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Editorial Article

Advances in Sustainable Materials and Structural Hydraulic Performance for Resilient Infrastructure Systems

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Summary

This issue of Smart and Green Materials Journal brings together a diverse yet coherent collection of studies that collectively advance sustainable materials and structural hydraulic performance for resilient infrastructure systems. The contributions span material innovation, performance optimization, and experimental validation across concrete technology, pavement engineering, masonry materials, timber structures, and open-channel hydraulics. Several articles address the sustainability and performance of cement-based systems through improved curing strategies, internal curing using super-absorbent polymers, optimized sand grading, and the incorporation of natural fibers as eco-friendly reinforcements. Complementing these efforts, the mechanical characterization of indigenous timber species and the reuse of reclaimed asphalt pavement as recycled aggregates highlight the role of locally sourced and recycled materials in reducing environmental burdens while maintaining structural reliability. Extending beyond material behavior, this issue also includes an experimental investigation into hydraulic jumps over rough and sloped beds, emphasizing the importance of boundary conditions in energy dissipation and flow stability. Together, these studies demonstrate how sustainable material choices and performance-oriented design can be synergistically applied to develop infrastructure systems that are both environmentally responsible and resilient to increasing operational demands.

Nagabe et al. [1] investigate how curing practices govern the strength development of pozzolanic concrete, emphasizing that sustainable binders demand equally appropriate curing strategies. Recognizing that pozzolanic materials often exhibit delayed hydration compared to ordinary Portland cement, the study evaluates whether conventional and chemical curing methods can adequately support strength gain. Five pozzolanic concretes incorporating agricultural and industrial by-products groundnut shell ash, coal bottom ash, locust bean pod ash, wood ash, and metakaolin were subjected to four curing regimes: ponding, sprinkling, impermeable membrane covering, and chemical curing. Compressive strength was monitored at early and later ages up to 28 days. The results reveal that while early-age strength differences are minimal, curing method becomes increasingly influential with time. Chemical curing consistently delivers superior strength performance, attributed to its enhanced moisture retention and sustained hydration. Ponding and membrane curing provide moderate effectiveness, whereas sprinkling proves least efficient. Across all mixtures, prolonged curing significantly improves strength, underscoring the sensitivity of pozzolanic systems to curing continuity. Overall, the study reinforces curing as a decisive factor in unlocking the performance potential of pozzolanic concrete. By demonstrating the clear advantage of chemical curing, Nagabe et al. [1] provide practical insight for aligning curing practices with sustainable concrete design, ensuring that environmental benefits are achieved without compromising structural performance.

Karim [2] investigates the role of internal curing using super-absorbent polymers (SAPs) in addressing the practical limitations of conventional curing, particularly in hard-to-access structural elements. By shifting the focus from external moisture supply to internally stored water, the study explores how SAPs influence surface hardness and internal integrity in normal-strength concrete. Concrete mixtures incorporating varying SAP contents were evaluated using surface hardness measurements, compressive strength tests, density assessment, and ultrasonic pulse velocity (UPV). The findings reveal that a small dosage of SAP can be beneficial: surface hardness improves by up to 19% at an optimal SAP content, while compressive strength also shows a measurable increase due to sustained internal hydration. These results highlight the effectiveness of SAPs in maintaining moisture availability beyond the early curing stage. However, the study also underscores an inherent trade-off. The swelling and subsequent void formation associated with SAP particles reduce concrete density and lower UPV readings, reflecting increased internal discontinuities. This dual effect emphasizes that while internal curing enhances hydration and mechanical performance, it simultaneously alters the concrete microstructure. In summary, the work provides a balanced assessment of SAP-based internal curing, demonstrating its potential as a practical and safer alternative to traditional curing in complex construction scenarios. By clarifying both the benefits and limitations of SAP incorporation, Karim [2] offers valuable insight for optimizing internal curing strategies to improve performance without compromising structural reliability.

Shkura et al. [3] present a comprehensive review on the use of natural fibers as sustainable reinforcements to address the inherent brittleness and low tensile capacity of conventional concrete. Drawing from a wide range of experimental studies, the review synthesizes how different types of natural fibers such as sisal, jute, coir, hemp, banana, and sugarcane influence both fresh and mechanical properties of concrete across varying fiber contents and curing ages. The analysis highlights a clear and recurring trade-off. In fresh concrete, workability consistently decreases as fiber content increases, largely due to the high-water absorption capacity and slender geometry of natural fibers. In hardened concrete, compressive strength is shown to be highly sensitive to fiber length and dosage: moderate fiber additions can enhance strength by controlling microcracking, while excessive fiber content leads to higher void ratios and strength reduction. In contrast, flexural and tensile strengths benefit more markedly from fiber incorporation, particularly for fibers with high elongation capacity. Notably, jute and henequen fibers demonstrate exceptional improvements in tensile strength, with reported increases exceeding 100% at optimal fiber contents. By systematically normalizing and comparing results from prior studies, the review identifies general trends and optimum fiber ranges rather than isolated outcomes. The findings emphasize that the effectiveness of natural fibers is governed not only by fiber type, but also by dosage, length, and interaction with mix design parameters. In general, the work positions natural fiber–reinforced concrete as a promising pathway toward greener and more ductile construction materials. Shkura et al. [3] underscore that achieving performance gains requires careful optimization, ensuring that sustainability benefits are realized without compromising workability or compressive capacity.

Kehinde [4] presents a comparative investigation into the mechanical performance of selected indigenous timber species from Southwestern Nigeria, addressing a critical gap in empirical data that has long limited their acceptance in structural applications. As sustainable construction increasingly favors renewable and locally sourced materials, the study evaluates whether commonly used but under-documented timbers can meet structural performance requirements. Four hardwood species such as Anogeissus leiocarpus (Ayin), Albizia ferruginea (Alakrity), Pterocarpus erinaceus (Ayere), and Ricinodendron heudelotii (Eru) were tested under standardized laboratory conditions to determine their Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) in both wet and oven-dried states. The results demonstrate clear performance differentiation among the species, with moisture content playing a decisive role in strength and stiffness development. Ayin consistently exhibits the highest MOR and MOE values, particularly in the oven-dried condition, positioning it as the most suitable candidate for load-bearing structural elements such as beams and joists. Alakrity follows with moderate yet reliable mechanical performance, while Eru and Ayere display comparatively lower strength and stiffness, suggesting their use may be better suited to secondary or non-critical applications. Across all species, oven-dried samples outperform wet specimens, reaffirming the importance of moisture control in timber utilization. Collectively, the study provides much-needed comparative benchmarks for indigenous Nigerian timbers and reinforces the potential of underutilized local species in structural engineering. By grounding material selection in standardized mechanical evidence, Kehinde's work [4] supports more sustainable, cost-effective, and regionally appropriate construction practices while reducing reliance on imported timber resources.

Bolaji and Oyedepo [5] examine the feasibility of reclaimed asphalt pavement (RAP) as recycled aggregates for green road construction, addressing growing concerns over natural aggregate depletion, greenhouse gas emissions, and construction waste. Rather than focusing on RAP as a binder-rich material, the study strategically isolates and evaluates the performance of extracted RAP aggregates as direct replacements for virgin aggregates. Using a centrifuge extraction process, the authors achieve complete recovery of aggregates, revealing that RAP consists of approximately 93.5% aggregates and only 6.5% aged binder. Detailed characterization shows that the recovered aggregates possess favorable gradation, low aggregate impact and crushing values, and reduced water absorption attributes that are comparable, and in some aspects superior, to conventional natural aggregates. The retained and absorbed aged bitumen is shown to enhance durability by limiting moisture ingress and chemical weathering. When incorporated into asphalt mixtures using the Marshall design method, RAP aggregates demonstrate satisfactory volumetric and mechanical performance. A peak Marshall stability of 31.91 kN at an optimum bitumen content of 5.3% confirms that mixtures can achieve a balanced resistance to rutting and cracking under traffic and temperature variations. Importantly, the presence of absorbed binder in RAP aggregates reduces the demand for fresh bitumen, offering additional environmental and economic benefits. In essence, the study positions extracted RAP aggregates as a viable and sustainable alternative for asphalt pavement construction, even at high replacement levels without reliance on rejuvenators. By shifting attention from binder recovery to aggregate reuse, Bolaji and Oyedepo [5] provide practical evidence supporting circular economy principles and the development of greener, resource-efficient road infrastructure.

Bhuiyan et al. [6] investigate how sand type and fineness modulus govern the compressive strength development of cement mortar, addressing a practical yet often underestimated aspect of masonry construction. Using locally sourced sands from Bangladesh, the study systematically compares Sylhet, Domar, and Local sands to clarify how gradation and material quality influence mortar performance. The experimental program evaluates mortar cubes prepared with two common cement-to-sand ratios (1:4 and 1:6) and cured for up to 28 days. Sieve analysis reveals distinct fineness characteristics, with Sylhet sand exhibiting the most favorable grading (FM = 2.53), followed by Domar sand (FM = 2.29), while Local sand shows excessive fines and impurities (FM = 1.72). These differences are directly reflected in compressive strength outcomes. Sylhet sand consistently delivers the highest strength at all curing ages, reaching about 32 MPa and 29.6 MPa at 28 days for the 1:4 and 1:6 mixes, respectively. Domar sand shows intermediate performance, whereas Local sand produces substantially lower strengths due to poor gradation and reduced paste–aggregate bonding. Beyond single-sand mixtures, the study demonstrates that blending sands can yield synergistic effects. In particular, the Sylhet–Domar combination enhances particle packing and achieves higher strength than either sand used alone. Across all mixes, strength gain between 7 and 28 days is pronounced, underscoring the critical role of adequate curing in mortar performance. From a holistic perspective, the work reinforces that sand selection and grading are decisive factors in achieving reliable and durable mortar. By providing quantitative benchmarks for local materials and highlighting the benefits of sand blending,

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Bhuiyan et al. [6] offer practical guidance for optimizing mortar design while supporting more sustainable and resource-efficient construction practices.

Ridoy and Mahi [7] present an experimental investigation into the coupled effects of channel slope and bed roughness on hydraulic jump behavior, addressing a critical gap in open-channel hydraulics where these parameters are often examined in isolation. Focusing on high-Froude-number flows ($Fr_1 \approx$ 5–10), the study provides new empirical insight into how boundary conditions govern sequent depth and energy dissipation. Experiments were conducted in a laboratory flume with adjustable positive and adverse slopes (±1° to ±2.5°) and two contrasting bed conditions: smooth and hydraulically rough beds formed using angular stone chips. Measurements of upstream and downstream flow depths, discharge, and energy loss reveal a pronounced asymmetry in hydraulic jump response. Positive slopes, where gravity assists the flow, consistently increase the sequent depth ratio (y_2/y_1) while reducing energy dissipation—an effect that is most evident on smooth beds. In contrast, adverse slopes dramatically reduce downstream depth and intensify energy dissipation, particularly when combined with rough beds that amplify turbulence and flow resistance. The results demonstrate that smooth beds favor depth recovery and continuity of subcritical flow, whereas rough beds function as effective energy dissipators. Notably, the combination of roughness and adverse slope yields the highest energy losses, highlighting its suitability for stilling basins, spillway aprons, and erosion control structures. Conversely, smooth positive slopes are shown to be advantageous in channels where maintaining downstream depth is a design priority. On the whole, the study advances the understanding of slope roughness interactions in hydraulic jumps and offers practical design guidance for tailoring channel configurations to either conserve flow depth or maximize energy dissipation. By providing experimentally validated trends, Ridoy and Mahi [7] contribute valuable evidence for more reliable and efficient hydraulic engineering practice.

Taken together, the collective contributions in this second volume aim to strengthen the understanding and engagement of both researchers and practitioners by providing integrated insights into sustainable materials, structural performance, and hydraulic behavior, thereby supporting the development of resilient and environmentally responsible construction applications.

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Conflicts of Interest

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Author Contributions

Ramadhansyah Putra Jaya: writing, reviewing and editing. **Reza Pahlevi Munirwan:** writing, reviewing and editing. **Bunyamin Bunyamin:** writing, reviewing and editing.

Declaration of Generative Ai and Ai-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT to enhance the clarity of the writing. After using the ChatGPT, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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