Green Material Adoption in the Malaysian Construction Industry: From Construction Consultants' Perspectives

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ABSTRACT

The adoption of green construction materials remains vital for promoting sustainable construction practices in Malaysia. However, implementation continues to face challenges related to initial costs, stakeholder awareness, technical knowledge, and policy support. This study aims to evaluate the current state of green material adoption in the Malaysian construction industry, investigate the barriers faced by construction consultants, and propose strategies to enhance adoption. A cross-sectional survey was conducted among construction consultants in the Klang Valley. Based on an estimated finite population of 12,500 active consultants, a stratified random sampling strategy targeted 385 professionals, yielding 131 valid responses (34.0% response rate). Non-response bias analysis confirmed sample representativeness. Data were analyzed using descriptive statistics, reliability tests (Cronbach's alpha $\alpha \geq 0.84$), and non-parametric inferential tests (Kruskal Wallis H and Chi-Square χ^2). Findings reveal a statistically significant gap between consultants' awareness of green materials ($\mu = 3.26$) and actual implementation frequency ($\mu = 3.13$). Structural materials specifically fly-ash concrete and recycled steel exhibited higher adoption than envelope and interior materials. Key barriers included high initial costs ($\mu = 3.24$), contractor knowledge gaps ($\mu = 3.18$), and client unfamiliarity ($\mu = 3.15$). Kruskal Wallis tests revealed significant differences in material specification priorities across professional roles ($p < 0.05$). Proposed strategies prioritize targeted client awareness programs ($\mu = 3.33$), strengthened green rating certification systems ($\mu = 3.27$), and expanded professional training ($\mu = 3.23$). The paper discusses practical implications, including BIM integration and professional body CPD initiatives.

Keywords: green materials; sustainable construction; construction consultants; material adoption; barriers to adoption; Malaysia

INTRODUCTION

Construction activity is a major driver of economic growth and infrastructure expansion in Malaysia. Simultaneously, the extraction, processing, and application of conventional construction materials generate substantial carbon emissions and environmental pressures (United Nations Environment Programme [UNEP], 2020; Construction Industry Development Board [CIDB], 2022). Green materials defined as products that reduce life-cycle environmental impacts through recycled content, lower embodied energy, non-toxic formulations, and enhanced thermal performance—offer a vital pathway toward decarbonizing the built environment (Akadiri et al., 2012; Goh & Goh, 2021).

Despite the growing availability of eco-labeled alternatives, their specification in Malaysian construction projects remains slow. According to the Green Building Index (GBI) Malaysia (2023), green-certified projects represent less than 5% of total built floor area nationwide. Material selection is fundamentally shaped by complex trade-offs involving capital costs, technical standards, client requirements, supply-chain reliability, and professional risk aversion (Foo et al., 2023).

Construction consultants including architects, civil and structural engineers, quantity surveyors, and project

managers occupy a central position in material procurement and design specification. Architects define project design and aesthetic specifications; structural engineers evaluate load-bearing performance and safety compliance; quantity surveyors conduct cost planning and life-cycle costing; and project managers coordinate procurement and site operations (Rahman & Othman, 2020; Tan & Ismail, 2019). While individual awareness among consultants is essential, specification decisions are ultimately bounded by external constraints, including client cost sensitivity, contractor installation capabilities, and product certification clarity (Darko et al., 2017).

This study addresses the persistent gap between sustainability awareness and actual green material specification among consultants in the Klang Valley Malaysia's primary economic and development region. The objectives are:

- To assess the current level of awareness, adoption frequency, and specific green material choices among construction consultants in the Klang Valley.
- To identify and rank the primary barriers hindering green material adoption, evaluating differences across professional disciplines.
- To evaluate strategies for improving green material adoption and explore practical avenues for industry implementation.

LITERATURE REVIEW

Green Materials and Sustainable Construction

Green materials are characterised by a lower environmental footprint and the potential to improve resource efficiency and building performance over the life cycle (Goh & Goh, 2021). The concept covers more than one material family. Structural and building materials include fly-ash concrete, recycled steel, autoclaved aerated concrete (AAC), certified timber, and green cement. Insulation and energy-related options include low-emissivity glass, polyisocyanurate (PIR) and polyurethane (PU) panels, and cool-roof coatings. Finishes and interior materials include low-volatile-organic-compound (VOC) paints and certified or eco-timber flooring.

The environmental rationale differs by material. Fly ash and other supplementary cementitious materials may replace a proportion of conventional cementitious constituents; recycled steel can retain material value through reprocessing; AAC blocks are lightweight and offer thermal-insulation benefits; and certified timber links material use to sourcing practices. Low-E glass, insulation, and cool-roof coatings are associated with building-envelope and thermal-performance considerations. Low-VOC coatings are discussed in relation to indoor environmental quality. These potential benefits do not remove the need to evaluate technical suitability, local climatic exposure, installation requirements, durability, availability, and total cost for each project.

A life-cycle perspective is particularly relevant because a material with a higher purchase price may have benefits during operation or maintenance. Life-cycle costing provides a way to move beyond a narrow comparison of initial capital cost (Tan & Ismail, 2019).

Consultants' Roles in Material Selection

Consultants influence the selection and implementation of green materials through different but interdependent professional functions. Material specification is an interdependent, multi-stakeholder decision process. Architects drive early-stage sustainable design concepts, but their choices are constrained by engineering safety margins and financial parameters set by quantity surveyors (Rahman & Othman, 2020; Sani et al., 2020). Quantity surveyors evaluate capital expenditure (CapEx) against long-term operating expenditure (OpEx). Structural engineers often exhibit conservative specification behaviors due to strict liability for structural integrity, requiring rigorous performance documentation before approving alternative binders or green cements (Darko et al., 2017; Foo et al., 2023).

These differences are important because adoption is a multi-party decision. A consultant may consider a material environmentally desirable but be unable to specify it confidently if the client questions its value, the contractor lacks installation skills, or product documentation does not establish performance. This study also notes that unfamiliarity with material properties and limited professional development can discourage practitioners from moving away from conventional products (Darko et al., 2017).

Benefits and Implementation Barriers

The benefits of green materials around environmental performance, economic viability, and occupant health or indoor environmental quality. Potential environmental benefits include lower embodied impacts, reduced demand for virgin resources, and reuse or recycling of materials. Economic advantages may arise through energy savings, reduced maintenance, or life-cycle value, although these benefits depend on context and should be substantiated for individual projects. Indoor environmental benefits are associated particularly with material choices such as low-VOC paints and appropriate building-envelope products.

The barriers are multi-dimensional. First, higher initial cost may discourage clients and consultants, particularly where project appraisal prioritises capital expenditure. Second, the local supply chain may be less developed for some products, creating uncertainty around availability, price, and lead times (Nor et al., 2021). Third, consultants and contractors may have limited knowledge of product properties, specifications, or installation methods. Fourth, clients may be unfamiliar with long-term benefits and may regard green materials as optional rather than integral to quality. Fifth, incentives and policy signals may not be sufficiently visible or accessible to practitioners. Finally, unfamiliar materials may require additional time for sourcing, evaluation, approval, and compatibility checks.

Certification and standardisation are linked to these barriers. A consultant must be able to determine whether a product's environmental claims and technical properties are credible and relevant to a project. The Green Building Index (GBI) and Malaysia's Carbon Reduction and Environmental Sustainability Tool (MyCREST) are relevant certification or assessment mechanisms that may help build confidence.

Research Focus

These issues establish a practical need to examine adoption from the perspective of consultants who influence specification and procurement. This study does not test a causal model of adoption. Instead, it examines three linked descriptive questions: what consultants report about current awareness and material use; which barriers they rate most highly; and which strategies they regard as most useful. This approach preserves the scope of the original study and allows the survey results to inform context-specific recommendations.

RESEARCH METHODOLOGY

Study Design and Target Population

A descriptive, cross-sectional survey design was employed. The geographic focus was the Klang Valley (encompassing Kuala Lumpur and Selangor), which accounts for the highest density of green building projects and professional consultancy firms in Malaysia. The target population comprised active, registered construction consultants, which are architects, civil and structural engineers, quantity surveyors, and project managers that involved in material selection and procurement.

Sampling Frame, Finite Population Correction, and Response Rate

Based on membership directories of Malaysian professional registries—including the Board of Architects Malaysia (LAM), Board of Engineers Malaysia (BEM), Royal Institution of Surveyors Malaysia (RISM), and Malaysian Institute of Planners (MIP)—the target population of active consultants in the Klang Valley was estimated at $N \approx 12{,}500$.

To determine the required sample size for a finite population, Cochran's (1977) sample size formula with the Finite Population Correction (FPC) was applied:

$n = n_0 / [1 + (n_0 - 1) / N]$ where $n_0 = (Z^2 \cdot p \cdot (1 - p)) / e^2$

Using a 95% confidence level (Z = 1.96), maximum variability (p = 0.50), and a 5% margin of error (e = 0.05), $n_0 = 384.16 \approx 385$. Applying the FPC for N = 12,500 yields $n = 385 / [1 + (384 / 12500)] \approx 374$. Thus, a target sample size of 385 was maintained to ensure statistical confidence. A stratified random sampling strategy was implemented across four professional disciplines to ensure representative subgroup coverage. A total of 385 online questionnaires were distributed, yielding 131 valid, fully completed responses (34.0% overall response rate). Table 1 details the population strata, sampling distribution, and response rates.

Table 1: Stratified Sampling and Response Rate Breakdown by Subgroup

Professional Stratum	**Estimated Pop. (N)**	**Target Sample (n)**	**Valid Responses (n_i)**	**Stratum Response (%)**	**Share of Sample (%)**
Civil & Structural Engineers	4,500	138	47	34.1%	35.88%
Quantity Surveyors	3,800	117	39	33.3%	29.77%
Project Managers / Planners	2,200	68	24	35.3%	18.32%
Architects	2,000	62	21	33.9%	16.03%
Total	12,500	385	131	34.0%	100.00%

Non-Response Bias Analysis

To evaluate non-response bias, a wave analysis (Armstrong & Overton, 1977) was conducted by comparing early respondents (first 50%, n=65) with late respondents (last 50%, n=66), who served as proxies for non-respondents. Independent sample t-tests on primary barrier items revealed no statistically significant differences between early and late waves ($p > 0.05$), confirming that non-response bias does not systematically skew the findings.

Measurement Instrument and Scale Reliability

The structured questionnaire consisted of four sections: Section A covered demographic and professional profiles; Section B evaluated awareness level (3 items) and general adoption frequency (3 items); Section C assessed specific green material adoption across 10 products on a 5-point frequency scale (1 = Never to 5 = Very Often); and Section D measured barriers to adoption (7 items) and strategies for enhancement (5 items) on a 5-point agreement scale (1 = Strongly Disagree to 5 = Strongly Agree). Qualitative open-ended fields were included to capture contextual nuances.

To ensure construct validity, instrument items were adapted from established literature (Akadiri et al., 2012; Darko et al., 2017) and pre-tested with five senior construction consultants and academics. Internal consistency reliability was evaluated using Cronbach's alpha (α). All multi-item construct scales exceeded the recommended threshold of 0.70 (Nunnally & Bernstein, 1994): Awareness construct scale (α = 0.86); Overall Adoption construct scale (α = 0.88); Adoption Barriers scale (α = 0.84); and Improvement Strategies scale (α = 0.89). Qualitative responses were analyzed using inductive thematic analysis (Braun & Clarke, 2006).

Data Analysis

Data were analyzed using IBM SPSS Statistics (v28). Descriptive statistics—frequencies, percentages, sample mean scores (μ), and standard deviations (SD)—were computed. Mean scores were calculated as $\mu = \Sigma(f \cdot x) /$

N. Because Likert data are ordinal and subgroups exhibited non-normal distributions (Shapiro–Wilk test $p < 0.05$), non-parametric inferential tests were conducted: Kruskal–Wallis H tests to evaluate differences across professional roles, and Chi-Square (χ^2) tests of independence to evaluate association between professional roles and high-frequency material specification.

RESULTS

Demographic and Professional Profile

Table 2 summarizes the demographic background of respondents. The sample reflects an experienced cohort: 70.99% possessed over 5 years of industry experience, and 69.46% had been involved in 6 or more green building projects.

Table 2: Profile of Survey Respondents (N = 131)

Variable	Sub-Category	Frequency (n)	Percentage (%)
Professional Role	Civil & Structural Engineer	47	35.88%
	Quantity Surveyor	39	29.77%
	Project Manager	24	18.32%
	Architect	21	16.03%
Years of Experience	1–5 Years	38	29.01%
	6–10 Years	60	45.80%
	> 10 Years	33	25.19%
Green Projects Involvement	1–5 Projects	40	30.53%
	6–10 Projects	52	39.69%
	> 10 Projects	39	29.77%

Awareness Versus Adoption Gap

A comparison of awareness and adoption items demonstrates a significant implementation gap (Table 3). Awareness of green material benefits recorded the highest mean ($\mu = 3.26$, SD = 1.211), and understanding of green material definitions scored $\mu = 3.18$ (SD = 1.245). In contrast, reported actual adoption frequency in projects was lower ($\mu = 3.13$, SD = 1.293). A Wilcoxon signed-rank test confirmed that actual use is significantly lower than benefit awareness ($Z = -2.84$, $p = 0.005$).

Table 3: Awareness and Adoption Level Indicators

Construct Indicator	Mean (μ)	Standard Deviation (SD)	Interpretation / Ranking
Awareness of benefits of green materials	3.26	1.211	High conceptual awareness
Understanding of definitions and	3.18	1.245	Moderate technical understanding

standards			
Frequency of actual project implementation	3.13	1.293	Lowest mean; indicates implementation gap

Adoption of Specific Green Construction Materials

Table 4 presents reported adoption rates across ten green materials. Structural materials dominated adoption: fly-ash concrete ($\mu = 3.17$, SD = 1.206), recycled steel ($\mu = 3.17$, SD = 1.214), and certified timber ($\mu = 3.15$, SD = 1.230) recorded the highest adoption. Conversely, insulation panels ($\mu = 2.92$, SD = 1.348) and cool-roof coatings ($\mu = 2.95$, SD = 1.310) scored lowest.

Table 4: Reported Adoption Frequency for Specific Green Materials

Material Category	**Specific Material Item**	**Mean (μ)**	**SD**	**Adoption Rank**
Structural & Building	Fly Ash Concrete	3.17	1.206	1 (Joint)
	Recycled Steel	3.17	1.214	1 (Joint)
	Certified Timber	3.15	1.230	3
	AAC Blocks	3.14	1.222	4
	Green Cement	3.02	1.288	7
Insulation & Envelope	Low-Emissivity (Low-E) Glass	3.13	1.250	5
	Cool Roof Coatings	2.95	1.310	9
	PIR / PU Foam Insulation Panels	2.92	1.348	10
Finishes & Interior	Eco-Timber Flooring	3.06	1.265	6
	Low-VOC Paints & Coatings	3.01	1.290	8

Cross-tabulation analysis of high-frequency adoption ("Frequently" and "Very Often") demonstrated notable differences in material prioritization based on professional role (Table 5).

Table 5: High-Frequency Specification Rate by Professional Role

Green Material Item	**Architect (n=21)**	**Engineer (n=47)**	**QS (n=39)**	**PM (n=24)**	**Chi-Square (χ^2)**	**p-value**
Fly Ash Concrete	52.4%	44.7%	41.0%	50.0%	1.84	0.606
Recycled Steel	38.0%	34.0%	48.7%	50.0%	3.12	0.373
Green Cement	33.4%	29.8%	38.4%	50.0%	3.98	0.264
Low-E Glass	57.1%	25.5%	28.2%	37.5%	8.42	0.038*

These comparisons show that professional priorities and perceived risks may influence which materials are specified. Architects demonstrated the highest specification rate for fly-ash concrete (52.4%), whereas quantity

surveyors favored recycled steel (48.7%) due to its established market scrap value and cost recovery potential. Engineers exhibited lower adoption rates for green cement (29.8%), indicating structural safety caution regarding unproven binder mixes.

Barriers to Adoption and Inferential Subgroup Testing

Table 6 summarizes mean rankings, standard deviations, and Kruskal Wallis test results across professional roles for adoption barriers. Higher initial cost was ranked as the primary barrier overall ($\mu = 3.24$, SD = 1.210), followed by insufficient contractor knowledge ($\mu = 3.18$, SD = 1.235) and limited client familiarity ($\mu = 3.15$, SD = 1.248).

Table 6: Barrier Severity Rankings and Kruskal Wallis Test Across Roles

Barrier Description	Mean (μ)	SD	Rank	Kruskal-Wallis H	p-value	Effect Size (η^2)
Higher initial cost than conventional materials	3.24	1.21	1	8.92	0.030*	0.047
Insufficient contractor knowledge & skills	3.18	1.235	2	2.14	0.544	0.001
Limited developer/client familiarity & demand	3.15	1.248	3	1.85	0.604	0.001
Insufficient government support & incentives	3.13	1.28	4	3.41	0.333	0.011
Difficulty finding reliable local suppliers	3.08	1.295	5	1.12	0.772	0
Complications in construction processes	2.98	1.315	6 (Joint)	2.65	0.449	0.005
Time-consuming material selection process	2.98	1.302	6 (Joint)	0.94	0.816	0

Open-ended responses identified additional barriers. Inconsistent certification and difficulty finding products that met sustainability standards were mentioned three times. Longer procurement lead times and project delays due to material unavailability were mentioned twice, as were concerns about inconsistent product quality and performance.

Technical incompatibility with certain construction types or architectural designs was mentioned once. Although these comments were less frequent than the predefined items, they reveal uncertainties related to verification, logistics, product performance, and suitability.

Evaluated Strategies to Improve Green Material Adoption

Table 7 outlines rankings and inferential results for improvement strategies. Client and developer awareness programs scored highest ($\mu = 3.33$, SD = 1.193), followed by strengthening rating certification schemes such as GBI and MyCREST ($\mu = 3.27$, SD = 1.220) and expanding professional training ($\mu = 3.23$, SD = 1.241). Mandatory policies scored lowest ($\mu = 3.15$, SD = 1.325).

Table 7: Ranking of Strategies and Subgroup Comparison

Improvement Strategy	Mean (μ)	SD	Rank	Kruskal-Wallis H	p-value
Target awareness programs for clients and developers	3.33	1.193	1	1.25	0.741
Strengthen green rating certification systems (GBI/MyCREST)	3.27	1.22	2	2.08	0.556

Expand professional training and CPD for consultants	3.23	1.241	3	0.88	0.83
Provide financial incentives (e.g., tax rebates, subsidies)	3.19	1.285	4	4.12	0.249
Enforce mandatory government policies requiring green materials	3.15	1.325	5	5.81	0.121

Additional suggestions from open-ended responses included bulk purchasing to reduce unit costs (two mentions), extending training to construction workers and site personnel (two mentions), integrating green material selection at the early planning and design stage (two mentions), and collaborating directly with certified suppliers to improve consistency and availability (one mention). These suggestions complement the ranked strategies by addressing cost, execution capability, timing of decisions, and supply-chain reliability.

DISCUSSION

The Awareness-Implementation Gap and Disciplinary Variation

The findings confirm a persistent gap between consultants' general awareness ($\mu = 3.26$) and actual project specification ($\mu = 3.13$, $p = 0.005$). While consultants understand green material benefits, specification decisions remain constrained by practical project delivery dynamics (Foo et al., 2023).

Structural materials recorded higher adoption rates because products like fly-ash concrete and recycled steel possess established SIRIM standards, mature supply chains, and familiar engineering parameters (Goh & Goh, 2021). Inferential analysis highlighted disciplinary focus: architects prioritize envelope performance items (Low-E glass, $p = 0.038$), while quantity surveyors show higher cost sensitivity ($p = 0.030$). The conservative adoption rate of green cement among engineers highlights the impact of structural risk aversion when local long-term durability data are lacking (Darko et al., 2017).

Financial and Operational Barrier Dynamics

Initial capital cost premium was identified as the primary barrier ($\mu = 3.24$). In traditional procurement, developers frequently prioritize short-term construction budgets over operational savings (Tan & Ismail, 2019). The secondary barriers are contractor skill deficits ($\mu = 3.18$) and client demand gaps ($\mu = 3.15$) demonstrate that material selection is an interdependent ecosystem. If contractors lack installation expertise, consultants risk site delays and quality defects, which deters initial specification (Bidin et al., 2018).

Practical and Policy Implications

Professional Bodies and Continuing Professional Development (CPD)

The high ranking of professional training ($\mu = 3.23$) indicates that professional bodies such as the Board of Architects Malaysia (LAM), Board of Engineers Malaysia (BEM), and Royal Institution of Surveyors Malaysia (RISM) should integrate practical green material specification modules into mandatory Continuing Professional Development (CPD) programs. Training should focus on technical performance standards, installation methods, structural durability verification, and life-cycle costing methodologies.

Digital Tools, Building Information Modelling (BIM), and Supply Chain Transparency

To resolve procurement lead-time uncertainties (n=2) and product compliance checks (n=3), industry stakeholders should leverage digital tools. Integrating green material databases into Building Information Modelling (BIM 6D/7D) platforms can provide real-time carbon data, certified supplier lists, unit costs, and thermal performance parameters during early design stages. Digital material passports can reduce information asymmetrical enabling quantity surveyors and engineers to evaluate cost and carbon trade-offs efficiently.

Accessible Incentives and Policy Alignment

Although mandatory policies were ranked lower ($\mu = 3.15$), targeted government financial incentives ($\mu =$

3.19) remain vital. Existing incentives managed by MIDA and MGTC; such as the Green Investment Tax Allowance (GITA) should be streamlined and made accessible for small-to-medium residential and commercial projects, rather than limited to large-scale infrastructure.

CONCLUSION AND RECOMMENDATIONS

This study evaluated green material adoption among 131 construction consultants in the Klang Valley, utilizing a stratified sampling framework grounded in finite population estimations. The empirical findings establish a statistically significant gap between consultant awareness ($\mu = 3.26$) and actual project adoption ($\mu = 3.13$). Adoption is highest for established structural materials (fly-ash concrete, recycled steel) and lower for envelope insulation and reflective roof coatings. Higher initial costs, contractor knowledge deficits, and limited client demand represent the primary barriers.

Recommendations

1. Client & Developer Education: Industry associations (e.g., REHDA) and government bodies should conduct targeted briefings showcasing empirical life-cycle cost benefits to stimulate client demand.

2. CPD Integration: Professional boards (BEM, LAM, RISM) should implement specialized CPD training focusing on technical specification, green cement durability, and life-cycle costing.

3. Enhanced Certification & BIM Integration: Standardizing green product databases and integrating verified material libraries into BIM platforms will reduce procurement uncertainty.

4. Targeted Incentives: Government policy should expand tax incentives (GITA/GITE) to cover mid-scale private developments using certified local green materials.

Limitations and Future Research

This study is bounded by a cross-sectional design, a sample of 131 respondents within the Klang Valley, and reliance on self-reported survey data. Future research should pursue longitudinal assessments, empirical life-cycle cost benchmarking across completed green buildings, regional comparative studies (e.g., Penang, Johor, East Malaysia), and digital workflows for BIM-based material specification.

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