade O. E. 2019. Public and Environmental Health Effects of Plastic Waste Disposal: A Review. J Toxicol Risk Assess 5: 021. doi.org/10.23937/2572- 4061.1510021

Dandin S., Sathe S., Wagale M. and Jomde A. 2024. Utilizing PET bottles for sustainable cellular reinforcement: A study on enhancing fly ash backfill bearing strength with an innovative geocell alternative. Construction and Building Materials, 433, 136641. https://doi.org/10.1016/j.conbuildmat.2024.136641

Deshmukh R., Patil G., Bhatt U., Shingote R. and Patil T. 2022. Use of waste plastic bottles as a geocell for ground improvement: A review. Advances in Geo-Science and Geo-Structures: Select Proceedings of GSGS 2020, 235-243. https://doi.org/10.1007/978-981-16-1993-9_25

Gopinath K. P., Nagarajan V. M., Krishnan A., and Malolan R. 2020. A critical review of the influence of energy, environmental, and economic factors on various processes used to handle and recycle plastic wastes: Development of a comprehensive index. Journal of Cleaner Production, 274, 123031. https://doi.org/10.1016/j.jclepro.2020.123031

Hejazi S. M., Sheikhzadeh M., Abtahi S. M. and Zadhoush A. 2012. A simple review of soil reinforcement by using natural and synthetic fibers. Construction and Building Materials, 30, 100-116. https://doi.org/10.1016/j.conbuildmat.2011.11.045

Krishna A. and Latha G. M. 2023. Evolution of geocells as sustainable support to transportation infrastructure. Sustainability, 15(15): 11773. https://doi.org/10.3390/su151511773

Kibria M. G., Masuk N. I., Safayet R., Nguyen H. Q. and Mourshed M. 2023. Plastic waste: challenges and opportunities to mitigate pollution and effective management. International Journal of Environmental Research, 17(1): 20. https://doi.org/10.1007/s41742-023-00507-z

Lamour M. and Cecchin A. 2021. Repurposed materials in construction: A review of low-processed scrap tires in civil engineering applications for disaster risk reduction. Construction and Building Materials, 293, 123368. https://doi.org/10.1016/j.conbuildmat.2021.123368

Maitlo G., Ali I., Maitlo H. A., Ali S., Unar I. N., Ahmad M. B., Bhutto D. K., Karmani R. K., Naich S. U., Sajjad R. U. and Ali S. 2022. Plastic waste recycling, applications, and prospects for a sustainable environment. Sustainability, 14(18): 11637. https://doi.org/10.3390/su141811637

Meidudga R. E., Faris F., Hardiyatmo H. C. and Diansyah A. A. 2021. Utilization of Plastic Waste Polyethylene (PET) for reinforced subgrade. In E3S Web of Conferences (325: 04004). EDP Sciences. https://doi.org/10.1051/e3sconf/202132504004

Moghaddas Tafreshi S. N., Parvizi Omran M., Rahimi M., and Dawson A. 2021. Experimental investigation of the behavior of soil reinforced with waste plastic bottles under cyclic loads. Transportation Geotechnics. 26, 100455. https://doi.org/10.1016/j.trgeo.2020.100455

Roque A. J., Paleologos E. K., O'Kelly B. C., Tang A. M., Reddy K. R., Vitone C., Mohamed A. O., Koda E., Goli V. S. N. S., Vieira C. S., Fei X., Sollecito F., Vaverková M. D., Plötze M., Petti R., Podlasek A., Puzrin A. M., Cotecchia F., Osiński P., Singh D. N. 2022. Sustainable environmental geotechnics practices for a green economy. Environmental Geotechnics, 9(2): 68-84. https://doi.org/10.1680/jenge.21.00091

Shah A., Modha H. 2020. Improving the soil subgrade with plastic waste reinforcement: an experimental study. In Advances in Sustainable Construction Materials and Geotechnical Engineering: Select Proceedings of TRACE 2018 (pp. 153-161). 35. https://doi.org/10.1007/978-981-13-7480-7_13

Tasalloti A., Chiaro G., Murali A., Banasiak L., Palermo A., Granello G. 2021. Recycling of end-of-life tires (ELTs) for sustainable geotechnical applications: A New Zealand perspective. 11(17): 7824; https://doi.org/10.3390/app11177824

Tiago G. A., Mariquito A., Martins-Dias S. and Marques A. C. 2023. The problem of polyethylene waste–recent attempts for its mitigation. Science of the Total Environment, 892, 164629. https://doi.org/10.1016/j.scitotenv.2023.164629

Vicuña L., Jaramillo-Fierro X., Cuenca P. E., Godoy-Paucar B., Inga-Lafebre J. D., Chávez Torres J. L., García J. F., Guaya D. and Febres J. D. 2024. Evaluation of the Effectiveness of Geogrids Manufactured from Recycled Plastics for Slope Stabilization-A Case Study. Polymers, 16, 1151. https:// doi.org/10.3390/polym16081151

Vuppaladadiyam S. S. V., Vuppaladadiyam A. K., Sahoo A., Urgunde A., Murugavelh S., Šrámek V., Pohořelý M., Trakal L., Bhattacharya S., Sarmah A. K., Shah K. and Pant K. K. 2023. Energy waste: Trending key challenges and current technologies in waste plastic management. Science of the Total Environment, 913, 169436. https://doi.org/10.1016/j.scitotenv.2023.169436

Yadav J. S., Tiwari S. K. 2019. The impact of end-of-life tires on the mechanical properties of fine-grained soil: A Review. Environ Dev Sustain 21, 485-568. https://doi.org/10.1007/s10668-017-0054-2