Review

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Review

Effect of Agricultural Waste Ash Stabilizers on the Moisture Durability of Earth Blocks for Low-Cost Housing in Tropical Regions

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Abstract

Earth blocks are attractive for low-cost housing because they use local soil, require less firing energy, and can provide good thermal mass, but their adoption in humid tropical regions is limited by moisture sensitivity. This review examines how agricultural waste ash stabilizers, with emphasis on palm kernel shell ash and related pozzolanic residues, influence moisture durability, dry/wet compressive strength behavior, and practical suitability of earth blocks for affordable housing. The paper synthesizes evidence from compressed earth block literature, pozzolanic material standards, and studies on ash-modified earthen masonry. It argues that wet-to-dry strength retention is a more realistic durability indicator than dry compressive strength alone because low-cost walls are exposed to wind-driven rain, capillary rise, damp surfaces, and imperfect maintenance. The review shows that ash stabilizers can improve particle bonding and pore refinement when properly processed, proportioned, compacted, and cured, but excessive ash, poor soil selection, or inadequate detailing can increase water absorption and reduce field reliability. The paper proposes a moisture-durability framework connecting material chemistry, block production, wall detailing, and tropical housing performance. It concludes that agricultural waste ash stabilized earth blocks are promising only when laboratory strength gains are tied to water-resistance testing and moisture-conscious architectural detailing.

Keywords: agricultural waste ash; palm kernel shell ash; compressed earth blocks; moisture durability; low-cost housing; tropical climate; wet compressive strength; sustainable construction

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1. Introduction

The construction sector is under pressure to reduce material cost, reduce carbon emissions, and respond to housing shortages without producing buildings that fail quickly in service. In many tropical countries, the issue is not simply the availability of walling materials; it is the availability of materials that can remain affordable while resisting rain, humidity, surface wetting, and rising damp. Earth-based construction sits directly inside this problem. Soil is local, familiar, and thermally useful, but unstabilized earth is vulnerable when exposed to water. For that reason, the discussion has shifted from whether earth can be used as a building material to how it can be engineered, detailed, tested, and maintained under real climatic exposure.

This paper takes its starting point from the experimental concern raised by comparative dry and wet compressive strength testing of cement-palm kernel shell ash stabilized earth blocks. A closely related benchmark study reported that the wet and dry compressive strengths of cement-PKSA stabilized earth blocks moved together positively, while also showing that moisture exposure reduced measured strength when compared with dry conditions [1]. That single observation is important because the most convincing earth-block material is not necessarily the one with the highest dry strength in a laboratory; it is the one that keeps enough of its strength when moisture is present.

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Sustainable construction research has repeatedly shown that material selection is one of the key areas through which the built environment can reduce its environmental load [2]. In low-income housing, however, sustainability cannot be reduced to environmental language alone. A material may be low-carbon, yet useless to a household if it erodes, stains, cracks, or absorbs water excessively after two rainy seasons. Therefore, any meaningful study of agricultural waste ash stabilized earth blocks must combine three questions: Does the stabilizer improve mechanical performance? Does it improve moisture durability? And can the improved block be translated into affordable wall construction without unrealistic workmanship demands?

Compressed stabilized earth blocks have been studied as alternatives to fired clay bricks and conventional concrete masonry because they can be produced with lower energy input, local soils, modest cement content, and simple presses [3]. Their performance, however, depends heavily on soil grading, clay content, stabilizer type, compaction pressure, curing regime, and water management during production and use. Earth construction manuals also stress that the material is not a magic solution; it requires correct design, protection from water, and technical discipline at block and wall levels [4,5].

Agricultural waste ash stabilizers respond to two practical problems at once. First, they reuse residues that are often burned, dumped, or left unmanaged. Second, they can partially replace cement or support cement action through pozzolanic reactions when they contain adequate reactive silica and alumina. In tropical regions with palm oil, rice, sugarcane, and other agro-industries, ash residues are locally available. This gives them potential value for community-level housing materials, provided that their chemical composition, burning conditions, fineness, and dosage are controlled.

The focus of this review is therefore not a general celebration of waste materials. The focus is the moisture durability of earth blocks stabilized with agricultural waste ash. The paper argues that dry compressive strength is only one part of the performance story. A block that performs well when oven-dry or air-dry may still fail in housing if it absorbs water, loses cohesion, swells, softens, or erodes under repeated wetting. For tropical low-cost housing, wet compressive strength, water absorption, capillary uptake, erosion resistance, drying behavior, and wall detailing must be treated as a single performance family.

2. Research Aim, Scope and Methodological Approach

2.1. Aim and Objectives

The aim of this review is to examine the effect of agricultural waste ash stabilizers on the moisture durability of earth blocks and to develop a practical interpretation framework for their use in low-cost housing in tropical regions.

The specific objectives are to:

- identify the moisture-related weaknesses that limit the use of earth blocks in tropical low-cost housing;
- explain how agricultural waste ash stabilizers can influence dry strength, wet strength, water absorption, and erosion resistance;
- compare palm kernel shell ash with other ash-based stabilizers in terms of likely contribution to moisture durability;
- connect laboratory indicators such as wet/dry compressive strength ratio to architectural detailing and wall performance;
- propose a field-oriented checklist for specifying and using ash-stabilized earth blocks in moisture-prone tropical environments.

2.2. Review Method

The manuscript was prepared as a focused narrative review rather than a fresh laboratory experiment. The reviewed evidence was organized around five themes: sustainable construction and low-carbon materials, compressed stabilized earth block technology, pozzolanic behavior of

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agricultural ashes, moisture-related durability indicators, and design implications for low-cost housing. Priority was given to peer-reviewed journal papers, standards, technical manuals, and earth-construction texts that directly address compressed earth blocks, wet strength, water absorption, erosion resistance, cement replacement, and tropical material performance.

The method deliberately treats moisture durability as a bridge between material science and architectural construction. This is necessary because a block can satisfy a laboratory strength target but still perform poorly if used without damp-proofing, adequate plinth height, roof overhangs, breathable finishes, and drainage. The synthesis therefore reads compressive strength results alongside production variables and wall-level detailing requirements.

Table 1. Review synthesis frame used in the manuscript.

Theme	Question asked	Evidence considered	Reason for inclusion
Material sustainability	Can earth blocks and ash stabilizers reduce environmental burden?	Systematic sustainability reviews, embodied energy studies, CSEB reviews	Connects low-cost housing to resource efficiency rather than only affordability.
Ash chemistry	Can the ash behave as a useful stabilizing or supplementary cementitious material?	Pozzolanic standards, PKSA and other agro-waste ash studies	Explains why ash content, fineness and burning conditions matter.
Moisture durability	How does water exposure reduce or preserve block performance?	Wet compressive strength, water absorption, capillary and erosion tests	Moves the review beyond dry strength alone.
Production control	Which production variables most affect repeatability?	Soil selection, water content, compaction pressure, curing and storage data	Shows why field production can fail even when the idea is technically sound.
Housing application	What must designers and builders do for tropical walls?	Earth construction manuals and design guidance	Links material tests with plinths, roof overhangs, finishes and maintenance.

3. Earth Blocks, Moisture and the Tropical Housing Problem

Earth blocks are often introduced as environmentally responsible materials because they can be made from local soil and require no firing. This advantage is real, but it can hide a serious limitation: earth is a moisture-sensitive material. Clay minerals give the block cohesion and workability, yet they also respond to water. Once water enters the pore network, suction changes, particle bonds weaken, swelling may occur, and surface particles can be detached by erosion. Stabilization is therefore not optional for many tropical applications. It is the technical bridge between the ecological promise of earth and the safety expectations of masonry construction.

The tropical housing context intensifies this challenge. Buildings may face long rainy seasons, high relative humidity, poor site drainage, splash-back from unpaved ground, leaking gutters, and inconsistent maintenance. Low-cost housing also tends to use simplified construction details. The wall may be built close to grade level, plastering may be thin or poorly cured, and roof overhangs may be short because of budget pressure. These conditions mean that a block selected only because it has acceptable dry compressive strength may be a risky choice.

The more useful measure is moisture durability. In this paper, moisture durability means the ability of an earth block or wall to retain enough strength, shape, surface integrity, and serviceability after exposure to water. It is not a single test result. It is a performance relationship among wet compressive strength, dry compressive strength, water absorption, capillary rise, erosion resistance, shrinkage, cracking, and drying. A durable earth block is not one that never absorbs water; it is one that manages moisture without losing unacceptable strength or disintegrating.

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Table 2. Moisture exposure routes and their relevance to tropical low-cost housing.

Exposure route	Typical source	Likely material effect	Architectural or construction response
Capillary rise	Ground moisture, missing damp-proof course, wet soil around foundation	Progressive saturation at wall base, salt movement, softening of low courses	Raised plinth, damp-proof course, drainage apron, stabilized base courses.
Wind-driven rain	Rainfall striking external wall surfaces	Surface erosion, staining, local softening, repeated wet-dry cycles	Roof overhangs, protective render, correct orientation, splash control.
Splash-back	Rainwater hitting bare ground or concrete apron and bouncing onto wall	Lower wall erosion and damp marks	Plinth height, gravel strip, paved drain channel, washable render at base.
Internal humidity	Cooking, crowding, poor ventilation	Slow drying, mold risk, elevated equilibrium moisture content	Cross ventilation, breathable finishes, moisture-tolerant internal plaster.
Leaks and service failure	Broken gutters, leaking pipes, damaged roof edges	Localized saturation and block decay	Maintainable roof drainage, inspection access, replaceable finishes.

4. Mechanisms by Which Agricultural Waste Ash Stabilizers Improve Earth Blocks

Agricultural waste ash can improve earth blocks through physical filling, chemical reaction, and cement economy. The physical effect occurs when fine ash particles fill voids between soil grains and reduce pore connectivity. The chemical effect occurs when reactive silica and alumina in the ash react with calcium hydroxide from cement hydration to form cementitious products. The cement-economy effect occurs when a portion of cement can be replaced or supported by ash without losing the required performance. These mechanisms are beneficial only when the ash is properly processed. Poorly burned ash can contain unburnt carbon, soluble salts, or coarse particles that increase water demand and weaken the matrix.

The general pozzolanic logic is widely used in cementitious materials. A material with sufficient silica, alumina, and iron oxide can react in the presence of calcium hydroxide and water, although its reactivity depends on mineral form, fineness, temperature history, and curing environment [6]. In earth blocks, this reaction is more complicated than in concrete because the soil matrix contains clay, silt, sand and sometimes gravel, each affecting packing, water demand, and inter-particle bonding.

Palm kernel shell ash is particularly relevant in West African contexts because palm oil processing produces shells in large quantities. When combusted under suitable conditions and ground or sieved to fine particles, the ash may contain enough silica-rich material to assist cement stabilization. Rice husk ash, sugarcane bagasse ash, fly ash, and clay pozzolana have also been examined as stabilizers or partial binder replacements in earthen or masonry materials [7–10]. The shared point is not that every ash performs equally, but that local waste streams can become construction resources when they are treated as engineered materials instead of casual additives.

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Table 3. Comparative interpretation of selected ash-based stabilizers for moisture-durable earth blocks.

Stabilizer	Main source	Probable contribution	Moisture-related risk if poorly controlled	Best use condition
Palm kernel shell ash (PKSA)	Palm oil processing residue	Pozzolanic reaction, cement support, improved bonding and possible pore refinement	Uncontrolled burning, high carbon, coarse ash and excessive replacement may increase absorption or reduce strength	Regions with palm processing, controlled combustion and fine sieving.
Rice husk ash (RHA)	Rice milling residue	High silica potential, filler effect and supplementary cementitious behavior	Crystalline or under-burnt ash can reduce reactivity and increase water demand	Areas with rice milling and capacity for controlled burning/grinding.
Sugarcane bagasse ash (SCBA)	Sugar industry residue	Potential strength gain through pozzolanic action and particle filling	Variable chemical content and porous particles may increase absorption	Best where ash quality is tested and cement content is not reduced blindly.
Fly ash (FA)	Coal combustion residue	Improved workability, delayed pozzolanic reaction, possible durability gains	Availability and chemical class vary; some sources may raise environmental concerns	Suitable where industrial quality control and safety screening are available.
Clay pozzolana	Calcined clay or natural pozzolanic deposits	Cementitious reaction, improved erosion resistance and strength	Requires calcination quality control and may not always reduce cost	Good where local clay resources and firing control exist.

5. Wet/Dry Compressive Strength Ratio as a Durability Indicator

Compressive strength is the most common performance language for masonry units, but earth blocks require a more careful reading. Dry compressive strength tells us what the block can carry when moisture is not a major active factor. Wet compressive strength tells us what remains after moisture has entered the matrix. The ratio between the two can be read as a strength-retention indicator. A high dry strength with a poor wet strength may be less desirable than a moderate dry strength with strong wet retention, especially for housing exposed to rain and humidity.

Testing methods influence the results. Compressed earth block strength is affected by specimen geometry, platen contact, moisture content at testing, loading rate, and density [11]. This means that comparing results across studies requires caution. Nevertheless, the wet/dry relationship is still useful because it asks a field-relevant question: how much strength does the block lose when water is present? For tropical low-cost housing, this question is more realistic than simply reporting maximum dry strength.

A durability-oriented reading should classify blocks according to both absolute strength and moisture sensitivity. The first requirement is that the block must meet the minimum strength expected for the intended wall type. The second requirement is that the block must not suffer excessive strength reduction when wet. The third requirement is that the block surface must resist erosion and capillary deterioration. In practice, these three requirements should be tested together because a block may pass compression but still erode under repeated rain impact.

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Table 4. Interpretation matrix for dry strength, wet strength and moisture durability.

Observed performance pattern	Meaning	Likely housing implication	Recommended action
High dry strength, high wet strength	Strong bonding and good moisture strength retention	Promising for structural or semi-structural low-rise walls if erosion is controlled	Proceed with water absorption, erosion and wall-detail verification.
High dry strength, low wet strength	Material performs well only in dry state	Risky in tropical walls exposed to dampness or rain	Revise stabilizer dosage, curing, soil grading or wall protection.
Moderate dry strength, moderate wet strength	Balanced but may be limited to non-load-bearing or protected walls	Usable when design loads are low and detailing is strong	Use in protected walls, partitions or single-storey housing after code check.
Low dry strength, low wet strength	Insufficient block cohesion and poor moisture resistance	Unsuitable for durable housing	Reject mix or redesign soil-stabilizer system.
Acceptable strength but high water absorption	Compression result hides capillary or pore-structure weakness	Long-term dampness, staining and erosion likely	Improve particle grading, compaction, curing and surface protection.

6. Production Variables That Control Moisture Durability

6.1. Soil Selection and Particle Packing

The soil is the largest component of an earth block, so stabilization cannot rescue every poor soil. A suitable soil should have enough clay to bind particles, enough sand or gravel to limit shrinkage, and a grading curve that permits dense packing. Too much clay can increase shrinkage, water sensitivity, and cracking. Too little clay can reduce cohesion. A well-graded soil reduces voids and helps the ash and cement act as binders rather than fillers lost inside a loose matrix. Practical projects should therefore begin with soil identification, sedimentation or sieve tests, Atterberg limits, trial blocks, and local weather exposure checks before finalizing a mix.

6.2. Ash Processing and Fineness

Agricultural ash is not automatically pozzolanic. The same waste source can produce useful ash or weak filler depending on combustion temperature, burning duration, contamination, and grinding. Unburnt carbon may absorb water and interfere with bonding. Coarse ash may act as inert particles rather than reactive material. Excessive soluble salts may cause efflorescence or long-term durability issues. For PKSA and similar ashes, field production should include drying, controlled burning where possible, sieving, storage away from moisture, and simple quality checks. This is especially important in low-cost housing, where inconsistent batches can silently produce weak walls.

6.3. Stabilizer Dosage and Cement Reduction

The temptation in low-cost housing is to replace as much cement as possible. This is dangerous. Agricultural ash should not be treated only as a cheap substitute; it should be treated as a performance modifier. Small to moderate cement replacement may support durability if pozzolanic reaction and particle packing are favorable. Excessive ash content can dilute cementitious bonding, increase water demand, reduce density, and create a block that is cheaper at purchase but costlier over its service life. The correct dosage is therefore not the highest ash percentage; it is the dosage that gives the best wet strength retention, acceptable water absorption, and stable curing behavior.

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6.4. Moisture Content, Compaction and Curing

The water added during mixing is both necessary and risky. Too little water prevents proper compaction and hydration; too much water increases voids after drying and can reduce strength. Compaction pressure improves density and interlocking, but compaction must be consistent across batches. Curing is equally important because cement hydration and pozzolanic reactions need time and moisture. If blocks dry too quickly, the surface may appear hard while the internal matrix remains weak. If blocks are soaked or left unprotected too early, they may lose shape. A reliable production sequence for tropical housing should include controlled mixing, immediate compaction, protected curing, gradual drying, and rejection of cracked or under-cured blocks.

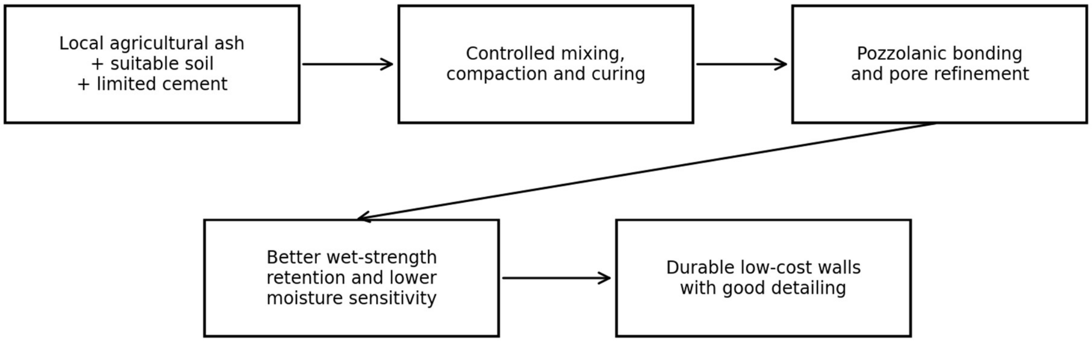
7. Design Translation: From Test Block to Tropical Low-Cost House

A major weakness in many discussions of alternative building materials is the gap between laboratory specimens and actual buildings. A block can be made carefully in a laboratory, cured under controlled conditions, and tested at a known age. A low-cost house, however, is built by artisans under time pressure, exposed to weather during construction, and maintained by occupants with limited money. The architectural question is therefore: what details allow an ash-stabilized earth block to survive in a humid environment?

The first answer is water avoidance. Earth-block walls should be raised above ground splash zones. Plinths should be high enough to protect the first courses from direct rain splash and surface runoff. A damp-proof course should separate the wall from foundation moisture. Roof overhangs should be generous enough to reduce rain impact. Gutters should not be treated as decorative additions; they are part of the moisture durability system. Site grading should move water away from the building, not toward it.

The second answer is breathable protection. Overly dense, cracked or impermeable finishes can trap moisture inside the wall. A good finish should reduce direct water entry while allowing drying. Stabilized renders, lime-based finishes, properly detailed cement-lime renders, and sacrificial plasters may be more useful than hard coatings that fail by cracking. The finish must also be maintainable. Low-cost housing needs repairable layers, not fragile systems that require expensive specialists.

The third answer is specification discipline. Designers should not write vague notes such as "use stabilized earth blocks." A usable specification should state soil source approval, stabilizer content by mass, ash processing requirements, water content control, compaction method, curing duration, minimum dry and wet compressive strength, water absorption limit, and rejection criteria. Without these instructions, a sustainable material can become an unsafe improvisation.



Material selection and processing must be joined with wall-level water control.

Figure 1. Conceptual framework linking agricultural waste ash stabilization, moisture resistance and low-cost tropical housing performance.

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Table 5. Moisture-conscious specification checklist for ash-stabilized earth blocks.

Stage	Minimum decision required	Why it matters
Soil approval	Confirm grading, plasticity and absence of excessive organic matter	Prevents shrinkage, weak bonding and unpredictable moisture behavior.
Ash preparation	Dry, burn under controlled conditions where possible, sieve fine and store airtight	Improves reactivity and prevents contamination or moisture uptake before mixing.
Mix design	Set stabilizer percentages by mass and produce trial blocks before construction	Avoids arbitrary cement replacement and batch-to-batch inconsistency.
Compaction	Use a consistent press and reject poorly compacted blocks	Density strongly affects strength and absorption.
Curing	Protect from direct sun and rain while maintaining curing moisture	Allows cement hydration and pozzolanic reaction to develop.
Testing	Use dry strength, wet strength, absorption and erosion indicators together	Prevents over-reliance on one favorable result.
Wall detailing	Provide plinth, damp-proof course, overhangs, drainage and breathable finishes	Controls real moisture exposure after construction.
Maintenance	Inspect roof edges, gutters, cracks and base dampness after rainy seasons	Durability depends on repairable moisture control.

8. Discussion

The central argument of this paper is that agricultural waste ash stabilizers should be judged by moisture durability, not by sustainability claims alone. A walling material can be local, cheap and low-carbon, but if it loses strength in the rainy season, it is not socially sustainable. Low-cost housing users cannot afford repeated wall repairs, moldy interiors, or early replacement. Therefore, the most responsible use of ash-stabilized earth blocks is cautious, tested and detailed.

The comparison between dry and wet compressive strength is useful because it expresses a material truth in a simple way. Water changes the internal condition of earth blocks. If the wet strength remains close to the dry strength, the block is likely to have a more stable internal bond and lower moisture sensitivity. If the wet strength drops sharply, the block may still look acceptable when dry but become unsafe or serviceably poor under damp conditions. This is why wet/dry strength ratio should be placed beside water absorption and erosion tests in material approval.

Agricultural waste ash can improve moisture durability through pore refinement and additional cementitious bonding, but the improvement is not automatic. The ash must be sufficiently reactive, fine and clean. The soil must be suitable. The cement content must remain adequate. The compaction pressure must be consistent. The curing environment must support reaction development. When any of these conditions fails, ash may become a weakness rather than an advantage. This is the main reason why laboratory results should be converted into practical production protocols before being recommended for housing delivery.

For tropical regions, PKSA has a particularly strong contextual logic because palm-based agricultural activity is common in many local economies. Instead of treating palm kernel shell as waste, it can be processed into a stabilizing component. The benefit is not only environmental; it is economic and regional. It suggests that building materials can emerge from local production chains. However, this also creates responsibility. Local availability should not be used as an excuse for poor quality control. The closer the material is to community production, the more necessary it becomes to provide simple testing routines and clear workmanship rules.

The architectural implication is equally important. Material performance and design detailing must be designed together. A high-performing block used in a wall with no plinth, poor roof edge and no drainage may fail. A moderate block used in a well-protected wall may perform adequately.

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This does not mean detailing can replace material quality; it means material quality and detailing must support each other. For low-cost tropical housing, the most realistic solution is not an expensive high-tech wall but a disciplined low-tech system: tested blocks, raised bases, roof protection, water-shedding site design and repairable finishes.

A further issue is standardization. Many studies report compressive strength under different specimen sizes, curing periods, soaking procedures and loading conditions. This makes direct comparison difficult. Future research on agricultural ash stabilized earth blocks should standardize wet conditioning, report moisture content at testing, and include both strength and moisture transport indicators. Without these details, designers may overestimate the reliability of a mix based on isolated strength values.

9. Proposed Moisture-Durability Framework

Based on the reviewed evidence, this paper proposes a five-layer framework for assessing agricultural waste ash stabilized earth blocks for low-cost tropical housing. The first layer is resource suitability: the waste ash must be locally available in reliable quantity and should not create new environmental or health problems. The second layer is chemical and physical suitability: the ash should show useful pozzolanic or filler behavior after controlled processing. The third layer is block performance: the mix should meet minimum dry strength, wet strength, absorption and erosion requirements. The fourth layer is construction practicality: the production process should be repeatable with available presses, curing space and workmanship. The fifth layer is architectural protection: wall details should reduce water entry, speed drying and make maintenance realistic.

This framework prevents two common mistakes. The first mistake is material romanticism, where earth blocks are promoted because they sound sustainable. The second mistake is laboratory isolation, where strength values are treated as if they automatically produce durable buildings. Moisture-durable low-cost housing requires the middle ground: material testing that understands construction, and architectural detailing that respects material limits.

Table 6. Five-layer assessment framework for agricultural waste ash stabilized earth blocks.

Layer	Assessment question	Pass condition
1. Resource suitability	Is the ash locally available, safe and economically realistic?	Stable source, manageable processing, no obvious contamination risk.
2. Ash suitability	Does the ash have useful fineness and pozzolanic or filler potential?	Controlled burning/sieving and acceptable chemical indicators.
3. Block performance	Does the block retain strength and resist moisture damage?	Acceptable dry and wet strength, absorption and erosion results.
4. Production practicality	Can artisans produce consistent blocks at housing scale?	Repeatable batching, compaction, curing and rejection process.
5. Architectural protection	Will the wall be protected from avoidable wetting?	Plinth, DPC, roof overhang, drainage, breathable finish and maintenance plan.

10. Limitations and Future Research Direction

This manuscript is a review and interpretive synthesis, not a new experimental test program. Its conclusions should therefore be treated as a framework for research and specification rather than as a substitute for laboratory testing of local soils and ashes. PKSA from one palm-processing area may differ from PKSA from another. Soil from one site may not behave like soil from a neighboring site. This variability is not a minor issue; it is one of the defining challenges of earth construction.

Future research should prioritize wet-durability testing under conditions that resemble tropical service. Useful work would include repeated wet-dry cycling, capillary rise tests, erosion under simulated rain, vapor permeability, long-term shrinkage and crack observation, and wall-panel

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testing rather than block-only testing. Research should also examine cost per durable wall area, not merely cost per block. A cheap block that requires expensive protection may not be cheaper at building scale.

Another useful direction is the development of simple field tests for community production. Low-cost housing projects may not always have access to advanced laboratories. Field-friendly quality checks for density, surface erosion, water uptake, curing completion and early strength could help builders reject poor batches before wall construction. This would make agricultural waste ash stabilization more practical and safer for real housing delivery.

11. Conclusions

- Agricultural waste ash stabilizers offer a credible pathway for improving earth blocks while reducing dependence on high cement content and reusing local residues.
- For tropical low-cost housing, moisture durability is more important than dry compressive strength alone. Wet strength retention, water absorption, erosion resistance and drying behavior should be assessed together.
- Palm kernel shell ash is contextually valuable in regions with palm oil processing, but its performance depends on controlled burning, fineness, cleanliness, correct dosage and proper curing.
- Excessive ash replacement can weaken the block or increase moisture vulnerability; the best mix is the one that balances cost, strength, water resistance and production repeatability.
- Architectural detailing is part of the durability system. Plinths, damp-proof courses, roof overhangs, drainage, breathable finishes and maintenance are not optional extras for earth-block walls in humid regions.
- Future research should move from isolated block strength to field-related durability protocols that include wet/dry cycling, capillary rise, erosion and wall-panel behavior.

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Abbreviations

The following abbreviations are used in this manuscript:

Abbreviation	Meaning
CEB	Compressed Earth Block
CSEB	Compressed Stabilized Earth Block
DCS	Dry Compressive Strength
WCS	Wet Compressive Strength
PKSA	Palm Kernel Shell Ash
RHA	Rice Husk Ash
SCBA	Sugarcane Bagasse Ash

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FA	Fly Ash
OPC	Ordinary Portland Cement
DPC	Damp-Proof Course

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