Sustainable Recycling of End-of-Life Solar Panels: Utilizing Recovered Glass in Concrete for Sand Reduction and Waste Minimization

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The alarming rise in solar photovoltaic (PV) waste, particularly non-biodegradable glass, poses a growing environmental concern, with global waste projected to reach 78 million metric tons by 2050. This research supports waste management by recovering glass from end-of-life solar panels and using it as a partial sand replacement in concrete, reducing carbon emissions and dependence on natural sand. RSP glass was incorporated at 10%, 20%, and 30% by weight as a partial replacement for natural sand in concrete, using three methods: Direct mixing, Surface spraying at 4000, 8000, and 12000 g/m², Combination method (partially mixed and sprayed). Ten concrete mixes, including an ASTM control, were tested using 60 samples. ASTM-standard tests evaluated compressive strength, density, slip resistance, surface reflectivity, chemical durability. The optimal performance was achieved through surface spraying at 4000 g/m² (10% equivalent), with compressive strength of 25.0 ± 0.5 kg/cm² ($p = 2.23\times10?5$), density of 2.43 kg/cm³ ($p = 0.003$), and slip resistance of 102 ± 1.3 BPN ($p = 0.049$). All treated samples showed reduced reflectivity, and sulfate and chloride levels remained within ASTM limits. Higher spray rates caused a slight performance decline, confirming 4000 g/m² as optimal. In parallel, environmental benefits were evident: CO2 emissions decreased by 0.96 kg/ton concrete, 7200 kg of waste glass (480 solar panels) were diverted per 1000 m² of pavement, as calculated from the mix design and material balance. These results demonstrate the structural, environmental, waste management benefits of RSP glass, along with significant natural sand reduction. Future work should assess long-term durability, cost-effectiveness, and lifecycle impacts within circular economy frameworks.

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