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# Weaving Sustainability: Women-Crafted Natural Fiber Geocells Replacing Plastic

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Modern infrastructure demands solutions that are not only technically effective but also environmentally conscious and socially inclusive in nature. Among the various geoengineering tools, geocells are widely used for slope stabilization, erosion control, road reinforcement, and ground improvement. Conventionally, these cellular confinement systems are made from High-Density Polyethylene (HDPE), a petroleum-based plastic. Although functionally successful, HDPE geocells contribute to plastic dependency, waste accumulation, and carbon footprints.

In parallel, millions of women in rural communities remain underemployed despite possessing strong traditional weaving and fibre-crafting skills. Government initiatives such as the National Rural Livelihood Mission (NRLM) / Deendayal Antyodaya Yojana, the NABARD SHG–Bank Linkage Programme, and DAY-NULM for urban women, along with various state-level women livelihood missions, provide financial assistance, training, credit access, and institutional backing. This ecosystem creates excellent opportunities for women's SHGs to contribute to sustainable engineering innovations. Bridging these national strengths with environmental needs opens an inspiring pathway: replacing plastic-based HDPE geocells with women-crafted natural fiber geocells, promoting sustainability while generating meaningful livelihoods.

To understand the problem, we first need to understand the working of geocells. These are honeycomb-like structures used in geotechnical engineering to stabilize and reinforce the soil. They work by creating a cellular confinement system that locks infill materials, such as soil, sand, or aggregates, in place, greatly enhancing the load-bearing capacity and shear strength of the soil beneath. There are many forces acting on the geocells, like vertical loads, lateral stresses, interface shear stress, passive resistance, and, of course, the tensile forces in cell walls. Here, the hoop stress mechanism plays a major role, as it contributes to the stability and load-bearing capacity of the soil within the cells. The effect of material stiffness also plays a major role in providing confinement; geocells made from

materials with a higher elastic modulus better resist lateral deformation when they are loaded. This maintains the confinement of the soil within the cells, more efficient load distribution, and higher apparent cohesion and stiffness. However, for high-quality polymers such as HDPE, the tensile forces produced by the hoop stress during typical use remain well within the elastic limits of the material. This implies that they do not undergo significant permanent deformation or creep, ensuring long-term confinement.

Natural geocells offer an environmentally friendly, sustainable, and economical option compared to synthetic polymer geocells like HDPE for reinforcing and stabilizing soil. These geocells are usually made from natural fiber mats or leaf sheaths, making them particularly suitable in areas where such materials are plentiful, such as in South Asia. Researchers have developed geocell networks utilizing various natural materials including coir, jute, sisal, and areca leaf sheaths. Coir, with its high lignin content, offers durability and effective soil friction. Jute, sourced from waste, enhances the bearing capacity of sand and clay. Sisal demonstrates superior tensile strength, while areca leaf sheaths can be woven into cells that are significantly stronger than HDPE, although less ductile. While these natural geocells are biodegradable, their lifespan varies: areca sheaths last about a year, coir over two years. To improve their durability, treatments with chemicals such as copper, chromium, arsenic or bitumen are employed. Natural geocells enhance soil performance by confining material and distributing stress, increasing the bearing capacity of soft soils by three to four times. They also show a gradual failure pattern compared to synthetic materials like HDPE, which can fail abruptly under pressure. In wet conditions, coir geocells perform comparably to HDPE by resisting pore-water pressure. The strategic applications of natural geocells include slope stabilization, where they provide temporary support to allow vegetation to establish, and in pavements, particularly with jute infill, extending the lifespan of rural roads.

Empowering women through Self Help Groups (SHGs) offers a transformative approach to developing natural fiber-based geocells in India. Engaging rural and semi-urban women, who are involved in fiber activities like weaving and mat crafting, can create a sustainable livelihood linked to eco-engineering technology. This initiative fosters regular income generation, financial independence, and enhanced socio-economic security for women, which strengthens their roles in family and community decision-making, thus reducing migration pressures. Moreover, the model enhances women's entrepreneurial skills. With the right training and institutional support, SHGs can evolve into structured micro-enterprises, contributing to formal supply chains and allowing women to transition from informal labor to skilled production and entrepreneurship. This empowerment not only boosts their confidence but also promotes local economic growth through decentralized manufacturing ecosystems. Utilizing locally sourced raw materials and reducing transportation costs, it aligns with circular economy principles while mitigating reliance on plastic production.

We can conclude that natural fiber-based geocells represent a promising step toward sustainable and

socially inclusive geoengineering. While challenges related to durability, standardization, large-scale field validation, eco-friendly coating development, and institutional support must still be addressed, the collaborative involvement of universities, research organizations, NGOs, industry, and government agencies can help transform this concept into practical reality. Beyond reducing dependence on plastic-based HDPE systems, this innovation creates meaningful livelihood opportunities for women-led Self Help Groups, linking environmental stewardship with social empowerment. By weaving natural fibers, women are quite literally weaving sustainability, resilience, and dignity into the future of modern infrastructure.