Optimizing Solar Energy-Based Sand Refinement for Enhanced Concrete Performance

Carlos Jerard O. Dela Cruz

Mapúa University, Manila, Philippines

Glenn V. Magwili

Mapúa University, Manila, Philippines

Abstract:

The accelerating depletion of construction-grade sand due to global infrastructure growth has intensified the search for sustainable alternatives in concrete production. This study presents a solar-powered refinement system that transforms abundant yet unsuitable fine desert sand into a functional concrete aggregate. The prototype employs a 52 cm Fresnel lens to concentrate solar energy for thermal sintering, combined with an Arduino-controlled dual-axis sun-tracking mechanism and adaptive sand bed regulation. Light-dependent resistors (LDRs) guide lens positioning, while a pyranometer continuously monitors solar irradiance. Concentrated heat from the lens alters the sand's morphology, producing coarser, more angular grains comparable to ISO standard sand. Mechanical analysis compared the refined sand against untreated and ISO benchmark samples. Concrete cylinders were fabricated using four aggregate types: ISO standard (control), untreated fine sand, solar-refined sand, and a 50/50 ISO-refined blend, and were tested for compressive strength following ASTM C39 after 21 days of curing. The concrete incorporating refined sand achieved an average compressive strength of 22.85 MPa, surpassing untreated sand at 21.5 MPa and nearly equaling the ISO standard at 23.45 MPa. The blended mix reached 22.33 MPa, demonstrating suitability for partial replacement. One-way ANOVA revealed significant performance variations ($p < 0.1$). These results confirm that solar-based refinement is a practical and eco-friendly method for improving the properties of fine desert sand, making it a sustainable substitute for conventional construction-grade aggregates.

Keywords:

Solar concentrator, sintering, concrete sand, sustainable construction.