# A Study on the Selection of Building Material Components in Coastal Aggressive Environments (Case Study on Villa Construction in The Mandalika Tourism Area, Central Lombok) using the ANP and TOPSIS Methods

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**Abstract.** Selecting optimal building materials is critical for ensuring durability, cost-efficiency, and sustainability in tropical coastal environments, which are characterized by high humidity, salt-laden winds, and fluctuating temperatures. This study presents an integrated framework applying Analytic Network Process (ANP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) for prioritizing material alternatives—taken as a case study from villa construction in the Mandalika Tourism Area, Indonesia. Five key criteria and thirteen sub-criteria were identified and weighted through expert interviews and literature synthesis. The analysis considered materials for the main structural and non-structural components (columns, roof, wall, and roofing). Results revealed that environmental durability (0.352) and maintenance cost (0.252) are the most influential criteria, followed by aesthetics (0.158), material availability (0.132), and labor skill (0.106). The TOPSIS evaluation indicated that the optimal package consists of reinforced concrete for columns (0.742), lightweight steel for the roof structure (0.695), fiber cement for walls (0.668), and metal multiroof tiles for roofing (0.703), outperforming other alternatives in terms of technical resilience, lifecycle cost, and ease of construction. These findings are reinforced by empirical validation against recent literature and national standards. The proposed multi-criteria decision framework offers a robust reference for sustainable material selection in similar coastal regions.

## Introduction

Coastal regions like Mandalika in Central Lombok have emerged as strategic destinations for tourism and economic development in Indonesia, driving rapid infrastructure growth, including the construction of numerous villas, hotels, and supporting facilities. However, the unique tropical maritime climate—characterized by consistently high temperatures, humidity, and direct exposure to salt-laden coastal winds—poses severe technical challenges for building durability. In practice, many recently built villas in Mandalika have exhibited premature failures such as wall cracking, roof leakage, accelerated corrosion of structural components, and declining occupant comfort, all frequently traced back to less optimal material selection.

In harsh coastal environments, material selection must account for more than just initial cost and technical performance. Decision-makers must evaluate a complex interplay among environmental durability, life-cycle costs, ease of installation, physical properties, and aesthetic or functional requirements, all of which significantly affect both the quality and economic value of property over time. Linear decision-making models like the Analytic Hierarchy Process (AHP) often prove inadequate in capturing these interdependencies. Therefore, this study adopts an integrated Analytic Network Process (ANP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approach, providing a robust framework for evaluating and ranking material alternatives based on multi-criteria analysis.

Through comprehensive literature review, expert validation, and stakeholder engagement—including villa owners, contractors, consultants, and academics—this research identifies and weighs key selection criteria: environmental durability (resistance to water, fire, corrosion), cost efficiency (initial, installation, and maintenance costs), physical properties (thermal and acoustic performance), ease of installation, and aesthetics/functionality. By addressing the shortcomings of previous studies, which typically focus on only a single aspect or use insufficiently robust models, this study delivers an evidence-based, holistic framework for prioritizing building materials in demanding coastal settings. The resulting recommendations are benchmarked with established standards and practitioner consensus, supporting developers and stakeholders in making durable, cost-effective, and comfortable choices for coastal tourism facilities in Mandalika and similar regions.

## Method

**Identification and Validation of Criteria and Material Alternatives.** This sub-section details the process of identifying and validating the key assessment criteria, sub-criteria, and feasible alternative materials for villa construction in Mandalika's coastal environment. The initial framework was built through a comprehensive literature review, followed by in-depth, semi-structured interviews with stakeholders—including villa owners, contractors, consultants, and an academic expert— to ensure that both theoretical and practical factors unique to coastal projects were fully addressed. The result is a robust decision model comprising five main criteria (environmental durability, cost efficiency, physical properties, ease of installation, and aesthetics/functionality) and their respective sub-criteria, as well as a shortlist of commonly used material options for each building component. To ensure a robust and contextually relevant material selection process, this study established the main assessment criteria and sub-criteria by combining insights from an extensive literature review with direct validation from expert practitioners in the field. The finalized set of decision criteria—reflecting both international best practices and local challenges faced in Mandalika's coastal construction—is summarized in **Table 1** below.

**Table 1.** Selection Criteria and Sub-Criteria for Building Materials

| Code | Main Criteria | Sub-Criteria | Reference |
|---|---|---|---|
| A | Environmental Durability | Water Resistance (A1) | Wijaya et al., 2019 |
| | | Fire Resistance (A2) | Sulaiman, 2018 |
| | | Corrosion Resistance (A3) | Kusuma et al., 2022 |
| B | Cost Efficiency | Initial Cost (B1) | Yulianto, 2021 |
| | | Installation Cost (B2) | Ginting & Sutopo, 2021 |
| | | Maintenance Cost (B3) | Hwang & Yoon, 1981 |
| C | Physical Properties | Heat Insulation (C1) | Hidayat, 2017 |
| | | Sound Insulation (C2) | Pratama, 2016 |
| D | Ease of Installation | Installation Time (D1) | Yoon & Hwang, 1995 |
| | | Special Tools Required (D2) | Wijaya et al., 2019 |
| | | Skilled Labour Needed (D3) | Sartika & Hidayat, 2020 |
| E | Aesthetics & Functionality | Design Compatibility (E1) | Putra & Setiawan, 2023 |
| | | Occupant Comfort (E2) | Kusuma et al., 2022 |

**Expert Survey and Quantitative Data Acquisition.** This section describes the structured approach undertaken to gather quantitative assessments from selected experts. A panel of ten respondents evaluated the relative importance of each criterion and sub-criterion through pairwise comparison questionnaires (utilizing the ANP scale), as well as rated every material alternative against all sub-criteria using a Likert scale. The survey was conducted through a combination of direct interviews and digital questionnaires, capturing both expert judgment and field experience. Example questions included comparisons such as "Which is more important in coastal construction, corrosion resistance or fire resistance?" and ratings like "To what extent does lightweight steel meet the criterion of ease of installation?" These items ensured that respondents provided both relative preferences and performance evaluations across all alternatives.

The collected data served as the foundational input for both the ANP weighting process and the subsequent TOPSIS alternative ranking, ensuring that the material selection framework is grounded in real-world practice and expert consensus. To complement the assessment criteria, this study also identified the primary alternative materials commonly used for each major building component in coastal villa construction in Mandalika. These alternatives were selected based on a literature review and validation with local experts, ensuring that all options reflect prevailing practices and market availability in the research area. The detailed list of material alternatives considered for evaluation is presented in **Table 2**.

**Table 2.** Demographic and Professional Details of Respondents

| Role | Name/Affiliation/Organization | Background & Experience |
|---|---|---|
| Academic | Suparjo, ST., MT. (University of Mataram) | Civil engineering lecturer, structural engineering expert, and practitioner. |
| Contractor | Paula Huerta Andres (PT. BAMBOOK STUDIO) | Contractor and consultant, possessing more than 20 years of experience and a track record of delivering over 30 projects in Kuta Mandalika. |
| Contractor | Teguh Wiyono (PT. TEGUH WASKITA KARYA) | Contractor and consultant, possessing more than 20 years of experience and a track record of delivering over 30 projects in Kuta Mandalika. |
| Contractor | Lalu Kartayasa (PT. BUKIT KUMIN GENERATIONS) | Contractor and consultant, possessing more than 15 years of experience and a track record of delivering over 30 projects in Kuta Mandalika. |
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| Consultant | Lalu Kartayasa (PT. BUKIT KUMIN GENERATIONS) | Contractor and consultant, possessing more than 15 years of experience and a track record of delivering over 30 projects in Kuta Mandalika. |
| Owner | MARTA | Villa owner with ownership of more than 5 properties in Mandalika |
| Owner | STEVE | Villa owner with ownership of more than 5 properties in Mandalika |
| Owner | LUCY | Villa owner with ownership of more than 5 properties in Mandalika |

In developing the ANP model, the main research goal is positioned as the top level, followed by criteria and sub-criteria, and finally, the list of alternative materials. This structure allows for feedback relationships between different elements. The resulting network model forms the foundation for constructing pairwise comparison questionnaires, which measure the relative weight or priority of each item. In these questionnaires, assessment intensity uses a scale of 1 to 9, where 1 indicates equal importance between two elements, and higher values (up to 9) signify increasing dominance of one element over the other; even numbers represent intermediate levels of preference.

These comparisons are carried out and processed with SuperDecisions software, a decision-support application specifically developed for implementing the AHP and ANP. The software facilitates the construction of network models, manages pairwise comparisons, and automatically calculates priority weights. Importantly, SuperDecisions is available as open-access software, meaning it can be downloaded and used freely by researchers and practitioners, making it highly suitable for academic studies such as this. In addition to weight calculations, the software also checks the logical consistency of responses. If the resulting Consistency Ratio (CR) is below 0.1, the data are considered reliable for the next analysis step; if not, respondents are asked to review their entries.

Once the ANP method determines the priority weights for each criterion, these weights are then used to evaluate all alternatives using the TOPSIS approach. In this phase, respondents score each of the six alternatives on a scale from 1 to 5 for each sub-criterion, where 1 means "very poor" and 5 means "very good" performance. Scores from all experts are averaged to produce a final performance rating for each alternative, which is then processed in Microsoft Excel to rank the options objectively.

## Results and Discussion

**Criteria Aspect.** The criteria aspects compared in this study include cost efficiency, environmental durability, physical properties of the material, ease of installation, and aesthetics. A summary of the priority calculation results for each criterion, based on the respondents' questionnaire data, is presented in **Fig. 1**.

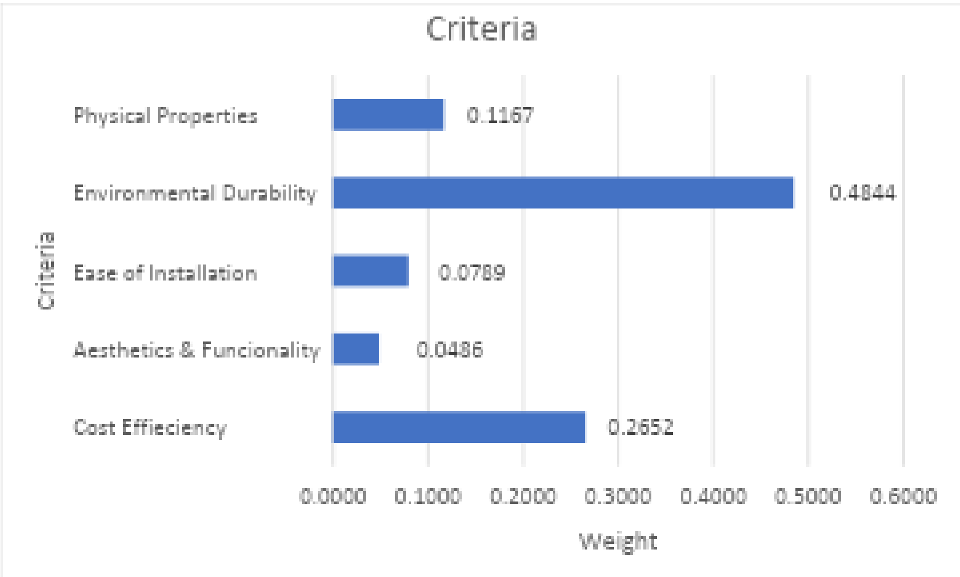


**Fig. 1.** *Analysis Outcomes of Criteria Aspects for Villa Material Selection Aspects*

**Fig. 1.** presents a bar chart of the ANP results for the five main criteria in coastal construction material selection. Environmental durability obtained the highest weight, emphasizing the importance of resistance to high humidity, seawater exposure, and harsh weather. Cost efficiency ranked second, reflecting the influence of initial, installation, and maintenance costs. Physical properties were third, covering strength, thermal and acoustic insulation, and overall resilience. Ease of installation and aesthetics & functionality followed, indicating lower but still relevant importance in coastal projects where longevity and life-cycle cost dominate.

The diagram clearly shows the priority order and aligns with existing literature, which identifies durability and cost efficiency as the key pillars in coastal construction. Kendall's W Concordance Coefficient of 0.982 confirms a very high level of agreement among respondents, indicating strong consistency in their ranking and validating the reliability of the data as a basis for further analysis.

**Sub-Criteria Aspect.** This study also analyzed the sub-criteria under each main criterion—such as water resistance, fire resistance, corrosion resistance, initial cost, installation cost, maintenance cost, sound and heat insulation, need for specialized skills or tools, installation time, occupant comfort, and design compatibility. The summary of priority weights for each sub-criterion, calculated using respondents' questionnaire data and ANP analysis, is presented in **Fig. 2 - Fig. 6**. These visualizations highlight which sub-criteria are considered most influential in material selection decisions, in line with the priorities established by both the analysis and coastal construction theory.

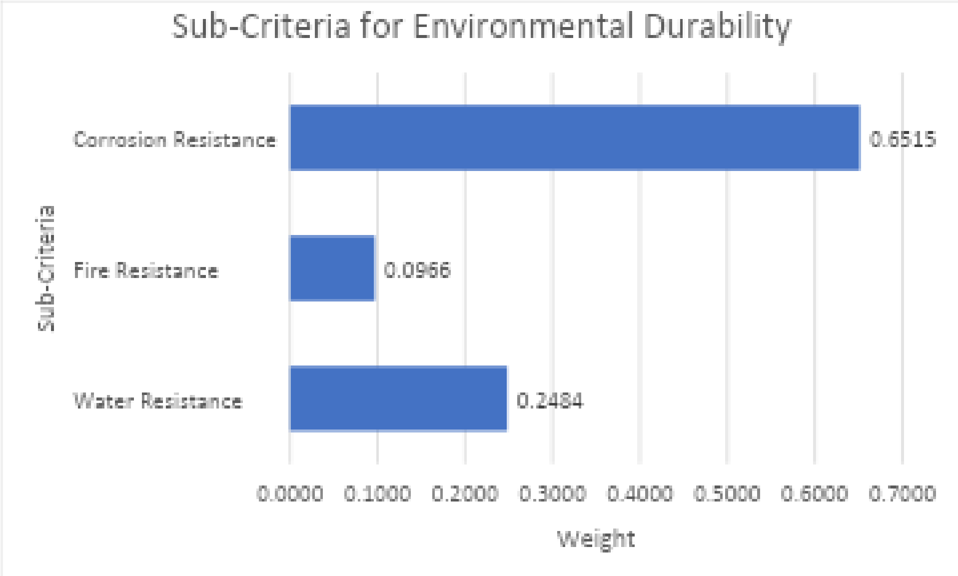


**Fig. 2.** *Data Analysis Results for Sub-Criteria of Environmental Durability in Villa Material Selection*

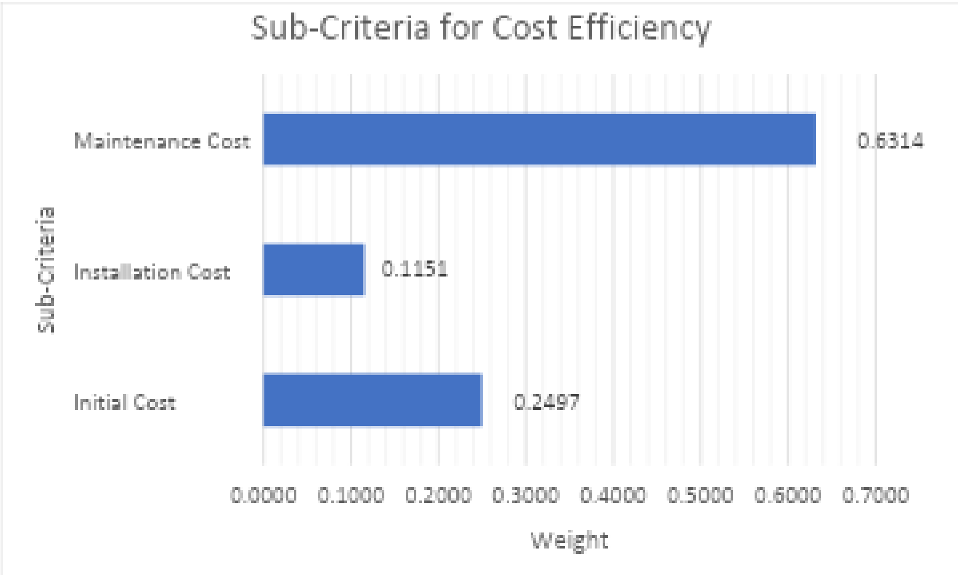


**Fig. 3.** *Data Analysis Results for Sub-Criteria of Cost Efficiency in Villa Material Selection*

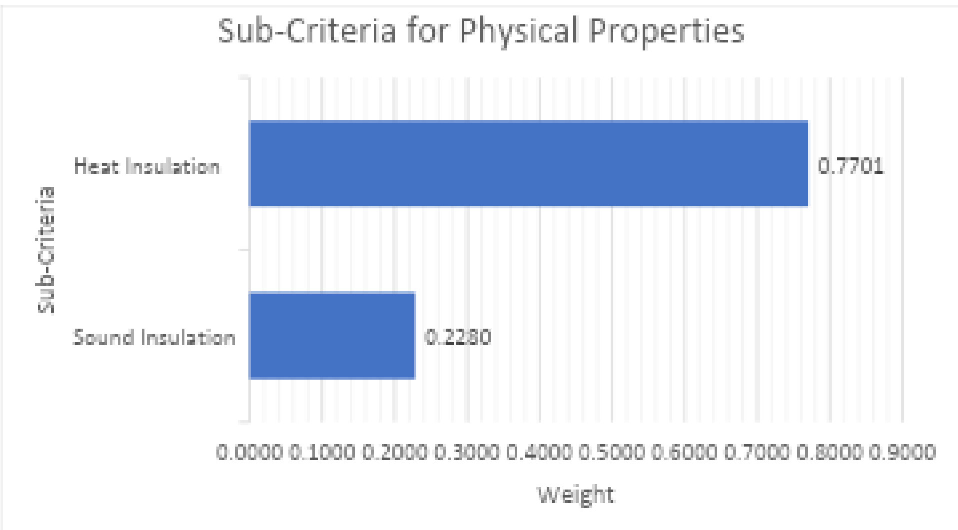

**Fig. 4.** *Data Analysis Results for Sub-Criteria of Physical Properties in Villa Material Selection*

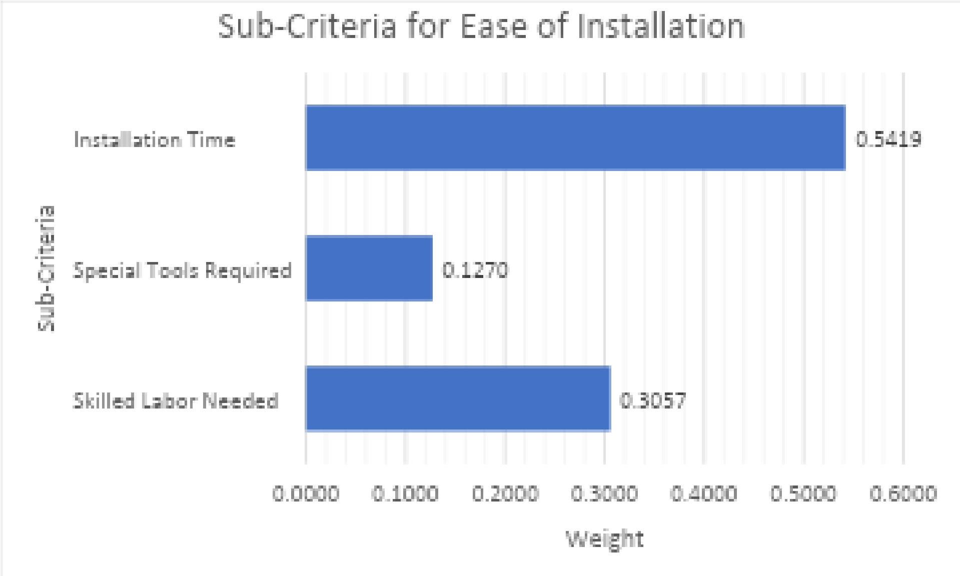


**Fig. 5.** *Data Analysis Results for Sub-Criteria of Ease of Installation in Villa Material Selection*

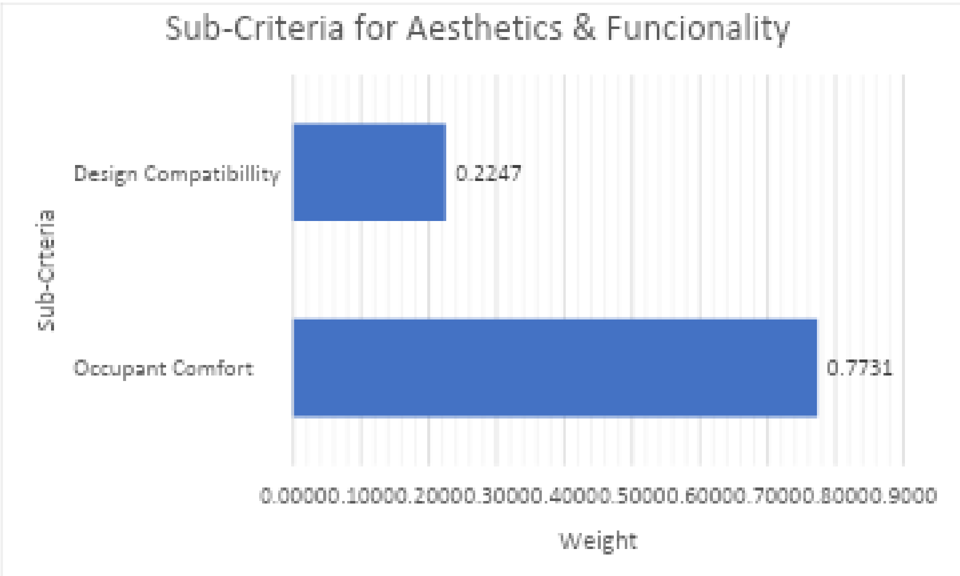


**Fig. 6.** *Data Analysis Results for Sub-Criteria of Aesthetics and Functionality in Villa Material Selection*

**Fig. 2 - Fig. 6** present the results of sub-criterion prioritization within each main criterion for coastal building material selection, visualized as bar charts. Each chart displays the relative priority weight of each sub-criterion, derived from the full ANP analysis of expert questionnaire data.

For example, within Cost Efficiency, maintenance cost emerges with the highest weight, indicating that experts prioritize long-term expenses over initial investment or installation costs—especially relevant in coastal settings where materials must endure harsh conditions and ongoing maintenance challenges. Under Aesthetics and Functionality, occupant comfort carries a greater weight than design compatibility, reflecting the emphasis on creating healthy, comfortable spaces rather than simply following design trends. In Installation Ease, installation time receives the top priority, showing that respondents value quick, resource-efficient construction processes. For Environmental Durability, corrosion resistance stands out as the leading sub-criterion, underlining concerns about saltwater and frequent rainfall accelerating material degradation in coastal regions.

These prioritization patterns are consistent with established theory and coastal construction literature, which highlight durability, lifecycle efficiency, comfort, and constructability as critical factors. Furthermore, the consensus analysis using Kendall's W coefficient consistently yielded a perfect value of 1 for each sub-criteria group, indicating complete agreement among all experts in their rankings. This perfect consensus confirms the reliability and robustness of the sub-criteria weights, making them a scientifically solid foundation for material selection decisions in coastal building projects.

**Priority Calculation of Alternatives Using the TOPSIS Method.** The final preference scores for each material alternative were calculated using the TOPSIS method, which considers all weighted criteria and sub-criteria. These TOPSIS scores reflect the overall performance and relative closeness of each alternative to the ideal solution, allowing for an objective ranking of material options. The detailed TOPSIS results for all evaluated alternatives are presented in **Table 3** - **Table 6**.

**Table 3.** Priority Scores and Ranking of Alternatives for Column Materials

| ALTERNATIVE | PREFERENCE | RANKING |
|---|---|---|
| REINFORCED CONCRETE | 0.9409 | 1 |
| STRUCTURAL STEEL | 0.7586 | 2 |
| TIMBER WOOD | 0.7469 | 3 |

**Table 4.** Priority Scores and Ranking of Alternatives for Roof Structure Materials

| ALTERNATIVE | PREFERENCE | RANKING |
|---|---|---|
| LIGHTWEIGHT STEEL | 0.8938 | 1 |
| CONVENTIONAL STEEL | 0.7607 | 2 |
| TIMBER WOOD/BAMBOO | 0.1856 | 3 |

**Table 5.** Priority Scores and Ranking of Alternatives for Walls Materials

| ALTERNATIVE | PREFERENCE | RANKING |
|---|---|---|
| FIBER CEMENT | 0.9925 | 1 |
| LIGHTWEIGHT BRICK | 0.7671 | 2 |
| RED BRICK | 0.2501 | 3 |
| TIMBER WOOD | 0.0382 | 4 |
| CONCRETE BLOCK | 0.0000 | 5 |

**Table 6.** Priority Scores and Ranking of Alternatives for Walls Materials

| ALTERNATIVE | PREFERENCE | RANKING |
|---|---|---|
| MULTIROOF | 0.9626 | 1 |
| CONCRETE TILE | 0.5997 | 2 |
| CLAY TILE | 0.5423 | 3 |
| NATURAL MATERIALS | 0.0182 | 4 |

**Validation of the Best Alternative with Previous Literature.** The selection of the best material alternatives for each main building component in coastal areas was validated using evidence from previous studies and relevant scientific journals to ensure that all recommendations are empirically grounded and reflect modern building practice [1], [2], [3].

For wall construction, fiber cement emerged as the top-ranked material due to its superior resistance to high humidity, saltwater, mold, termites, and extreme weather, making it especially well-suited for coastal environments. This is supported by experimental studies demonstrating strong durability and low maintenance requirements [4], [5], [6]. Lightweight brick was ranked second, valued for its light weight, rapid installation, good thermal and acoustic insulation, and cost efficiency [7], [8], [9], while red brick, though conventional, is less recommended in coastal environments due to its vulnerability to moisture absorption and faster deterioration without additional protection [10], [11].

For structural columns, reinforced concrete is the preferred choice, supported by literature for its high compressive strength and proven durability against moisture and corrosion in coastal settings[12], [13], [14]. Timber is considered less suitable due to its susceptibility to decay [15], and steel is generally used only for specialized applications [16].

In terms of roof structures, lightweight steel is consistently validated as the optimal material for its low weight, corrosion resistance, ease of installation, and ability to meet structural demands in coastal climates [17], [18]. Conventional steel and timber or bamboo roof frames are typically reserved for specialized or treated applications [19], [20]. Multiroof tiles (sand-coated metal roofing) are recommended as the best roofing cover material, given their proven resistance to corrosion, wind, heavy rain, and temperature fluctuations, along with installation efficiency. Their advantages in thermal insulation and mold resistance for humid, saline environments are also noted [21], [22]. Concrete and clay tiles can be used, but often require stronger support or more frequent maintenance[23], [24].

These validation results, drawn from both field studies and national standards, confirm that the recommended alternatives are fully aligned with scientific evidence and practical experience in modern coastal construction [25], [26].

**Conclusion**

Based on the ANP analysis and expert validation, five main criteria were identified with corresponding weights: environmental durability (0.4844), cost efficiency (0.2652), physical properties (0.1167), ease of installation (0.0789), and aesthetics and functionality (0.0486). Environmental durability emerged as the dominant factor. At the sub-criteria level, the most influential were corrosion resistance (0.6515), maintenance cost (0.6314), heat insulation (0.7701), installation time (0.5419), and occupant comfort (0.3197).

Using these weights in TOPSIS, the preferred alternatives were determined as follows: fiber cement for walls (0.992), reinforced concrete for columns (0.941), lightweight steel for roof structures (0.894), and multiroof for roof covering (0.963). Other options ranked lower, including lightweight and red brick, timber, concrete block, conventional steel, bamboo, concrete tiles, clay tiles, and natural materials.

The reliability of these results is supported by a consistency ratio (CR) below 0.1 and perfect agreement among experts (Kendall's W = 1). Moreover, the findings align with previous studies on tropical coastal construction in Indonesia, reinforcing that the recommended materials offer the best balance of durability, cost efficiency, and practicality for coastal environments.

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