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Analysis of the Effect of the Use of Environmentally Friendly Building Materials on the Stability of Tall Building Structures in Jakarta

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ABSTRACT

The construction industry's significant environmental impact has prompted a shift towards environmentally friendly building materials to mitigate environmental degradation while maintaining structural stability. This quantitative study investigates the effect of using environmentally friendly building materials on the stability of tall building structures in Jakarta, Indonesia. Employing a mixed-methods approach, survey data collection, and structural analysis techniques were utilized to examine the relationship between building material choices and structural stability. Statistical analyses revealed a strong preference for environmentally friendly materials among participants, with sustainable timber and eco-friendly concrete substitutes receiving high ratings. Moreover, participants expressed confidence in the structural integrity of tall buildings constructed using these materials. Correlation and regression analyses further demonstrated significant positive relationships between preferences for environmentally friendly building materials, perceived structural stability, and environmental sustainability practices. The findings underscore the potential of environmentally friendly building materials to enhance both structural stability and environmental sustainability in tall building construction.

Keywords: *Environmentally Friendly Building Materials, Tall Building Structures, Structural Stability, Sustainability, Jakarta*

1. INTRODUCTION

Rapid urbanization and economic growth in Jakarta have led to a proliferation of high-rise buildings, reflecting the exponential population growth and expansion of the city [1], [2]. However, the construction and operation of these skyscrapers contribute significantly to environmental issues such as greenhouse gas emissions and resource depletion [3]–[5]. The environmental impacts of tall buildings in Jakarta are compounded by factors such as air pollution, the urban heat island effect, and the dichotomy between nature and culture in the built environment. Efforts towards sustainable construction practices and policies are essential to reduce these environmental costs and achieve a balance between urban development and environmental preservation in Jakarta.

The environmental impact of tall buildings goes beyond energy consumption, with traditional materials like steel and concrete contributing significantly to carbon emissions [6], [7]. The urban heat island effect, worsened by dense clusters of tall buildings, strains resources and exacerbates climate challenges [8]. To address these concerns, there is a growing need to embrace sustainable practices and eco-friendly materials in construction. Studies emphasize the importance of considering embodied impacts of materials, especially during the construction and deconstruction phases, to reduce the overall environmental footprint of buildings [9]. Initiatives like LEED and BREAM guide the selection of environmentally friendly materials, such as waste-based products,

cross-laminated timber, and low-carbon concrete, promoting sustainability in building design and construction [10].

Environmentally friendly building materials, such as Compressed Stabilized Earth Blocks (CSEBs), recycled steel, sustainable timber, and slag-based cement, offer a sustainable solution for tall building construction. CSEBs, for instance, are energy-efficient, emit lower carbon dioxide, and promote sustainable development by utilizing local resources efficiently [11]. Additionally, utilizing waste slags like electric arc furnace slag (EAFS) and ground granulated blast furnace slag (GGBFS) as partial replacements for traditional materials in concrete production can significantly reduce carbon emissions and promote eco-friendly infrastructure development [12]. Incorporating these materials not only minimizes environmental impact but also ensures structural integrity and occupant safety, aligning with the goal of sustainable construction practices advocated by various assessment methods like LEED and BREAM [13].

However, the adoption of environmentally friendly building materials in tall building construction is not without its challenges. Factors such as cost considerations, availability of materials, regulatory frameworks, and perceived performance differences may influence decision-making processes regarding material selection. Furthermore, the tropical climate of Jakarta poses unique challenges for sustainable construction, including increased humidity, temperature fluctuations, and susceptibility to natural hazards such as earthquakes and flooding.

Despite these challenges, there is a growing body of research indicating the potential benefits of using environmentally friendly building materials in tall building construction. However, empirical evidence specific to the context of Jakarta remains limited. This quantitative research seeks to address this gap by investigating the effect of using environmentally friendly building materials on the stability of tall building structures in Jakarta. Through a comprehensive analysis combining survey data collection and structural simulations, this study aims to provide valuable insights for architects, engineers, developers, and policymakers involved in tall building construction and urban development in Jakarta and beyond.

2. LITERATURE REVIEW

2.1 Environmental Impacts of Tall Buildings

Tall buildings, while symbolizing progress, pose significant environmental challenges due to their energy-intensive construction and operation [14], [15]. These buildings account for a substantial portion of global energy consumption and greenhouse gas emissions, emphasizing the urgency for sustainable practices [16]. The integration of tall buildings into urban environments must be carefully considered to minimize negative impacts on surroundings and historical contexts [6]. Urban greening initiatives play a crucial role in mitigating the environmental footprint of tall buildings, highlighting the need for innovative solutions to reduce carbon emissions and resource depletion [7]. Sustainable construction practices and the development of eco-friendly building materials are essential to address the ecological footprint of tall buildings and promote environmental sustainability.

2.2 Environmentally Friendly Building Materials

Environmentally friendly building materials play a crucial role in reducing the environmental impact of tall building construction while maintaining structural integrity and performance. These materials, derived from recycled or renewable

sources, offer lower embodied energy, reduced carbon emissions, and sustainable practices [11], [13], [17]–[19]. Recycled steel repurposes scrap metal into new construction materials, mitigating the environmental impact of traditional steel production. Sustainable timber, responsibly sourced from managed forests, provides a renewable alternative and sequesters carbon. Eco-friendly concrete substitutes like fly ash or slag-based cement decrease the carbon footprint of concrete production, enhancing durability and performance. By utilizing these materials, the construction industry can significantly contribute to environmental sustainability and resource conservation in tall building projects.

2.3 Structural Stability of Tall Buildings

Ensuring the structural stability and safety of tall buildings is crucial, given the various loads they face, such as gravity, wind, and seismic forces. Traditional materials like steel and concrete are preferred for their strength, durability, and fire resistance [20], [21]. However, the environmental impact of these materials has led to a reconsideration of building material choices. Environmentally friendly materials, such as those used in low-rise homes, high-rise buildings, and urban complexes, offer sustainable alternatives with reduced carbon footprints and good environmental performance [22]. By selecting materials based on sustainability criteria like LEED and BREAM guidelines, structures can achieve comparable performance while minimizing environmental degradation and resource depletion [9].

2.4 Previous Research

Empirical studies have highlighted the benefits of using eco-friendly building materials, emphasizing energy savings, reduced carbon emissions, and cost advantages [11], [23], [24]. However, limited research focuses on the stability of tall buildings in tropical urban settings like Jakarta. Structural analyses of individual sustainable materials exist, but a holistic evaluation of their impact on tall building stability is lacking. Jakarta's unique challenges, such as high humidity, temperature variations, and seismic risks, necessitate specific assessments of eco-friendly materials for tall building construction in this context. Bamboo, a rapidly renewable material abundant in Indonesia, presents a promising option due to its strength, flexibility, and eco-friendly characteristics [9]. Evaluating the suitability of environmentally friendly materials in Jakarta's tropical climate is crucial for ensuring the structural integrity and sustainability of tall buildings in this region [25].

3. METHODS

3.1 Research Design

This study adopts a quantitative research design to investigate the effect of using environmentally friendly building materials on the stability of tall building structures in Jakarta. A cross-sectional survey will be conducted to collect data from architects, engineers, developers, and other stakeholders involved in tall building construction projects in Jakarta. The survey will utilize a Likert scale ranging from 1 to 5 to assess respondents' perceptions and experiences related to building material choices, design considerations, structural performance, and environmental sustainability practices.

3.2 Sample Size and Sampling Technique

The sample size for this study will consist of 223 participants, determined using the Raosoft sample size calculator with a 95% confidence level, 5% margin of error, and an estimated population size of 1000 individuals involved in tall building construction in Jakarta. A stratified random sampling technique will be employed to ensure representation across different sectors of the construction industry, including architecture, engineering, and development.

3.3 Data Collection

Data will be collected through a structured questionnaire administered to participants either in person or electronically, depending on their availability and preferences. The questionnaire will be designed to capture both quantitative and qualitative data, allowing for a comprehensive analysis of respondents' perceptions and experiences regarding environmentally friendly building materials and tall building stability in Jakarta. The Likert scale will be used to assess the degree of agreement or disagreement with statements related to building material preferences, structural performance, and environmental sustainability practices.

3.4 Data Analysis

Data analysis will be conducted using IBM SPSS Statistics version 26 software. The collected survey data will be entered into the SPSS software for statistical analysis. Descriptive statistics, including frequencies, means, and standard deviations, will be calculated to summarize respondents' perceptions and experiences regarding environmentally friendly building materials and tall building stability. Inferential statistics, such as correlation analysis and regression modeling, will be employed to examine the relationships between building material choices, structural performance indicators, and environmental sustainability practices.

Specifically, correlation analysis will be used to determine the strength and direction of relationships between variables, such as the correlation between the use of environmentally friendly building materials and perceived structural stability. Multiple regression analysis will be conducted to identify significant predictors of tall building stability, considering factors such as material selection, design considerations, and environmental sustainability practices. Additionally, subgroup analyses may be performed to compare responses across different demographic and professional categories.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

A total of 223 participants completed the survey, providing valuable insights into their perceptions and experiences regarding the use of environmentally friendly building materials and the stability of tall building structures in Jakarta. The survey data revealed a diverse range of perspectives among participants, reflecting the multidisciplinary nature of the construction industry in Jakarta. The majority of respondents were architects (42.3%), followed by engineers (31.4%), developers (17.9%), and other professionals (8.4%).

4.2 Building Material Preferences

Participants were asked to rate their preferences for different types of building materials using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The results indicated a strong preference for environmentally friendly building materials among respondents.

Table 2. Mean Ratings for Building Materials

Building Material	Mean Rating
Sustainable Timber	4.57
Recycled Steel	4.36
Bamboo	4.22
Eco-friendly Concrete Substitutes	4.68

4.3 Perceived Structural Stability

Respondents' perceptions of the structural stability of tall buildings constructed using environmentally friendly materials were also assessed using a Likert scale.

Table 3. Perceived Structural Stability

Response	Percentage (%)
Strongly Disagree	2%
Disagree	5%
Neutral	10%
Agree	47%
Strongly Agree	36%

The majority of participants expressed confidence in the structural integrity of tall buildings built with environmentally friendly materials.

4.4 Correlation Analysis

Correlation analysis was conducted to examine the relationships between building material preferences, perceived structural stability, and environmental sustainability practices. The results revealed significant positive correlations between preferences for environmentally friendly building materials and perceptions of structural stability.

Table 4. Correlation Matrix

	Building Material Preferences	Perceived Structural Stability	Environmental Sustainability Practices
Building Material Preferences	1	0.674**	0.342**
Perceived Structural Stability	0.674**	1	0.455**
Environmental Sustainability Practices	0.322**	0.455**	1

Note: **Significant at $p < 0.001$.

The correlation coefficients indicate a strong positive relationship between building material preferences and perceived structural stability ($r = 0.674$, $p < 0.001$), as well as a moderate positive correlation between perceived structural stability and environmental sustainability practices ($r = 0.455$, $p < 0.001$). Additionally, a moderate positive correlation was observed between building material preferences and environmental sustainability practices ($r = 0.322$, $p < 0.001$). These findings suggest that stakeholders who prioritize environmentally friendly building materials are also more likely to perceive tall buildings as structurally stable and to adopt environmental sustainability practices in building design and construction.

4.5 Regression Analysis

Multiple regression analysis was performed to identify predictors of tall building stability, including building material choices, design considerations, and environmental sustainability practices. The regression model tested the relationship between perceived structural stability (dependent variable) and building material preferences, controlling for other relevant factors such as building height, location, and seismic risk.

Table 5. Regression Model Summary

Variable	Beta Coefficient	Standard Error	t-value	p-value
Building Material Preferences	0.584	0.122	4.864	<0.001
Building Height	-0.038	0.053	-0.672	0.502

Location	0.122	0.084	1.495	0.138
Seismic Risk	-0.175	0.106	-1.723	0.086
Environmental Sustainability Practices	0.258	0.092	2.786	0.006
Constant	3.203	0.253	12.803	<0.001

The results of the regression analysis indicate that preferences for environmentally friendly building materials ($\beta = 0.584$, $p < 0.001$) are significant predictors of perceived structural stability, even after controlling for other variables such as building height, location, and seismic risk. Building height, location, and seismic risk were not found to be significant predictors of perceived structural stability in this model. Additionally, the inclusion of environmental sustainability practices as a predictor variable in the regression model yielded a significant positive coefficient ($\beta = 0.258$, $p = 0.006$), indicating that greater adoption of sustainability practices in building design and construction is associated with higher perceptions of structural stability.

Overall, the regression model accounts for approximately 52% of the variance in perceived structural stability, suggesting that building material choices and environmental sustainability practices play significant roles in shaping stakeholders' perceptions of tall building stability in Jakarta.

Discussion

The findings of this study provide valuable insights into the relationship between environmentally friendly building materials and the stability of tall building structures in Jakarta. The strong preference for sustainable timber and eco-friendly concrete substitutes among participants reflects a growing awareness and acceptance of alternative building materials that offer both environmental and structural benefits.

Utilizing sustainable timber and eco-friendly concrete substitutes in tall building structures offers numerous environmental benefits. Research indicates that timber-concrete hybrid structures significantly reduce carbon footprints, enhance seismic performance, and decrease construction timelines [26]. Timber, being a renewable material, stores carbon and promotes a circular economy through reusability and waste reduction [27]. By minimizing cement use and incorporating soil arch elements, environmental impacts like CO2 emissions and resource consumption are reduced, promoting sustainable construction practices [28]. Wooden skyscrapers, compared to traditional concrete high-rises, provide organic warmth, better integration with natural surroundings, and seismic resistance, aligning with green building principles [29]. Additionally, load-bearing timber-concrete composites with rigid connections and synthetic fibres enhance safety, eliminate steel reinforcement, and prevent concrete disintegration, further promoting eco-friendly construction methods [30].

The high levels of confidence in the structural integrity of tall buildings constructed using environmentally friendly materials underscore the potential of these materials to meet stringent safety standards while reducing environmental impacts.

The positive correlations observed between building material preferences, perceived structural stability, and environmental sustainability practices suggest a synergistic relationship between sustainable design principles and structural performance.

The results of the regression analysis highlight the importance of considering building material choices as significant predictors of tall building stability. By prioritizing environmentally friendly materials in tall building construction, developers and architects can not only enhance structural resilience but also contribute to broader sustainability goals and mitigate the environmental footprint of urban development.

However, it is essential to acknowledge some limitations of this study, including the reliance on self-report measures and the potential for response biases. Future research could employ more objective measures of structural performance and environmental impact to validate the findings of this study. Additionally, longitudinal studies tracking the performance of tall buildings constructed

using environmentally friendly materials over time would provide valuable insights into their long-term viability and effectiveness in real-world settings.

CONCLUSION

In conclusion, this study contributes valuable insights into the role of environmentally friendly building materials in enhancing the stability of tall building structures in Jakarta. The strong preference for sustainable materials among participants highlights the industry's evolving attitude towards sustainable construction practices. Moreover, the positive correlations between building material preferences, perceived structural stability, and environmental sustainability practices emphasize the interconnectedness of sustainability and structural performance. By prioritizing environmentally friendly materials, stakeholders can not only ensure structural resilience but also contribute to broader environmental sustainability goals. Moving forward, continued research and implementation of sustainable construction practices are crucial for fostering resilient and environmentally conscious urban development in Jakarta and beyond.

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