

Multifaceted Role of Construction Materials in Javanese Vernacular Houses

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Abstract

Construction materials have multifaceted roles in traditional vernacular houses. This study explores them within the Javanese vernacular houses in the Saradan village in Wonogiri, Indonesia. It is guided by theoretical frameworks of Gibson's theory of affordances, Pallasmaa's multisensory architecture, Gestalt principles, and Howes' cultural perspectives. It thus investigates their properties, identifies and analyzes the materials used, and ascertains their impact on culture sensory experiences and sustainability.

Data is collected through a comprehensive document survey using VOSviewer software, field observations, photographic documentation, and interviews with local inhabitants and craftsmen. The document survey identifies the thematic clusters relevant to vernacular architecture, while fieldwork provides detailed insights into the materials and construction techniques used in Saradan village. This mixed-method approach ensures a robust analysis of the multifaceted roles of the materials.

The findings reveal that construction materials in Javanese vernacular houses serve several important functions: they provide structural integrity and functionality, uphold culture, enhance sensory experiences, and support sustainable practices. Teak wood and mahogany are preferred for their durability and resistance, bamboo and clay roof tiles promote sustainability, and the tactile and visual qualities of materials enrich the sensory environment. Moreover, these materials contribute to cultural symbolism and environmental adaptation, demonstrating a deep connection between traditional practices and local conditions. This study highlights the importance of preserving traditional building techniques to maintain cultural identity and promote sustainable living.

Keywords: Javanese vernacular houses, Construction materials, Cultural significance, Sustainability, Traditional construction techniques, Sensory experiences

Introduction

The rich cultural heritage embodied in the traditional house architecture is facing significant challenges due to the transformative forces of modernization and globalization. This phenomenon has led to a decline in the values and meanings associated with traditional houses, particularly in regions such as Java, Melaka, and Southeast Asia (Aziz, 2017; Badriyah, 2019; Ju, 2017; Kinanthi, Muqoffa, and Pitana, 2021; Ronarizkia and Giriwati, 2020; Sufyan, Prajnawrdhi, and Agusintadewi, 2020). Factors such as rapid urbanization, changing family structures, economic pressures, and Western architectural influences have contributed to the diminishing importance of these architectural gems (Weichart, 2020; Wijono, 2015). In stark contrast to this trend, the vernacular architecture of Javanese houses in Indonesia remains a testament to the region's rich cultural heritage, environmental adaptation, and sustainable construction practices. These houses exemplify how traditional architecture can coexist harmoniously with the environment, utilizing locally sourced materials and techniques that have been refined over generations. The design of Javanese houses reflects a deep understanding of the local climate and topography, ensuring comfort and durability. Moreover, these structures are imbued with cultural significance, embodying the social and spiritual values of the communities that inhabit them. Despite the challenges posed by modernization and globalization, the vernacular architecture of Javanese houses stands resilient, offering valuable lessons in sustainability and cultural preservation.

This research investigates the materials used in Javanese vernacular houses, drawing insights from the architectural practices and cultural context of the Saradan village in Wonogiri, Indonesia. Existing literature acknowledges the importance of sensory experiences in understanding traditional houses, but there is limited research on the specific construction materials used in Javanese houses and their impact on the overall sensory experience (Chatzigrigoriou et al., 2021; Lah et al., 2015). This study builds upon existing research that focuses on the environmental impact of materials, raw material properties crucial for restoration strategies, thermal performance in different climates, and negotiations between vernacular forms and modern influences (Faisal and Wihardyanto, 2020; Iranfar and Al-Din, 2020; Mendonca and Vieira, 2022; Muşkara and Bozbaş, 2022; Saskia, Susanto, and Suganda, 2020). The research addresses the specific gap concerning the materials used in Javanese vernacular houses, given the unique cultural nuances, climate, and available resources in these regions.

The aim of this research is to contribute to the broader discourse on vernacular architecture, environmental sustainability, and cultural preservation by providing a comprehensive understanding of the materials used in Javanese vernacular houses. The objectives of study are:

- To identify the traditional construction materials used in Javanese houses in Saradan village.
- To analyze the properties and characteristics of these construction materials.
- To understand the role of construction materials in shaping the sensory experiences associated with traditional Javanese houses, sustainability, and cultural significance.
- To identify gaps in the current research on construction materials in Javanese houses, with a focus on Saradan village.

Theoretical Framework

This theoretical framework explores how traditional construction materials contribute to sustainable and culturally resonant architectural practices, with a specific focus on Javanese houses in Saradan village. By integrating diverse theoretical perspectives, it seeks to uncover the interplay between functional cultural, and environmental dimensions of materials used in vernacular architecture.

Importance of Local Context and Adaptability

According to Oliver (1997), the importance of local context in vernacular architecture cannot be overstated. He emphasizes that adaptability to environmental conditions and the

utilization of available materials are foundational elements (Oliver, 1997). Oliver describes vernacular architecture as the human ability to create shelters constrained by the availability of resources and materials, especially in primitive times (Nabakov and Nabokov, 1999). Francaviglia argues that socio-cultural dynamics are pivotal in shaping architectural forms, reflecting communal values and societal norms (Rapoport and Francaviglia, 1969). Paul Oliver's emphasis on local context and material adaptability (Oliver, 1997) aligns with Francaviglia's view on socio-cultural dynamics shaping architectural forms (Rapoport and Francaviglia, 1969). Both perspectives underscore how vernacular architecture emerges organically from its environment, addressing climatic challenges and resource constraints through culturally embedded practices.

Paul Oliver highlights the importance of local context and adaptability in vernacular architecture, asserting that the use of locally available materials and techniques allows buildings to respond effectively to environmental conditions. This adaptability is essential for creating structures that are both sustainable and resilient. In the context of Javanese houses, the use of materials like bamboo and teak wood is a prime example of Oliver's principles. These materials are abundant in the region and possess qualities that make them suitable for the local climate. Bamboo, known for its rapid growth and flexibility, is used for lightweight and durable constructions, while teak wood, valued for its strength and resistance to termites, ensures longevity and structural integrity. These choices are not merely practical but are deeply embedded in the local building traditions and cultural practices, reflecting a harmonious relationship with the environment.

Richard Francaviglia, on the other hand, underscores the socio-cultural dimensions that shape architectural forms. He argues that vernacular architecture is a reflection of communal values, societal norms, and cultural identity. In the case of Javanese houses, the architectural form and material use are imbued with cultural symbolism and social meaning. The joglo roof, a distinctive feature of Javanese houses, is not only designed for effective ventilation and cooling but also symbolizes social status and spiritual beliefs. The elevated platform of the house, often constructed with teak wood, signifies a connection to ancestral traditions and a respect for the natural elements.

The connection between Oliver's and Francaviglia's theories lies in the recognition that vernacular architecture is a product of both environmental adaptation and cultural expression. In Javanese architecture, this connection is evident in how the local materials and construction techniques are chosen not only for their practical benefits but also for their cultural significance. The integration of these materials into the built environment reflects a deep understanding of the local ecological conditions and a commitment to preserving cultural heritage.

Symbolic Functions of Materials

In the context of Javanese architecture, materials carry significant symbolic functions. Mangunwijaya (1992) notes that traditional Javanese houses use materials to create harmony and balance between the physical and spiritual realms. The choice of materials often reflects broader cosmological beliefs and cultural values, emphasizing a holistic approach to architecture (Mangunwijaya, 1992). Similarly, Dakung (1983) highlights those traditional Javanese buildings, including the joglo, are characterized by the use of specific materials and construction techniques that reflect cultural values. The use of teak wood, for instance, is not only due to its availability and durability but also because of its cultural symbolism and spiritual significance within Javanese culture (Dakung, 1983).

In contrast, Balinese architecture uses bamboo extensively but with different symbolic connotations and applications. Bamboo in Balinese architecture is not only a building material but also a medium for artistic expression (Tahmasebinia et al., 2024). It is often used in the construction of temporary structures for religious ceremonies and festivals, symbolizing impermanence and the cyclical nature of life, which are central themes in Balinese Hinduism (Arinasa and Bagus, 2010). The lightweight and flexible nature of bamboo make it ideal for creating intricate and elaborate ceremonial pavilions and offerings, showcasing the Balinese people's craftsmanship and devotion.

The comparison between Javanese and Balinese architecture further reveals how regional adaptations address environmental challenges while maintaining cultural integrity. The symbolic functions of materials in Javanese and Balinese architecture provide deep insights into how regional adaptations address environmental challenges while preserving cultural identity. Javanese architecture emphasizes durability and heritage through the use of teak wood and the practical and symbolic roles of bamboo, reflecting the community's values of strength and harmony with nature. Balinese architecture, on the other hand, showcases the adaptability and artistic expression of bamboo, highlighting the impermanence and spiritual aspects of Balinese culture. Both architectural traditions illustrate the intricate relationship between material use, environmental adaptation, and cultural significance in vernacular architecture.

Sustainability and Community Involvement

According to Hassan Fathy (1973), the use of traditional, locally-sourced materials like mud brick is crucial for sustainability and climate-responsiveness. Fathy's approach is a testament to the enduring relevance of indigenous building techniques and their ecological compatibility (Fathy, 1973). He promotes the use of traditional building methods, particularly mud bricks, and emphasizes the importance of involving the community in the construction process (Fathy, 1973). This approach not only helps reduce costs but also empowers residents, creating a sense of pride and ownership (Fathy, 1973). Moreover, contemporary studies support this by showing that the use of traditional materials and techniques in Javanese architecture is heavily influenced by the tropical climate and the need for thermal comfort (Harjanto and Widarthara, 2021). Natural ventilation and shading devices, commonly seen in Javanese houses, help to reduce the reliance on artificial cooling systems, showcasing a sustainable approach to building design that is both environmentally and culturally sensitive (Satwiko, 1999).

Applying Hassan Fathy's architectural principles to contemporary urban environments poses significant challenges. Urbanization introduces higher population densities, escalating land costs, and stringent building regulations (Angel, 2023). Integrating traditional methods within modern urban contexts necessitates innovative approaches and compromises. For instance, adhering to contemporary building codes often requires modifications to traditional materials like mud brick to meet safety and structural standards, such as fire resistance and seismic resilience (Irsyam et al., 2010; Nugroho, Sagara, and Imran, 2022; Vagtholm et al., 2023). Additionally, urban landscapes prioritize efficient land use, which may conflict with the spatial configurations of vernacular architecture. Balancing these considerations involves exploring alternative materials that mimic traditional properties while conforming to urban demands (He et al., 2020). Moreover, fostering community involvement, a cornerstone of Fathy's approach, remains crucial in urban settings to cultivate a shared sense of pride and ownership in architectural projects. Furthermore, integrating modern technologies like solar panels or water recycling systems into traditional designs requires careful planning to enhance sustainability without compromising the cultural integrity inherent in vernacular architecture. Solutions to these challenges lie in adaptive reuse strategies, where traditional building techniques are innovatively combined with contemporary materials and technologies. For example, integrating mud brick facades with reinforced concrete structures or incorporating passive design principles such as natural ventilation and shading devices into urban vernacular designs.

Moreover, promoting awareness and appreciation of vernacular architecture's benefits—such as sustainability, cultural continuity, and community resilience—among urban planners, policymakers, and the general public is crucial (Jagatramka, Kumar, and Pipralia, 2020; Nguyen et al., 2019). This can foster supportive policies and incentives for integrating vernacular principles into contemporary urban development. Therefore, while adapting Hassan Fathy's principles to contemporary urban contexts presents challenges, innovative approaches can successfully blend traditional wisdom with modern needs. By leveraging local materials, community engagement, and technological advancements, vernacular architecture can

contribute to sustainable, culturally resonant urban environments that meet the challenges of today and tomorrow.

Pattern Language and Non-professional Ingenuity

According to Alexander (1977), recurring patterns in successful vernacular designs can inform contemporary practices to create environments that inherently meet human needs. Alexander, in collaboration with Sara Ishikawa and Murray Silverstein, developed a "pattern language" that includes 253 enduring patterns (Alexander et al., 1977). These patterns describe various problems and propose solutions, enabling ordinary individuals to work together to enhance their environments (Alexander et al., 1977). One practical application of Alexander's principles is seen in the design of communal spaces within vernacular architecture. Integrating small public squares or communal courtyards into these houses fosters social interaction and community cohesion, akin to traditional village squares that serve as focal points for communal activities and celebrations. Another critical aspect of Alexander's pattern language applicable to vernacular houses is the concept of thick walls for thermal mass. Traditional building techniques in vernacular architecture frequently employ thick walls made from locally sourced materials like adobe or stone. By leveraging Alexander's pattern of thermal mass, these walls not only regulate indoor temperatures effectively but also contribute to energy efficiency, crucial in contexts where modern heating and cooling systems may be limited.

Furthermore, according to Rudofsky (1964), the ingenuity of non-professional builders is worthy of celebration. He emphasizes the sophistication and efficiency of vernacular architecture, which arises from necessity and pragmatic responses to environmental challenges (Rudofsky, 1964). Rudofsky showcases the richness of art, functionality, and culture in vernacular architecture, focusing on indigenous tribal structures and ancient dwellings (Rudofsky, 1964). In Javanese and Balinese architecture, the use of local materials such as bamboo and teak reflect Rudofsky's emphasis on resourcefulness. These materials are not only abundant and sustainable but also well-suited to the local climate. Bamboo, for example, is lightweight yet strong, making it ideal for earthquake-prone areas. Its rapid growth rate ensures a continuous supply, aligning with sustainable building practices. The intricate jointing techniques used in bamboo construction, which are often passed down through generations without formal education, demonstrate the kind of practical ingenuity Rudofsky admired. These techniques allow for the creation of structures that are both resilient and aesthetically pleasing, integrating seamlessly with the natural environment.

Moreover, Brunskill (1983) further illustrates regional construction techniques and materials, revealing how local conditions and resources shape building practices. This adaptability and resourcefulness are crucial for understanding how vernacular architecture thrives in various contexts (Brunskill, 1983). In the context of Javanese and Balinese houses, Brunskill's theory is evident in the regional variations of construction techniques and materials. For instance, in coastal areas where stone is more readily available, traditional houses may incorporate coral stone into their foundations and walls, providing durability against the humid climate and saltwater exposure. In contrast, in the mountainous regions of Java, timber from local forests is preferred, reflecting the availability and suitability of this material for the cooler, wetter climate.

In summary, the application of Rudofsky's and Brunskill's theories to vernacular houses highlights the practicality, adaptability, and community-based nature of traditional building practices. These theories underscore the importance of using local materials and techniques that are well-suited to the specific environmental and cultural contexts. Together with Alexander's pattern language, they provide a comprehensive framework for understanding and enhancing vernacular architecture in a way that preserves its heritage while addressing contemporary needs.

Cultural and Poetic Meanings

According to Kenneth Frampton, understanding the cultural and poetic meanings of traditional architecture requires considering material properties, structural logic, and the craft

of making (Frampton, 1995). However, the use of materials like wood and bamboo in traditional Javanese architecture is not just a structural decision but also a cultural one, reflecting the deep connection between the built environment and the cultural practices of the people (Frampton, 1995). Teak wood, known for its durability and resistance to pests, is not only a practical choice but also carries significant cultural symbolism. In Javanese culture, teak is considered a noble material, often used in the construction of important structures such as the joglo houses. The joglo, with its distinctive high-pitched roof supported by a central column (*saka guru*), symbolizes the connection between the earthly and the divine. This architectural form is imbued with spiritual meaning, reflecting the Javanese cosmological view where the house is a microcosm of the universe. The tactile quality of teak wood, with its warm, smooth texture, enhances the sensory experience of the space, aligning with Frampton's emphasis on materiality. The open, airy design of the joglo, which facilitates natural ventilation and light, also resonates with Frampton's advocacy for architecture that responds to the local climate and enhances the lived experience.

According to studies on Javanese architecture, traditional houses are seen as manifestations of cultural values that contain elements of function, meaning, and symbol (Tarigan, Antariksa, and Salura, 2022). The shape of the house is a mode of materializing human existence and serves as a cosmological symbol of self-orientation, reflecting a deep philosophical and spiritual understanding of space and form (Tarigan, Antariksa, and Salura, 2022). These theoretical perspectives are crucial in understanding and interpreting traditional Javanese houses as embodiments of cultural identity and philosophical thought. In both Javanese and Balinese vernacular architecture, the cultural and poetic meanings of materials are deeply embedded in local practices. For instance, the use of *alang-alang* (thatched grass) for roofing in both regions is not only a response to local climate conditions, providing excellent insulation and natural cooling, but also carries cultural significance. The thatched roof is a traditional element that evokes a sense of continuity with the past and a connection to the natural environment.

In summary, the theories of Kenneth Frampton and the perspectives of Tarigan, Antariksa, and Salura reveal how vernacular architecture in Java and Bali is a profound expression of cultural identity, spiritual beliefs, and environmental adaptation. The choice and use of materials like teak, bamboo, and *alang-alang* are not merely functional decisions but are laden with cultural and poetic meanings that reflect the deep connections between the built environment, the natural world, and the spiritual realm. These architectural practices demonstrate how vernacular architecture can achieve a harmonious balance between practical needs and cultural values, creating spaces that are both meaningful and sustainable.

Classical Principles and Vernacular Practices

Applying Vitruvius' principles of *Firmitas* (strength), *Utilitas* (functionality), and *Venustas* (beauty) to indigenous Javanese interpretations can enrich the theoretical framework. According to Pisei and Ikaputra (2020), indigenous Javanese interpretations of these principles reveal a theoretical framework that bridges classical architectural tenets with vernacular practices. *Firmitas*, or strength, is exemplified in the construction of traditional Javanese Joglo houses. These structures utilize durable teak wood for central pillars and an intricate roof truss system, ensuring the structural integrity and resilience needed to withstand the tropical climate. This use of locally sourced, robust materials not only provides physical stability but also connects the architecture to its natural environment. In contemporary practice, the principle of *Firmitas* can be applied by using sustainable materials like cross-laminated timber (CLT) for constructing strong and durable buildings (Greefhorst and Proper, 2011; Wieruszewski and Mazela, 2017). This approach not only enhances structural stability but also promotes sustainability by utilizing renewable resources.

Utilitas, or functionality, is evident in the design of Balinese compound houses, which feature separate pavilions arranged around a central courtyard known as a "*natah*" (Rajendra, 2012). This layout promotes natural ventilation and passive cooling, essential for comfort in a tropical climate. The spatial organization reflects the practical needs of daily life and cultural

practices, ensuring that each area of the house serves a specific purpose. Contemporary architects can draw inspiration from this principle by incorporating bioclimatic design strategies that enhance functionality and energy efficiency (Aghimien, Li, and Tsang, 2022). For instance, passive cooling techniques, flexible spaces, and modular design elements can be integrated into modern buildings to improve their usability and adaptability.

Venustas, or beauty, is manifest in the aesthetic qualities and cultural significance of Ndebele painted houses in South Africa (Van Vuuren, 2008). These houses are adorned with vibrant geometric patterns that not only beautify the structures but also express cultural identity and artistic tradition. This integration of art and architecture creates a visually engaging environment that resonates with the local community. In modern architectural practice, incorporating local artistry and cultural elements can enhance the visual appeal and contextual relevance of buildings. Public art installations, culturally inspired motifs, and biophilic design elements can transform urban landscapes, making them more engaging and meaningful (Cheng et al., 2023).

This framework elucidates how local materials are employed not only for their structural integrity but also for their functional suitability and aesthetic contribution to the built environment (Pisei and Ikaputra, 2020). Applying Vitruvius' principle of *Firmitas* in modern architecture involves selecting materials that provide long-term durability and resilience. Contemporary practices can learn from vernacular techniques by incorporating locally sourced, sustainable materials that enhance structural stability. For example, using cross-laminated timber (CLT) in modern construction provides similar benefits to traditional teak wood, offering strength and sustainability. In addition, according to Gunawan (2019), the adaptability of Joglo structures, focusing on the durability of materials and construction techniques, is crucial for the development of sustainable architecture. This adaptability is a key aspect of Javanese vernacular architecture, where the choice of materials such as teak wood ensures longevity and resilience against the tropical climate (Gunawan, 2019). Therefore, modern architects can apply these principles to create buildings that are not only robust and functional but also aesthetically pleasing and culturally meaningful. Green building certifications like LEED or BREEAM can guide the integration of these principles, promoting innovation and sustainability in contemporary architecture (Burton, 2014). By drawing from the timeless wisdom of Vitruvius, architects can design structures that harmoniously blend tradition and modernity, ensuring longevity, practicality, and beauty in the built environment.

Bioclimatic Design and Modern Relevance

According to Hui Huang et al. (2024), the bioclimatic design strategies used in vernacular architecture offer valuable insights for energy-efficient restoration and contemporary architectural design. Their research shows that these strategies vary based on local conditions and do not always follow the recommendations from the Mahoney Table (H. Huang et al., 2024). Recent debates on climate change and sustainable development have reignited interest in vernacular architecture. Innovations such as bioclimatic design and adaptive reuse of traditional materials offer new pathways for integrating vernacular principles into contemporary architecture, as highlighted by Hui Huang et al. (2024).

Vernacular architecture has long embodied these principles intuitively, making them a valuable source of inspiration for contemporary practices. In traditional adobe houses found in hot, arid climates, thick earthen walls serve as thermal mass, absorbing heat during the day and releasing it at night (Acosta et al., 2010). This passive heating and cooling mechanism stabilize indoor temperatures, reducing the need for artificial climate control. Similarly, Malay houses known as “rumah kampung” in Southeast Asia, elevated on stilts with large operable windows and ventilated roof spaces, promote cross-ventilation (Tahir et al., 2005). This design allows hot air to escape and cooler air to circulate, effectively cooling the interior without mechanical intervention.

In the Middle East, traditional architecture employs *Mashrabiya* screens that provide shade while allowing air flow, reducing solar gain and cooling the interior (Abdelkader and Park, 2018; El Semary, Attalla, and Gawad, 2017; Eljaouhari, Amhamdi, and Bouayad, 2020).

These wooden screens block direct sunlight but let in diffused light, maintaining a comfortable indoor environment. In contrast, traditional Chinese courtyard houses known as Siheyuan are strategically oriented to face south, optimizing solar exposure in winter while using overhanging eaves to provide shade in summer (Tratsiakovich, 2018). This orientation maximizes natural heating and cooling, demonstrating a deep understanding of solar dynamics.

Hui Huang et al. (2024) argue that bioclimatic design should be context-specific, integrating climate data, local traditions, and modern technology to create sustainable buildings. In contemporary architecture, integrating thermal mass can involve using materials like insulated concrete forms (ICFs), which combine thermal mass with high insulation, mimicking the stability provided by traditional adobe walls. ICFs offer superior insulation with R-values between R-18 and R-35, far exceeding the R-10 to R-12 range of traditional wood-framed walls of similar thickness (Hawk and Percer, 2005). Enhancing natural ventilation in modern buildings can be achieved by designing operable windows, ventilated facades, and atriums that facilitate airflow, similar to the passive cooling techniques seen in Malay houses (Anaebonam et al., 2023). Meanwhile, modern shading devices, such as adjustable louvers, brise-soleils, and green facades, can effectively control solar gain (Dim, 2017). Smart glass technology preventing 99.4% of ultraviolet light, which adjusts transparency based on sunlight intensity, offers dynamic shading similar to the passive systems of Mashrabiya screens (Abdel Gelil Mohamed, Hamid Abd El-Rahman, and Sadek, 2023; Al Dakheel and Tabet Aoul, 2017). Furthermore, optimizing building orientation and layout by considering solar orientation and wind patterns can significantly improve energy efficiency (Valladares-Rendón, Schmid, and Lo, 2017). Contemporary urban planning can draw inspiration from the orientation principles of traditional Chinese courtyard houses, using parametric design tools to create facades that adapt to solar exposure dynamically. Moreover, the Bullitt Center in Seattle serves as a case study of bioclimatic design principles applied in a modern context (Tabb, 2020). Designed by the Miller Hull Partnership, the building incorporates advanced glazing, automated exterior blinds, and a rooftop solar array to manage solar gain and produce energy. Its natural ventilation systems, inspired by traditional strategies, ensure high indoor air quality and thermal comfort. This approach not only reduces reliance on mechanical systems but also fosters a deeper connection between the built environment and natural ecosystems.

Thus, the bioclimatic design strategies observed in vernacular architecture, as explored by Huang et al. (2024), provide a robust framework for contemporary architectural practices. By integrating thermal mass, enhancing natural ventilation, utilizing shading devices, and optimizing orientation, modern buildings can achieve greater sustainability and energy efficiency. These strategies underscore the enduring relevance of traditional knowledge in addressing current environmental challenges and promoting harmony between architecture and the natural world.

Sensory Experiences and Cultural Context

According to Gibson's theory of perceptual systems, the role of materials in shaping sensory experiences is fundamental (Gibson, 1966). Gibson expands the classic five senses to include orienting, auditory, haptic, taste/smell, and visual senses, emphasizing that perception is an active process of seeking information through exploration (Covarrubias et al., 2017). In vernacular houses, this theory manifests through the tactile qualities of materials like adobe, timber, or bamboo, which engage the haptic sense as occupants touch and feel the textures of walls or floors. For instance, in adobe houses of the American Southwest, the earthy texture of mud walls and the smoothness of wooden beams contribute to a sensory-rich environment that connects inhabitants with their surroundings on a tactile level (Schroder and Ogletree, 2010).

Furthermore, according to Pallasmaa (1994), there is a need to move beyond the dominance of visual experiences in architecture. He advocates for a multisensory approach that involves other senses such as hearing, smell, and touch, arguing that these senses shape our sensory thinking and contribute to our spatial understanding and cultural perception (Holl, Pallasmaa, and Gómez, 2006). In vernacular houses, this approach is evident in the design of spaces that amplify acoustic qualities or incorporate natural scents from materials like cedar

wood or thatch roofs. For example, in Japanese traditional houses (Minka), sliding doors (shoji) made from paper and wood not only regulate light but also soften sounds, creating an atmosphere conducive to contemplation and auditory comfort.

Gestalt theory, as discussed by Bustamante (2023) and Wertheimer (1912), emphasizes holistic sensory perceptions shaped by cultural contexts, highlighting how materials and architectural forms influence human experiences. This theory emphasizes the importance of considering the whole rather than just the parts in understanding sensory experiences and perceptions (Bustamante, 2023; Wertheimer, 1912). This approach highlights how cultural influences shape our perception and structuring of sensory experiences (Bustamante, 2023; Todorovic, 2008). In vernacular houses, this theory underscores how materials and architectural forms contribute to coherent sensory experiences. For instance, the spatial layout of courtyard houses in Morocco (Riad) promotes visual harmony through intricate tile patterns, carved wooden screens, and geometrically shaped gardens, reflecting Islamic design principles that integrate geometric patterns with symbolic meanings.

Additionally, according to Howes (1991), the cultural context significantly shapes sensory experiences. Each culture accords different importance to various modalities of perception, highlighting how materials and construction techniques influence these experiences in vernacular architecture within specific cultural contexts (Howes, 1991). Each culture assigns different values to sensory modalities, influencing architectural choices and spatial perceptions. For instance, in Balinese traditional houses (Rumah Bali), the use of thatch roofs and bamboo structures not only responds to tropical climates but also reflects a cultural preference for natural materials that evoke a sense of harmony with the environment. The rhythmic sounds of rain on a thatched roof or the scent of bamboo in the air contribute to a sensory landscape that resonates deeply with local cultural values of sustainability and connection to nature.

In conclusion, sensory experiences in vernacular houses are deeply intertwined with cultural contexts, shaping how individuals perceive and inhabit spaces. The theories of Gibson, Pallasmaa, Gestalt, and Howes provide a comprehensive framework for understanding how materials, spatial configurations, and sensory stimuli interact to create meaningful architectural experiences. By embracing these theories, contemporary architects can design spaces that not only prioritize functionality and aesthetics but also foster a profound sensory engagement that honors local traditions and enhances human well-being.

Synthesize Theories and Future Directions

Vernacular architecture encompasses a rich tapestry of theories that collectively contribute to a holistic understanding of how built environments interact with cultural contexts and human experience. These theories, ranging from Gibson's perceptual systems to Juhani Pallasmaa's multisensory approach, Gestalt theory, and David Howes' cultural perspectives on sensory experiences, offer complementary insights into how materials, spatial organization, and sensory stimuli shape architectural perception. In addition, Gibson's theory lays the foundation by expanding the scope of sensory perception beyond the traditional five senses, highlighting how individuals actively engage with their surroundings through orientation, auditory cues, haptic sensations, and more. This perspective is crucial in vernacular architecture, where tactile materials like adobe, timber, or bamboo contribute to a sensory-rich environment that enhances occupants' connection to their cultural and natural surroundings.

Building upon Gibson's framework, Pallasmaa emphasizes the importance of a multisensory approach in architecture, arguing that spaces should evoke sensory responses beyond visual aesthetics. In vernacular houses, this approach manifests through design elements that amplify acoustic qualities, incorporate natural scents from building materials, and create tactile interactions that enrich spatial experiences. For example, in Mediterranean vernacular architecture, the use of stone walls not only provides thermal mass but also offers a tactile and visual connection to the local landscape, enhancing the sensory coherence of the built environment. Gestalt theory further complements these perspectives by emphasizing holistic sensory perceptions shaped by cultural contexts. In vernacular architecture, this theory underscores how materials and architectural forms contribute to a unified sensory experience.

For instance, the layout of traditional courtyard houses in Iran (Ganjali Khan Complex) integrates geometric patterns and lush gardens, creating visually and spatially harmonious environments that reflect Islamic design principles and cultural values of privacy, communal living, and connection to nature. Meanwhile, David Howes' cultural theory extends this discussion by examining how different cultures attribute significance to sensory modalities, influencing architectural choices and spatial perceptions. In vernacular houses across cultures, materials such as thatch, bamboo, adobe, or stone not only respond to environmental conditions but also embody cultural values of sustainability, harmony with nature, and community identity. For instance, in African vernacular architecture, the use of locally sourced materials like thatch roofs and mud walls not only ensures thermal comfort but also reflects a cultural preference for organic materials that resonate with local beliefs and practices.

Moving forward, future research in vernacular architecture should focus on empirical studies that validate these theoretical insights and explore their practical applications in contemporary architectural projects. Empirical research could investigate how specific design strategies informed by Gibson's, Pallasmaa's, Gestalt, and Howes' theories enhance user well-being, environmental sustainability, and cultural identity in modern building practices. For instance, studies could analyze the impact of bioclimatic design principles inspired by vernacular architecture on energy efficiency and occupant comfort in contemporary urban contexts. Moreover, integrating these theoretical frameworks into architectural education and practice can foster a more holistic approach to design that prioritizes sensory engagement, cultural responsiveness, and environmental sustainability. By embracing these insights, architects can create spaces that not only meet functional requirements but also enrich human experience by resonating deeply with cultural narratives and natural environments.

Review of Literature

Vernacular architecture is deeply rooted in the cultural, environmental, and social contexts of its region. According to Rapoport and Francaviglia (1969), vernacular architecture is deeply embedded in the cultural, environmental, and social contexts of a region, reflecting the historical and cultural heritage of the community (Rapoport and Francaviglia, 1969). Similarly, Oliver (1997) emphasizes that vernacular architecture encapsulates traditional wisdom and local craftsmanship, which are pivotal in understanding the architectural identity of a place (Oliver, 1997). In the context of Javanese houses, Rahim, Arham, and Darmawijaya (2021) highlight that these structures are repositories of historical and cultural knowledge, mirroring the adaptive strategies developed over centuries (Rahim, Arham, and Darmawijaya, 2021). This viewpoint aligns with the study on the vernacular architecture of Assam, which underscores the importance of preserving traditional construction techniques and materials within their cultural context (Barman, Roy, and Dasgupta, 2020).

Furthermore, Nasir and Kamal (2021) argue that vernacular architecture inherently promotes sustainability through the use of locally sourced materials and eco-friendly construction techniques (Nasir and Kamal, 2021). They argue that vernacular architecture inherently promotes sustainability through the use of local and eco-friendly materials (Nasir and Kamal, 2021). This theory is supported by research conducted in Ladakh, located in northern India, a region with an extremely harsh environment. The indigenous people of Ladakh have developed efficient and climate-sensitive vernacular architecture, drawing on their ancient understanding of building construction (Nasir and Kamal, 2021). This theory also provides a fundamental framework for rediscovering the characteristics of communities and uncovering contemporary architectural identities worldwide. This perspective is supported by Hu (2023), who discusses the use of low-carbon materials such as wood, adobe, and bamboo in vernacular buildings, contributing to reduced environmental impacts and promoting a circular economy (Hu, 2023). Hu reports on low-carbon materials and construction techniques commonly used in vernacular buildings (Hu, 2023). He identifies eight low-carbon bio-based materials frequently employed in vernacular architecture, including wood, adobe, rammed earth, cob, sod, straw, bamboo, and straw bales. Hu discusses the characteristics, availability, and environmental impact of each of these materials (Hu, 2023). Additionally, he elaborates on the

construction techniques associated with these materials, emphasizing their simplicity, cost-effectiveness, and adaptability. Hu also proposes two key design approaches used in vernacular buildings: design for disassembly and modular design (Hu, 2023). These approaches contribute to waste reduction and environmental impact mitigation, supporting a circular economy in the construction industry. Furthermore, the research by Majumder, Debsarkar et al. (2024) underscores the importance of adapting traditional construction practices to meet modern sustainability challenges, emphasizing the role of renewable energy and sustainable materials (Majumder and Debsarkar, 2024). The study on the sustainable features of vernacular architecture in the Eastern Black Sea Region further emphasizes the role of local materials and techniques in reducing energy consumption and promoting indoor air quality.

Similarly, traditional construction materials used in Javanese vernacular houses include timber, bamboo, and laterite (Nardiati et al., 2023; Saputria and Alimin, 2021). These materials are locally sourced and possess unique properties that enhance the sensory experiences of these structures. Bamboo, for instance, is noted for its durability and resistance to natural disasters (Saputria and Alimin, 2021). Timber, often used for structural elements, is a sustainable and renewable resource, while laterite provides thermal mass, helping regulate indoor temperatures (Nardiati et al., 2023). Moreover, the construction materials in vernacular houses significantly shape sensory experiences (Idham, 2018). Natural materials such as timber and bamboo used in Javanese architecture establish a tactile connection with the environment, while the integration of local colors and patterns enhances cultural significance (Nardiati et al., 2023; Saputria and Alimin, 2021). Similarly, in the Te Papa Museum in New Zealand, the use of natural materials like timber and stone connects visitors to the tactile and sensory qualities of the environment (Harrington et al., 2017). Therefore, it can be demonstrated that various types of materials and textures create diverse sensory experiences and interactions with the built environment.

Sustainable features of Javanese vernacular houses include several passive cooling techniques that enhance their sustainability (Widjaja and Setiawan, 2018). Overhanging eaves provide shade, reducing direct sunlight and minimizing heat gain, while strategically designed openings and windows facilitate natural ventilation, reducing the need for mechanical cooling systems. Additionally, thick mud or stone walls function as thermal mass elements, absorbing heat during the day and releasing it at night to maintain comfortable indoor temperatures. The strategic orientation and layout of Javanese houses maximize natural light and minimize direct sunlight, enhancing indoor comfort and reducing reliance on artificial lighting and cooling systems. Local communities are often involved in the design and construction process, ensuring that the buildings meet their needs and reflect cultural values. This community involvement, coupled with the cultural significance of traditional materials, fosters a strong sense of identity and continuity.

According to Pardo (2023), the primary challenge is integrating modern materials and comfort standards without compromising traditional features (Fuentes and Pardo, 2023). This challenge is significant because vernacular architecture accounts for more than 75% of the world's existing buildings (Fuentes and Pardo, 2023). This challenge is echoed by Faycal, Ilvitskaya et al. (2023), who illustrate the delicate balance between preserving historical identity and evolving to meet modern needs (Faycal, Ilvitskaya, and Lobkova, 2023). They explore the vernacular Kabylean houses constructed from earth, stone, and other local materials. Vernacular Kabylean architecture reflects the principles of vernacular and bioclimatic architecture, forming a foundation for sustainable development. These houses combine architectural expertise without architects, drawing inspiration from their surroundings and creating beautiful architectural compositions (Faycal, Ilvitskaya, and Lobkova, 2023). The use of local materials and respect for the social and cultural values of the local population are central to this architecture (Faycal, Ilvitskaya, and Lobkova, 2023). Meanwhile, according to Laksmiyanti, Poedjioetami et al. (2023), incorporating vernacular architectural features into contemporary projects is crucial for cultural preservation and offers environmental benefits, as demonstrated in their study on the Reog Ponorogo Art Museum in Java (Laksmiyanti et al., 2023). The study on vernacular architecture in Bali echoes these sentiments, stressing the importance of

preserving traditional building practices amidst rapid modernization and tourism (Baskaya, 2024). Bali's architectural heritage, shaped by Hindu, Buddhist, and local traditions, flourishes within its picturesque terraced landscapes (Baskaya, 2024). Traditional Balinese houses, known as "rumah adat," intricately blend with their natural surroundings. Elevated on stilts to safeguard crops from moisture and pests, these homes employ a simple framework of posts, beams, and lintels that distribute weight directly to the ground, often with non-load-bearing walls crafted from wood or bamboo (Baskaya, 2024). Thatching materials like coconut leaves, grass, or rice straw further complement these structures. However, Bali faces a critical juncture as rapid modernization and burgeoning tourism increasingly challenge the preservation of these iconic buildings (Baskaya, 2024). Moreover, the region's vulnerability to climate change and natural disasters underscores the urgent need for sustainable conservation strategies to safeguard Bali's architectural legacy amidst evolving environmental and socio-economic dynamics (Baskaya, 2024). Therefore, despite the extensive body of research on vernacular architecture, there remains a significant knowledge gap concerning the specific materials used in Javanese vernacular houses and their sensory impact.

Chamasemani et al. (2024) discuss the environmental impact of construction materials (Chamasemani et al., 2024). They evaluated the impact of material selection on the carbon footprint of reinforced concrete buildings aimed at reducing embodied carbon. In this study, two reinforced concrete buildings were designed to measure their embodied carbon footprint. The first building used conventional materials such as ceramics, clay bricks, stone, and plaster (Chamasemani et al., 2024). In contrast, the second building incorporated sustainable materials such as cork, plywood, and stone wool (Chamasemani et al., 2024). The findings showed that the use of sustainable materials in the second building reduced the construction process carbon footprint by 41.0% (Chamasemani et al., 2024). Moreover, Y. Huang et al. (2023) examine thermal performance in different climates and the negotiation between vernacular forms and modern influences. The research on PCM-integrated roofs in Moroccan climates, focusing on RT27, RT31, RT35HC, and PT37 PCM types, offers insights into enhancing thermal performance through innovative materials (Y. Huang et al., 2023). Vernacular architecture, rooted in local traditions and materials, often prioritizes passive cooling techniques and natural materials like adobe, stone, and thatch roofs to adapt to regional climates sustainably. However, the introduction of PCM technology into traditional structures raises critical considerations. While PCM integration can potentially improve thermal comfort and reduce energy consumption in modern buildings, its compatibility with vernacular architecture requires careful assessment. Issues such as the adaptation of PCM technology to traditional building methods, the availability and sustainability of PCM materials locally, and the impact on cultural heritage preservation need to be critically evaluated. Integrating PCM into vernacular architecture could enhance comfort and efficiency but must align with the principles of cultural continuity, environmental sustainability, and community involvement that define vernacular architectural practices. Therefore, while PCM research shows promise, its application in vernacular contexts necessitates a balanced approach that respects and integrates local knowledge and practices. Furthermore, Yemoh et al. (2024) examine also the thermal performance across different climates and the interaction between vernacular architectural forms and modern influences. The focus is on evaluating the thermal efficiency of bio-based building envelopes locally produced from composite bricks made of coconut and corn husks. These materials aim to reduce heat transmission through building walls and minimize energy consumption, promoting the adoption of green building practices in hot-humid climates (Yemoh et al., 2024). However, a consolidated exploration of materials used in Javanese houses, emphasizing their cultural, environmental, and sensory implications, is still lacking.

The review of literature reveals a growing awareness of the need to integrate traditional materials and techniques with modern sustainability goals. The work Sarker and Ishtiaq (2018) on the efficiency of traditional building materials in Bangladesh highlights the potential for similar studies in Indonesia to enhance the durability and sustainability of Javanese vernacular houses. They investigate the effectiveness of traditional construction materials in Bangladesh, focusing on their environmental sustainability and energy implications in the building industry.

They employ an integrated method, combining Life Cycle Assessment (LCA) and Material Flow Analysis (MFA) within the circular economy framework, to evaluate the environmental impact throughout the lifecycle of recycled construction materials. Their study underscores the opportunity to integrate recycled materials, which can substantially lower greenhouse gas emissions and conserve energy, thereby promoting the adoption of sustainable construction methods (Sarker and Ishtiaq, 2018).

Moreover, Harjanto and Widyarthara (2021) identify elements of traditional Javanese architecture that could be adapted for contemporary designs, suggesting a pathway for future research (Harjanto and Widyarthara, 2021). They examine the reinterpretation of traditional Javanese architecture for contemporary design concepts, focusing on Balai RW 7. It explores the transformation of five Javanese roof typologies to meet modern design requirements and adapts spatial patterns to accommodate public activities while preserving traditional architectural elements. Ornamental elements inspired by flora, fauna, and cultural beliefs are reinterpreted, blending traditional aesthetics with modern sensibilities. The design considers orientation principles like facing north or south, adapting them to site-specific environmental conditions (Harjanto and Widyarthara, 2021). Modern materials substitute some traditional ones for practicality and sustainability, and specific Javanese roof construction techniques, such as empyak raguman and umpak, are adapted using alternative materials (Harjanto and Widyarthara, 2021). This study provides insights for architects aiming to integrate Javanese architectural heritage into contemporary built environments. In addition, Hardiilla and Nugroho (2020) emphasize the role of vernacular architecture in resilience planning, indicating an opportunity to explore how these principles can be applied to modern urban challenges (Hardiilla and Nugroho, 2020). They discuss resilience capacity planning for vernacular architecture in Lampung, Indonesia, exploring its role in addressing climate change, disaster risk, and local food security, all while preserving cultural heritage (Hardiilla and Nugroho, 2020).

The review of literature underscores the pivotal role of vernacular architecture in addressing contemporary challenges through its inherent sustainability, cultural preservation, and community resilience. By examining studies from various regions such as Javanese houses, Ladakh, and the Eastern Black Sea Region, a clear pattern emerges: vernacular architecture not only adapts to local environmental conditions but also embodies sustainable practices through the use of indigenous materials and passive design strategies. Nasir and Kamal's (2021) exploration of eco-friendly construction techniques and Hu's (2023) analysis of low-carbon materials exemplify how vernacular architecture aligns with modern sustainability goals. These studies collectively illustrate how integrating traditional wisdom with contemporary environmental principles enhances architectural resilience and fosters sustainable development. Moreover, the emphasis on community involvement in design and construction processes, as highlighted in studies by Rahim, Arham, and Darmawijaya (2021) and Laksmiyanti et al. (2023), reinforces the social and cultural dimensions of vernacular architecture, thereby reinforcing local identity and fostering community cohesion. By explicitly connecting these studies, it becomes evident that vernacular architecture serves as a paradigm for sustainable building practices that prioritize both environmental stewardship and cultural continuity.

The exploration of construction materials in Javanese vernacular houses reveals a nuanced landscape characterized by significant research achievements alongside notable deficiencies. Studies by Nardiati et al. (2023), Saputria and Alimin (2021), and Hu (2023) have shed light on traditional materials such as timber, bamboo, and laterite, providing valuable insights. However, the incorporation of these materials into modern technologies and sustainable practices remains inadequately explored. Divergent findings concerning their adaptation to contemporary needs underscore the necessity for more comprehensive research that harmonizes traditional craftsmanship with evolving environmental and cultural imperatives. Furthermore, despite occasional mentions in the literature, there exists a lack of a cohesive framework to guide sustainable conservation efforts in Javanese architectural heritage, particularly concerning the sensory and cultural impacts of these materials. Addressing these knowledge gaps is pivotal for advancing our comprehension of how construction materials

influence the sustainability, cultural significance, and community resilience of Javanese vernacular houses. Therefore, while considerable research exists on the cultural and sustainable aspects of vernacular architecture, there is an urgent call for focused investigations into the specific materials employed in Javanese vernacular houses. Such endeavors should aim to comprehensively document and analyze these materials' roles in promoting sustainability and preserving cultural heritage, thereby bridging current gaps in scholarly understanding. The integration of traditional materials with modern sustainable practices presents a promising avenue for future research, enriching both academic discourse and practical applications within the construction industry.

Research Methodology

Research approach

This study advances the discourse on vernacular architecture, environmental sustainability, and cultural preservation by providing a nuanced understanding of construction materials used in Javanese vernacular houses in Saradan village, Baturetno district, Wonogiri regency. It employs a qualitative approach utilizing a case study methodology, selected for its capacity to offer detailed insights into the complex dynamics of Javanese architecture. The research is grounded in a theoretical framework that integrates cultural geography and phenomenology. This framework elucidates how traditional construction materials shape sensory experiences and cultural significance within Javanese house architecture. Central concepts such as sense of place, cultural perceptions, and sustainability guide both the research questions and methodological choices.

Case Study Selection

The selection of Saradan village in Baturetno district, Wonogiri regency, Indonesia, as the case study site was based on specific criteria as follows,

1. **Architectural Heritage:** Saradan village is renowned for its historical significance and its commitment to preserving traditional Javanese house architecture. This makes it an ideal location to study the evolution and persistence of these architectural practices over time.
2. **Cultural Significance:** The village embodies cultural values and practices deeply rooted in Javanese traditions. Studying Saradan allows researchers to explore how architectural elements contribute to and reflect cultural identity.
3. **Representativeness:** By selecting Saradan village, the research provides insights that can be extrapolated to understand broader architectural practices across Java, ensuring that the findings are not only insightful for Saradan but also applicable in a regional context.

Data Collection Methods

The research employed a variety of methods to gather comprehensive insights into Javanese vernacular architecture and its use of construction materials:

1. Literature Survey using VOSviewer:

- Conducted a systematic review of scholarly literature focusing on Javanese vernacular architecture and construction materials.
- Utilized VOSviewer to analyze and visualize key literature, identifying themes and gaps related to materials, sense of place, and cultural perceptions.
- Search criteria and keywords included terms related to traditional Javanese construction, cultural heritage, and sustainability.

2. Field Observations:

- Conducted detailed field observations to document physical attributes such as roof designs, material types (wood, bamboo), and spatial arrangements.
- The sampling strategy involved selecting a representative set of houses based on age, preservation state, and architectural features.
- Observations were carried out by the research team between January 2023 and December 2023.

3. Photography:

- Photographs were taken to capture architectural details and aesthetics, systematically stored, and analyzed to complement observational data.
- Visual documentation served as both illustrative and analytical tools, enhancing qualitative observations.

4. Semi-Structured Interviews:

- Developed interview guides focusing on experiences, perceptions, and cultural interpretations related to construction materials.
- Conducted interviews with local architects, designers, craftsmen, and community members, each lasting approximately 60-90 minutes.

Data Analysis

- Thematic Content Analysis: Employed thematic content analysis to analyze qualitative data from literature, field observations, and interviews. The coding process involved developing, applying, and refining codes to uncover patterns and themes.
- Triangulation: Integrated findings from different data sources through triangulation to ensure robustness and comprehensive insights.

Ethical Considerations

- Ethical approval and responsibilities were obtained from the LPPM, and the confidentiality and rights of participants were safeguarded through data anonymization and the acquisition of informed consent.

Overview of the Case Study

Saradan Village, located in the Baturetno district of Wonogiri regency in Central Java, Indonesia, serves as a prime example of traditional Javanese vernacular architecture. This village is renowned for its rich historical and cultural heritage, which is deeply embedded in its architectural practices. The selection of Saradan Village as the case study site is motivated by its exceptional preservation of traditional Javanese house forms and construction materials, making it an ideal location for examining the intersection of architecture, environmental sustainability, and cultural preservation. Saradan Village is situated in the southern part of Wonogiri regency, which lies in the southeastern region of Central Java. The village is approximately 70 kilometers from the city of Surakarta, a major cultural and economic hub in Central Java as shown in Fig. 1. The geographical coordinates of Saradan Village are approximately 7.97520° S latitude, 110.94545° E longitude. The village is accessible via local roads connecting it to the district center of Baturetno and other surrounding areas.

Saradan Village is characterized by its rural landscape, with lush greenery, terraced fields, and a mix of natural and built environments that reflect traditional Javanese rural life.

The village has a population of around 4,523 residents, consisting of 50.83% men and 49.17% women (Wonogiri, 2020). There are 1546 households, resulting in an average of 3 residents per household in Saradan village (Wonogiri, 2020). The primary occupations of the villagers include agriculture, small-scale crafts, and traditional industries. The social fabric of the village is closely knit, with strong communal ties and a collective commitment to preserving their cultural heritage. The built environment of Saradan Village is dominated by traditional Javanese houses, known as "rumah adat Jawa," which exhibit distinctive architectural features such as joglo roofs, wooden structures, and intricately carved ornaments. These houses are constructed using locally sourced materials such as teak wood, bamboo, and clay, which not only embody the local craftsmanship but also promote environmental sustainability through the use of renewable resources.

The architectural heritage of Saradan Village is a testament to the enduring legacy of Javanese craftsmanship and design principles. The traditional houses in the village are typically laid out in a linear arrangement along narrow lanes, with each house compound featuring a main house (omah), secondary buildings, and open courtyards. The joglo roof, with its steeply pitched form and layered structure, is a prominent feature that signifies the social and cultural status of the inhabitants. The construction techniques used in these houses are rooted in age-old traditions that have been passed down through generations. Carpenters and craftsmen employ traditional joinery methods without the use of nails, ensuring that the structures are both resilient and aesthetically pleasing. The intricate wood carvings and decorations on the houses often depict symbolic motifs that reflect Javanese cosmology and spiritual beliefs. Saradan Village is not only significant for its architectural heritage but also for its role in preserving the cultural and social practices of the Javanese people. The village is a living museum where traditional ceremonies, festivals, and rituals are regularly observed, providing a dynamic context for understanding the relationship between architecture and culture. The village's commitment to maintaining its architectural and cultural heritage has made it a focal point for studies on vernacular architecture and cultural preservation.



Fig. 1: Location Map of Saradan Village and Surakarta City

Source: google maps

Findings

Key Insights from Scholarly Work on Vernacular Architecture

Based on a thorough review of 7,026 scholarly works focused on vernacular architecture, several key insights emerge across diverse fields of study as shown in Fig. 2.

Dominant disciplines such as Vernacular architecture (3,354 documents), Architecture (3,243), and Vernacular (3,055) indicate robust academic interest and interdisciplinary research into traditional building practices. This is complemented by significant contributions from Geography (2,149) and Engineering (1,721), highlighting the comprehensive approach to understanding vernacular architecture's technical and geographical contexts.

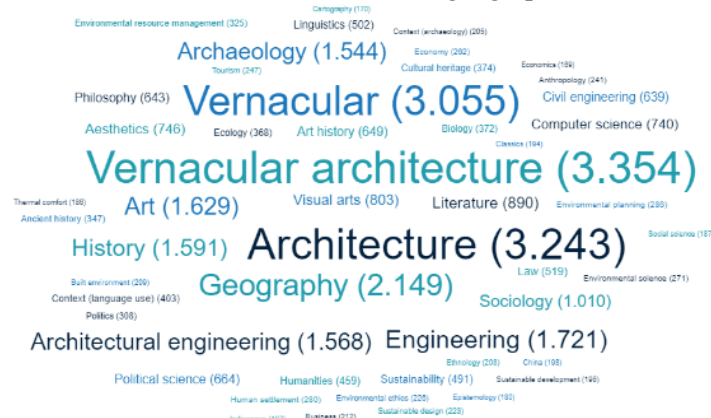


Fig. 2: Thematic Distribution of Scholarly Works on Vernacular Architecture
Source: Lens.org

Interdisciplinary perspectives from fields like Art (1,629), History (1,591), and Archaeology (1,544) enrich our understanding by integrating cultural, historical, and archaeological insights into these architectural forms. Social perspectives from Sociology (1,010), Literature (890), and Visual Arts (803) provide nuanced analyses of societal values, artistic expressions, and cultural symbolism inherent in vernacular architecture. Moreover, Environmental concerns are addressed through contributions from Sustainability (491) and Environmental Science (271), emphasizing the importance of eco-friendly practices and environmental stewardship in architectural discourse. Policy dimensions from Political Science (664), Law (519), and Economics (169) highlight legal, economic, and policy frameworks influencing the preservation and adaptive reuse of vernacular structures amidst urbanization.

Ethical considerations are evident in Cultural Heritage (374), Ethics (226), and Indigenous Studies (197), underscoring efforts to preserve diverse cultural identities and heritage through vernacular architecture. Theoretical frameworks from Philosophy (643), Epistemology (180), and Anthropology (241) contribute methodological approaches that deepen scholarly discourse on traditional building practices and community-centered architectural solutions. Meanwhile, practical applications in Sustainable Design (223), Business (212), and Tourism (247) demonstrate how vernacular architecture promotes sustainable development, economic resilience, and cultural tourism globally. These findings collectively highlight the multifaceted significance of vernacular architecture in addressing contemporary challenges, blending traditional knowledge with innovative approaches to foster sustainable, culturally resonant built environments worldwide. Continued interdisciplinary research and collaboration are crucial for advancing knowledge and enhancing the global relevance of vernacular architecture.

Distinct Thematic Clusters from Scholarly Work in Material Vernacular Architecture Research in Indonesia

Based on a comprehensive review of 7,026 documents on vernacular architecture, 74 articles specifically address material vernacular architecture in Indonesia. Drawing on an extensive analysis of these 74 scholarly works from the Scopus database, distinct thematic clusters have been identified using VOSviewer 1.6.19. Each cluster is characterized by specific research foci and is color-coded for clarity, as illustrated in Fig. 3.

Cluster 1, depicted in red, comprises 14 items centered on architectural elements and cultural heritage. This cluster includes topics such as architectural elements, cultural heritage,

Furthermore, an in-depth analysis of scholarly works reveals the diverse range of building materials employed in vernacular architecture as shown in Fig. 4, each making unique contributions to architectural heritage, sustainability, and cultural identity. Below is a summary of these materials and their significance:

1. **Adobe:** Adobe is recognized for its sustainability and excellent thermal properties. Widely studied, adobe's historical use and contemporary applications continue to draw attention due to its ability to regulate indoor temperatures naturally and its minimal environmental impact.
2. **Rammed Earth:** Rammed earth is valued for its durability and low environmental impact. Research often focuses on the technical aspects and cultural significance of this material, highlighting its robustness and sustainable attributes in various climatic conditions.
3. **Bamboo:** Bamboo is noted for its strength, flexibility, and rapid growth. Studies explore bamboo's structural capabilities, environmental benefits, and cultural contexts, emphasizing its potential as a sustainable and versatile building material.
4. **Brick:** Brick is prized for its durability and aesthetic appeal. Scholarly attention often emphasizes local variations in brick-making techniques and their integration into vernacular architecture, reflecting regional craftsmanship and material adaptability.
5. **Composite Material:** Composite materials are valued for their enhanced structural properties and sustainability. Research investigates their performance in diverse environmental conditions, exploring their potential to improve the resilience and sustainability of vernacular buildings.
6. **Masonry:** Masonry's geological properties and construction techniques make it integral to vernacular construction. Studies focus on the historical evolution of masonry practices, underscoring their importance in maintaining structural integrity and aesthetic continuity.
7. **Wood:** Wood, with its renewable nature and aesthetic appeal, is explored for traditional timber framing methods and sustainable forestry practices. Research highlights its role in vernacular architecture, emphasizing both environmental and cultural sustainability.
8. **Thatch:** Thatch is valued for its insulation properties and cultural significance. Studies examine regional variations in thatching techniques, illustrating how local knowledge and materials contribute to efficient and sustainable roofing solutions.
9. **Stone:** Stone is noted for its durability and aesthetic value. Research highlights the geological properties and architectural integration of stone in vernacular buildings, showcasing its long-lasting and visually appealing characteristics.
10. **Earthen Materials:** Earthen materials, including clay and mud, are fundamental to vernacular building traditions. Known for their thermal properties and environmental sustainability, these materials are extensively studied for their role in creating comfortable and eco-friendly living environments.

The findings illustrate the diverse range of building materials used in vernacular architecture, each contributing uniquely to architectural heritage, sustainability, and cultural identity across different regions. The rich variety of materials and their applications highlight

the ingenuity and adaptability of traditional architectural practices, offering valuable lessons for modern sustainable development.

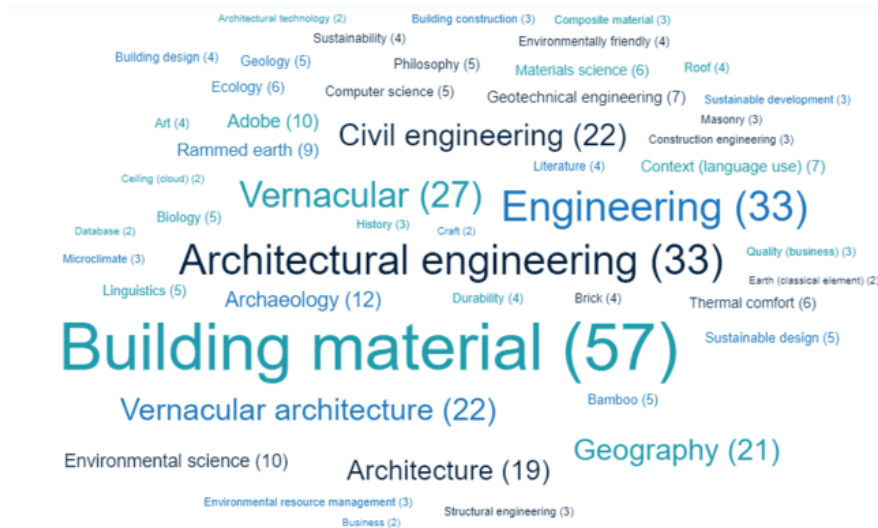


Fig. 4: Materials Commonly Discussed in Scholarly Works and Used in Vernacular Architecture
Source: Lens.org

Case Study Findings of Javanese Vernacular Houses

Vernacular architecture embodies a synthesis of cultural heritage, environmental adaptation, and sustainable building practices. This study investigates the construction materials utilized in Javanese vernacular houses, specifically in Saradan village, Wonogiri, trying to elucidate their roles in sensory experiences, sustainability, and cultural preservation. The research draws upon theories from Gibson, Pallasmaa, Gestalt, and Howes to explore how these materials shape architectural perception and community identity.

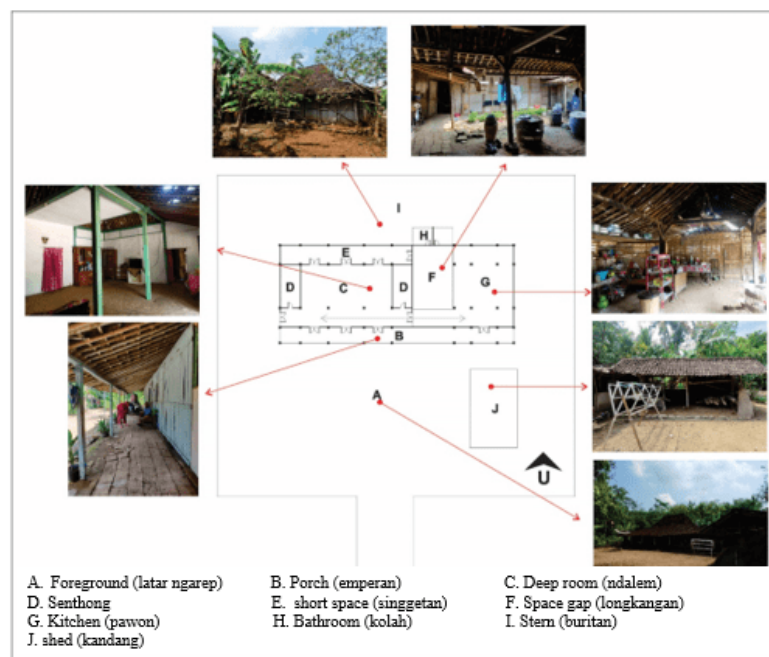


Fig. 5: Form, Space, Orientation, and Roof Structures of Traditional Javanese Houses in Saradan Village
Source: Authors

Saradan Village, situated at coordinates 7.97520° S latitude, 110.94545° E longitude, with an elevation of 149 meters above sea level, the village's terrain features rocky ground, black soil, and red soil. The traditional dwellings, referred to as "Omah Gedhe," comprise two distinct primary spaces, namely the deep room (ndalem, C) and the kitchen (pawon, G). The deep room is surrounded by the senthong (D) and a short space (singgetan, E), while the kitchen is enclosed by a space gap (longkangan, F) and a bathroom (kolah, H). At the back of the house, there is a stern (buritan) used for cultivating crops. On the front side, there is a porch (emperan, B), foreground (latar ngarep, A), and a shed (kandang, J). The porch, also known as emper or emperan, functions as an initial reception area situated outdoors, extending from the main house to the pawon, with additional overhangs covering the entire residence. The jogan serves as the central space, fulfilling various roles as a family room, reception area, and a venue for traditional activities. In contrast to the conventional placement at the rear in Javanese houses, the senthong is positioned on either side of the jogan. The rear part of the jogan includes the singgetan, essentially a hallway designated for storing crops and other unused items. The pawon, typically located on the east side of Omah Gedhe, maintains its position regardless of the house's orientation (refer to Fig. 5).

In Saradan Village, situated within Wonogiri Regency, this study employs triangulation to integrate insights from various data sources, ensuring a comprehensive analysis of traditional Javanese house architecture. The orientation of houses towards the south, as depicted in Fig. 5, is corroborated through geographical analysis and interviews with local residents and craftsmen. Geographically, the southern orientation is influenced by the village's terrain, impacting solar exposure and airflow dynamics. Interviews reveal that this orientation is rooted in local beliefs of security and stability, underscoring its cultural and spiritual significance within the community.

The distinctive roof structures, also shown in Fig. 5, are examined through architectural documentation and interviews with craftsmen. This triangulation elucidates how roof designs not only meet functional requirements but also embody cultural identity and craftsmanship traditions. A notable feature is the roof crafted from fired-clay, showcasing styles such as the pyramid-shaped design for the primary structure with spacious open room layouts and multi-tiered roof shapes for the kitchen. Historical records complement these insights by tracing the evolution of roof styles over time, highlighting their cultural continuity and adaptation to local climatic conditions.

The use of construction materials—such as timber, bamboo, and fired-clay tiles—is analyzed through material testing and interviews with local builders. Fig. 6 provides context on Saradan Village's climate, with temperatures ranging from 18°C to 36°C and humidity levels between 85.9% and 92.0%. To cope with the hot weather, the traditional Joglo house design is employed, featuring a spacious interior (Omah Gedhe) with an average area of 12 x 12 m². The pyramid-shaped Joglo, with a height from the floor ranging between 4 and 5 meters, creates a voluminous effect in the Omah Gedhe, acting as a thermal sink. This design ensures that Omah Gedhe receives sufficient light and comfortable airflow during the day without the need for air conditioning or fans. Additionally, these environmental conditions, which are hot and humid, influence material selection and architectural design to enhance thermal comfort and sustainability.

Interviews with craftsmen provide practical knowledge on the properties of local materials, revealing how bamboo and timber offer natural ventilation and thermal regulation despite challenges like humidity-related issues. The use of wood or bamboo for walls, doors, and windows allows natural infiltration. However, these materials can be susceptible to the humid conditions, promoting the growth of mold, termites, and decay, leading to warping and rotting of wood or bamboo boards or beams. Therefore, traditional practices involve treating bamboo and wood before use as construction materials, such as immersing them in river mud for three months and allowing natural drying for up to six months.

Furthermore, the study integrates findings on construction practices, including traditional methods for treating bamboo and timber to enhance durability. These practices are informed by local knowledge and craftsmanship, reflecting sustainable approaches to resource

management and cultural preservation. The collective insights from this triangulated approach underscore the intricate relationship between cultural heritage, environmental adaptation, and sustainable building practices in traditional Javanese house architecture.

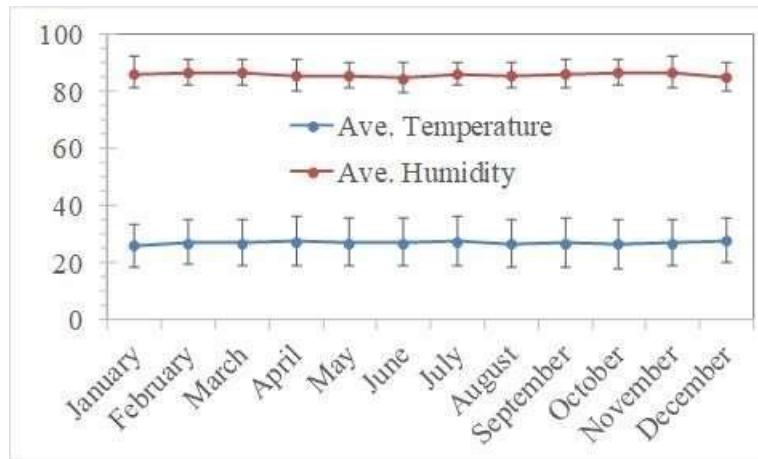


Fig. 6: Climatic Conditions in Saradan Village

Source: BMKG Wonogiri

Findings of Materials in Traditional Javanese Architecture

When examining different wood types commonly used in construction, their distinctive attributes play a crucial role in determining their suitability for specific purposes. Teak wood (*Tectona grandis*) stands out due to its elevated density, moderate compressive strength, and remarkable modulus of elasticity, making it a durable choice for outdoor structures in Saradan's hot and humid climate (Colbu et al., 2021; Wibowo and Sulisty, 2021). Achieving a balance between moderate density, high compressive strength, and a smooth texture, Mahogany (*Swietenia macrophylla*) offers versatility in crafting furniture (Colbu et al., 2021). *Intsia* spp., characterized by very high density and dimensional stability, presents itself as an excellent option for decorative purposes and applications requiring resistance to defects during the drying process (Chin, Baharuddin, and Mustapha, 2021; Prasetya et al., 2021). Conversely, Bangkirai wood (*Shorea laevifolia*), with its low compressive strength and hygroscopic nature, might find utility in contexts where flexibility and adaptability to changing environmental conditions are paramount (Dwi Laksono, Basyaruddin, and Adlina, 2019). In the realm of vernacular building materials, Sonokeling wood (*Dalbergia latifolia*) stands out due to its exceptionally high density, making it a preferred choice for crafting durable and high-quality wooden products (Colbu et al., 2021). Conversely, *Melia azedarach* Linn (Mindi), with its low density and limited dimensional stability, is not recommended for construction purposes (Pramana gentur Sutapa, 2020; Praptoyo, 2010).

The material analysis of traditional Javanese houses in Saradan village reveals a composition of wood, bamboo, and clay, with teakwood dominating the primary construction due to its high density, resilience, and pest resistance, albeit at a higher cost. Cheaper wood alternatives, such as mahogany and sonokeling, are specifically utilized for walls, doors, and windows. In some traditional Javanese houses, bamboo has been entirely replaced by wood, especially in the deep ndalem sections, while it is still utilized in the kitchen and shed areas. The roof is constructed from fired clay. As local materials diminish in availability and increase in price, the choice between bamboo and wood as building materials becomes crucial for traditional Javanese vernacular houses (Akinlabi, Anane-Fenin, and Akwada, 2017; Hartono et al., 2022).

Table 1 offers a comparative analysis of wood properties, emphasizing Teak, Mahogany, *Intsia* spp., Bangkirai, Sonokeling, and *Melia azedarach* Linn. Teakwood, with a density of 655 kg/m³, exhibits stability against temperature variations and resistance to pests.




Conversely, Mahogany offers moderate dimensional stability with a density ranging from 495 to 545 kg/m³. *Intsia* spp. boasts high density and stability, while Bangkirai wood has lower compressive strength and hygroscopic behavior. Sonokeling wood stands out for its exceptionally high density, while *Melia azedarach* Linn is not recommended for construction due to low dimensional stability and significant shrinkage rates.

Table 2 provides a comparison of bamboo properties, including Kuning Bamboo, Betung Bamboo, *Bambusa vulgaris*, and *Bambusa arundinacea*. Bamboo, with its various species, exhibits a wide range of physical, chemical, and mechanical properties. Kuning Bamboo has the lowest density, while Betung Bamboo boasts the highest density. Compressive strength in *Bambusa vulgaris* and Betung Bamboo surpasses that of some wood species, reaching values of 113.54 MPa and 98.80 MPa, respectively. Additionally, *Bambusa arundinacea* demonstrates impressive tensile strength (114 MPa) and modulus of elasticity (126.2 MPa (Akinlabi, Anane-Fenin, and Akwada, 2017; Hartono et al., 2022)).

When comparing bamboo to wood for traditional Javanese vernacular houses, several considerations arise. Bamboo, with its rapid growth and renewability, presents an environmentally sustainable option. Its impressive compressive strength and tensile strength make it suitable for load-bearing structures. Additionally, bamboo's versatile nature allows for a range of design possibilities. Wood, on the other hand, provides a diverse array of species with varying properties, catering to different construction needs. Teak, Mahogany, and *Intsia* spp. offer high-density options with excellent stability, making them suitable for various structural elements. The choice between bamboo and wood for Javanese vernacular houses depends on factors such as availability, environmental considerations, structural requirements, and traditional building practices within the specific cultural context of Java. Each material brings its unique set of advantages, and a thoughtful evaluation of these properties will guide the selection process for constructing sustainable and culturally resonant dwellings.

Table 1: Comparative Analysis of Wood Properties

Source: Author

Materials	Image	Properties	Ref
Tectona grandis (Teak) Wood		<ul style="list-style-type: none"> - Density: 655 kg/m³ - Compressive Strength: 54.8 MPa - Elasticity Modulus: 12.28 GPa - Physical Structure and Texture: Straight grains, occasionally wavy or interlocked, coarse, uneven texture. - Stability: Excellent stability against temperature fluctuations, low shrinkage, and swelling. - Other Characteristics: Exhibits durability and resistance to pests. 	(Colbu et al., 2021; Wibowo and Sulisty, 2021)
Swietenia macrophylla (Mahogany)		<ul style="list-style-type: none"> - Density: 495-545 kg/m³ - Compressive Strength: 87.99 N/mm² - Elasticity Modulus: 18000 N/mm² - Physical Structure and Texture: Red to pink tone, smooth, easy to cut, and shape. - Thermal Conductivity: 0.36 W/mK - Stability: Resistance against stem borers, moderate dimensional stability. 	(Anoop et al., 2014; Langbour et al., 2011)
Intsia spp. (Merbau)		<ul style="list-style-type: none"> - Density: 815 kg/m³ - Compressive Strength: 73.4 MPa - Elasticity Modulus: 15.93 GPa - Physical Structure and Texture: Rough texture, smooth and polished when touched. - Stability: High dimensional stability, low shrinkage rate. 	(Chin, Baharuddin, and Mustapha, 2021; Prasetya et al., 2021)
Shorea Laevifolia (Bangkirai)		<ul style="list-style-type: none"> - Compressive Strength: 7.03 MPa 	(Dwi Laksono, Basyaruddin, and








Materials	Image	Properties	Ref
		- Physical Structure and Texture: Hygroscopic, anisotropic behaviour.	Adlina, 2019; Sutandar, Juniardi, and Syahrudin, 2021)
Dryobalanops aromatica (Kamper)		- Elasticity Modulus: 13.26 GPa	(Chauf, 2005)
Dalbergia latifolia (Sonokeling)		- Density: 830 kg/m ³	(Safitri, n.d.)
Melia azedarach Linn (Mindi)		- Density: 416 kg/m ³ - Low Stability: Not recommended for wood construction due to low dimensional stability. - Shrinkage: 3.94% (longitudinal), 5.74% (tangential), 2.60% (radial).	(Pramana gentur Sutapa, 2020; Praptoyo, 2010)

Table 2: Comparative Analysis of Bamboo Properties

Bamboo	Image	Properties	Ref
Kuning Bamboo (B. vulgaris var. vittata)		- Striking yellow or golden-yellow culms (stems) and green stripes - Density: 490-703 kg/m ³ - Compressive strength: 43 – 113.54 MPa - Modulus elasticity: 5668-15543 MPa	(Akinlabi, Anane-Fenin, and Akwada, 2017;
Betung Bamboo (Dendrocalamus asper)		- Large and sturdy culms - Density: 485-734 kg/m ³ - High compressive strength: 42-65 MPa - Modulus elasticity: 1163-10672 MPa	Ardhyananta et al., 2014; Hartono et al., 2022; Salzer et al., 2018;
Bambu duri (Bambusa arundinacea or Bambusa blumeana)		- Compressive strength: 20 MPa - Tensile Strength: 95-114 MPa - Shear strength: 5 MPa - Bending strength: 34.6 MPa - Modulus of elasticity: 126.2-23600 MPa	Sattar, Kabir, and Bhattacharjee, 1994)

Discussion

Role of Construction Materials in Sensory Experiences, Sustainability and Cultural Significance in Traditional Javanese Vernacular Houses

In the context of traditional Javanese vernacular houses, particularly in Saradan Village, Wonogiri, the role of construction materials is pivotal in shaping sensory experiences, sustainability, and cultural significance. These materials not only contribute to the structural integrity but also significantly impact the overall aesthetic, comfort, and functionality of these dwellings. Wood, bamboo, and clay roof tiles, integral to the architectural framework, serve a tripartite function in ensuring structural integrity, promoting sustainability, and embodying cultural identity. Meanwhile, wood and bamboo, possessing distinctive characteristics, contribute to creating unique sensory experiences within these traditional houses. Teak wood, renowned for its high density and elasticity modulus, is chosen for its durability in both indoor and outdoor applications. Meanwhile, Mahogany (*Swietenia macrophylla*), prized for its versatility and smooth texture, finds its optimal use in crafting doors, windows, and furniture, adding to both functionality and aesthetic appeal. Moreover, *Intsia* spp. and Sonokeling wood, characterized by high density and dimensional stability, serve decorative purposes and are occasionally utilized as substitutes for teak wood. The various textures, colors, and scents of these woods collectively contribute to creating a warm and natural ambiance within the living spaces. Teak, Mahogany, and *Intsia* spp., each with their specific characteristics, allow for a diverse yet cohesive architectural language.

In terms of sensory experiences and perceptions of the rural community in Saradan, Wonogiri, it is evident that the color and texture of teak wood hold greater prominence compared to other wood types. Teak wood, revered as a symbol of strength, durability, and permanence, exhibits a dark brown color and robust texture, symbolizing courage, stability, and peace. In contrast, the shades of pink to deep red in mahogany wood are associated with indicators of luxury and beauty. Mahogany becomes the preferred choice for crafting furniture or art items with high aesthetic value when teak wood is either unavailable or priced unreasonably. Meanwhile, Sonokeling wood, characterized by its dark brown to black color and visible grain, is considered exotic and possesses high artistic value. Sonokeling, along with Merbau wood, becomes the alternative selection when teak and mahogany are either unavailable or priced prohibitively high, showcasing the adaptability of construction material choices.

In exploring the role of construction materials in sensory experiences in traditional Javanese vernacular houses, bamboo emerges as a rapidly growing and remarkably robust option, offering an environmentally sustainable alternative that enhances tactile sensations. With its impressive compressive and tensile strength, bamboo becomes a suitable choice for load-bearing structures, showcasing its diverse properties in species like Kuning Bamboo (*B. vulgaris* var. *vittata*) and Betung Bamboo (*Dendrocalamus asper*), opening up a wide array of design and construction possibilities. The perception of bamboo's color and texture by Javanese communities in Saradan village is intricately linked to local customs, traditions, and the practical applications of bamboo in their daily lives. The three distinct bamboo types—Kuning Bamboo, Betung Bamboo, and Bambu Duri—are perceived uniquely within this context.

Kuning Bamboo, characterized by its yellow hue and green stripes, is viewed as refreshing and connected to themes of fertility and abundance. Its smooth texture and tightly woven fibers make it an ideal choice for various crafts and decorations, appealing to the aesthetic preferences of the Javanese people. Moreover, Betung Bamboo, with its natural green to brown color or dark blue, exudes a sense of simplicity that harmonizes with the natural environment. Despite its rougher texture and thicker fibers compared to certain wood types, its strength and sustainability are qualities likely to be valued by the Javanese community. Meanwhile, Bambu Duri, displaying a yellow to dark brown coloration, is perceived as a durable and robust material. The rough texture and the presence of small thorns on the stem contribute to its reputation as a sturdy and long-lasting substance, suitable for both construction and agricultural purposes in the eyes of the Javanese people.

Clay roof tiles, known as "genting" locally, stand as a vital component in the construction of traditional Javanese vernacular houses. Crafted through molding and firing clay, these tiles offer a blend of durability, weather resistance, and aesthetic appeal. Genting tiles play a significant role in shaping the visual identity of these structures, introducing a traditional aesthetic while seamlessly incorporating functional elements. The brown hues of wood and the red tones of fired clay provide a refreshing and serene accent, contributing to the overall ambiance of Javanese vernacular homes.

The perception of clay roof tiles, or "genting" made from fired clay holds pivotal importance in the aesthetics and cultural heritage of Javanese vernacular architecture. The red color of the fired clay is not only seen as a traditional hue, imparting a timeless quality to Javanese buildings, but it also exudes warmth and sustainability, carrying strong associations with tradition and authenticity. In terms of texture, clay roof tiles present a natural and rugged surface. Intricate patterns or small cracks on the tiles add character and distinct allure, becoming an integral part of the visual charm of traditional Javanese homes.

The significance of clay roof tiles extends beyond their utilitarian role as roofing material. They serve as a unifying element with the surrounding environment, fostering a deep connection with nature and local traditions, a feature highly cherished by the Javanese community. Moreover, the durability and sustainability of fired clay roof tiles symbolize longevity. Their resilience in withstanding extreme weather conditions further establishes them as a revered choice for constructing enduring traditional homes. Within the cultural context of Java, clay roof tiles transcend their functional role to become intrinsic components of cultural

heritage. The positive perception of the color and texture of these tiles reflects the profound appreciation of the Javanese people for tradition, the natural beauty of their surroundings, and the sustainability inherent in the construction of their vernacular homes.

Drawing from Gibson's theory, the tactile nature of teak and bamboo in Javanese houses fosters a sensory-rich environment, enhancing occupants' connection to cultural narratives and natural surroundings. Pallasmaa's multisensory approach underscores how materials like clay tiles and bamboo evoke sensory responses beyond visual aesthetics, promoting a deeper engagement with spatial contexts. Gestalt principles highlight the holistic integration of materials and architectural forms, reinforcing cultural values of communal living and environmental harmony in Saradan village. Howes' cultural perspectives further emphasize how local beliefs and practices influence material choices, embedding sustainability and cultural identity within architectural design.

Comparison with Theoretical Frameworks reveals how each theory enhances our understanding of the role of construction materials in Javanese vernacular houses. Gibson's perceptual systems highlight residents' active engagement with their built environment, wherein materials like teak and bamboo amplify sensory interactions. Pallasmaa's multisensory theory extends this discussion by advocating for architectural designs that provoke emotional and sensory responses, resonating with the tactile qualities of clay tiles and earth-based plasters. Gestalt principles elucidate how these materials foster spatial coherence and cultural symbolism, reminiscent of Islamic design principles found in regional courtyard houses. Howes' cultural theory further contextualizes these materials within broader socio-cultural narratives, emphasizing their contribution to sustainable practices and community resilience.

In the construction of houses in the village of Saradan, Wonogiri, traditional tools take precedence, primarily employing hand saws, hand chisels, adzes, planes, and sickles. Javanese vernacular houses exhibit distinct characteristics in terms of wood and bamboo joint techniques. Traditional Javanese houses are constructed using a knock-down (disassemble and reassemble) construction system with seamless joints devoid of nails. The wood joints found in traditional Javanese houses include the mortise-and-tenon system and the cathokan system, as depicted in Fig. 7. The cathokan system is a lap joint mechanism reinforced with axial movement restraint and pegs utilizing tight adjustments, forming a robust locking joint capable of bearing loads from various directions, as illustrated in Fig. 7. In the traditional houses of Saradan village, the cathokan joint system is employed to connect the main pillars (*saka guru*) with the crossbeams and rafters. The commonly used size for pillars is 8 x 12 cm. This cathokan system symbolizes two hands firmly shaking, representing the strength of familial bonds and communal cooperation in Saradan, Wonogiri. As for bamboo joints, the technique involves using a lashing method with fibers from woven *ijuk* ropes, as shown in Fig. 7b. The smooth and sleek surface of bamboo is addressed by the Javanese community through the use of coarse *ijuk* ropes, creating a robust binding.

The arrangement of wood and bamboo materials in Javanese houses, influenced by socio-cultural factors, signifies a profound connection to cultural values. This layout is carefully crafted to encourage social interaction, emphasizing balance, harmony, and the significance of social relations, spirituality, and a harmonious connection with nature. The spiritual significance of the pyramid-shaped main room establishes a sense of balance and harmony across various aspects of life. Distinctive architectural styles like Joglo and Limasan roofs play a pivotal role in shaping the unique identity of Javanese houses in Saradan, conveying social hierarchy and cultural symbolism, thereby contributing significantly to the overall cultural richness of the residences. Motifs, carvings, and symbols linked to these architectural elements embody the Javanese worldview and cultural heritage, creating a sensory experience deeply rooted in tradition, spirituality, and a harmonious connection with nature. Consequently, the integration of wood, bamboo, clay roof tiles, and culturally significant architectural styles in traditional Javanese houses results in a comprehensive sensory experience. These materials not only serve practical functions but also elevate the cultural significance and identity of the residences in Saradan, establishing a distinctive connection between the inhabitants and their architectural heritage.

The construction of Javanese vernacular houses in Java, Indonesia, is deeply intertwined with considerations of sustainability and cultural significance. The architectural process is heavily influenced by local traditions and customs, with knowledge passed down from generation to generation. In the village of Saradan, Wonogiri, these houses are crafted with a keen understanding of the tropical environment, social-spatial organization, and the cultural context of rice and crop farming. The construction process, predominantly using wood, reflects the local wisdom of Javanese communities in their interaction with nature. The simple structural elements, including pillars, beams, and thresholds, distribute loads directly to the ground, with wooden or bamboo walls that do not bear the load.

Fired-clay roof tiles, a prevalent material in Javanese vernacular houses, enhance the sustainability of these structures. Crafted from locally sourced clay, these tiles boast a lifespan of around 60 years, with their sustainability further reinforced by proximity to manufacturing plants, reducing transportation fuel needs. Additionally, Teak wood (*Tectona grandis*) introduces a nuanced sustainability perspective in the Javanese context. Despite the expansion of Teak plantations, concerns persist regarding declining populations and potential exploitation in its native range. Culturally, teak holds paramount importance in Javanese regions, symbolizing durability, craftsmanship, and refined aesthetics. Mahogany (*Swietenia macrophylla*) grapples with sustainability challenges in Java, classified as vulnerable due to population reduction from a decline in its natural range and exploitation. Despite these concerns, mahogany gains international recognition for its durability and aesthetic properties, contributing to its cultural significance in Javanese contexts. Merbau wood (*Intsia spp.*), categorized as vulnerable, faces population reduction challenges but remains a valuable resource for traditional Javanese construction, contributing to local forest production. Shorea laevis, known as Bangkirai, confronts vulnerability due to deforestation for agriculture and logging in Java. Valued for its strength, it serves as a prominent building material for traditional houses in Java. Kamper wood (*Dryobalanops aromatica*) encounters sustainability challenges, deemed vulnerable and threatened by logging and habitat loss, yet holds historical and cultural significance in traditional Javanese applications. Sonokeling wood (*Dalbergia latifolia*) is esteemed for its high-quality characteristics in Java, culturally utilized for its aesthetic appeal and durability, adding to the refined cultural elegance of Javanese architecture. Mindi wood (*Melia azedarach* Linn) presents varying sustainability characteristics in Javanese contexts, necessitating a detailed assessment. Culturally valued for its durability, Mindi wood finds applications in traditional Javanese woodworking. Bamboo, including *B. vulgaris* var. *vittata*, *Dendrocalamus asper*, and *Bambusa arundinacea* or *Bambusa blumeana*, generally considered sustainable in Java, holds significant cultural value in traditional Javanese construction, symbolizing strength, resilience, flexibility, and resourcefulness. Consequently, these materials play a pivotal role in the sustainability and cultural significance of Javanese vernacular houses, integrating traditional knowledge, local wisdom, and an understanding of the local environment for enduring and meaningful architecture.

In summarizing the findings of this study on Javanese Vernacular Houses in Saradan village, several key roles of construction materials emerge, highlighting their significance in both practical and cultural contexts. Firstly, materials such as teak and *Intsia spp.* are pivotal for ensuring the structural integrity of these traditional houses. They provide durability and stability against the region's challenging environmental conditions, including high temperatures and humidity levels. Secondly, bamboo stands out for its adaptive properties, offering resilience and flexibility that suit the local climate. Beyond its functional benefits, bamboo promotes sustainable construction practices by providing natural insulation and ventilation, thus enhancing energy efficiency within these dwellings. Culturally, the use of wood carving techniques and clay roof tiles plays a crucial role in the aesthetic appeal of Javanese vernacular architecture. These materials not only enhance visual beauty but also embody centuries-old craftsmanship traditions, reflecting the cultural identity and artistic sensibilities of the community.

Moreover, these construction materials contribute significantly to the sensory experience within the houses. They impart distinctive textures, colors, and scents that enrich

daily life, fostering a deeper connection between inhabitants and their architectural heritage. This sensory richness creates a harmonious living environment that resonates with the natural and cultural landscapes of Saradan village. Lastly, the study underscores the sustainability of using locally sourced materials and traditional building techniques. By minimizing environmental impact and preserving cultural values, these practices align with broader ecological principles and community aspirations for continuity and resilience in vernacular architecture. Overall, the multifaceted roles of construction materials in Javanese Vernacular Houses extend far beyond mere structural support. They embody cultural heritage, enhance environmental adaptation, enrich sensory experiences, and promote sustainable living practices, thereby contributing to the enduring legacy of architectural traditions in Saradan village.

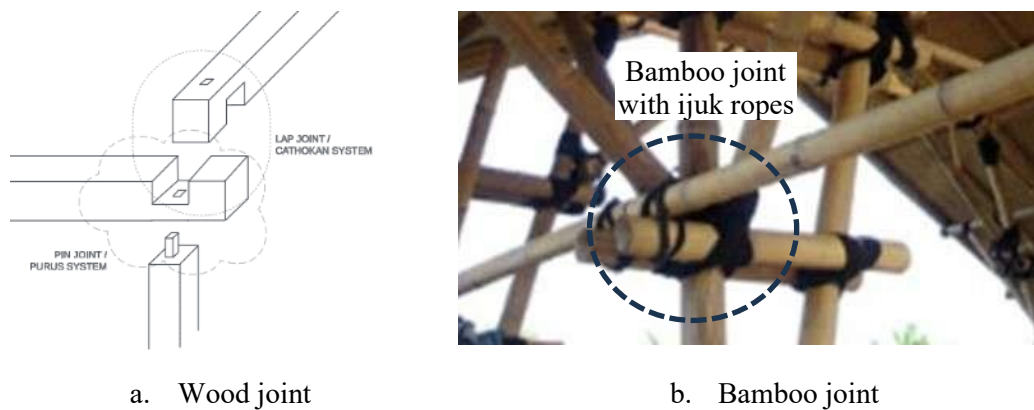


Fig. 7: Types of Wood and Bamboo Joints Found in Javanese Houses in Saradan, Wonogiri.
Sources: Authors

Drawing from theoretical frameworks such as Gibson's theory of affordances, Pallasmaa's multisensory architecture, Gestalt principles, and Howes' cultural perspectives, this study enhances our understanding of how construction materials shape sensory experiences, sustainability practices, and cultural significance in traditional Javanese architecture.

- **Gibson's Theory of Affordances:** This theory highlights how materials like teak and bamboo afford specific interactions and experiences for the inhabitants of Javanese houses. Teak's robustness and bamboo's flexibility provide tactile engagements that enhance users' spatial perceptions and functional adaptations within their environment.
- **Pallasmaa's Multisensory Architecture:** Emphasizing sensory richness beyond visual aesthetics, Pallasmaa's framework underscores how materials such as clay roof tiles and bamboo stimulate emotional and sensory responses. The textures and natural hues of these materials resonate deeply with the cultural and environmental contexts of Saradan, fostering a holistic experience of architectural space.
- **Gestalt Principles:** These principles elucidate how the integration of materials and architectural forms in Javanese houses forms cohesive spatial configurations. The traditional jointing techniques in wood and bamboo exemplify this principle, creating unified structures that symbolize communal values and environmental harmony.
- **Howes' Cultural Perspectives:** Howes' framework contextualizes the cultural significance of construction materials within broader socio-cultural narratives. It emphasizes how local beliefs and practices influence material choices, embedding sustainability and cultural identity within architectural design decisions.

Detailed Exploration of Multifaceted Roles of Construction Materials

The multifaceted roles of construction materials in Javanese Vernacular Houses are crucial for their structural integrity, climate adaptation, aesthetic appeal, cultural preservation, and the overall comfort of inhabitants. These roles are deeply intertwined with theoretical frameworks that provide insights into how these materials influence sensory experiences, sustainability practices, and cultural significance.

- **Structural Stability:** Teak (*Tectona grandis*) and *Intsia* spp. are pivotal for ensuring structural stability in Javanese houses. Teak, renowned for its high density and elasticity modulus, provides durability against the region's challenging environmental conditions. The use of traditional joints like mortise-and-tenon and cathokan systems reinforces load-bearing elements such as pillars and beams, exemplifying principles from structural engineering and architectural theory. The robustness of these materials supports Gibson's theory of affordances, which posits that materials afford specific actions and perceptions, influencing how inhabitants interact with their built environment.
- **Climate Adaptation:** Bamboo (*Bambusoideae*), with its natural properties, plays a vital role in climate adaptation within Javanese houses. Species like Kuning Bamboo (*B. vulgaris* var. *vittata*) and Betung Bamboo (*Dendrocalamus asper*) offer natural insulation and ventilation, regulating indoor temperatures and humidity levels throughout the year. This aligns with principles of environmental psychology and bioclimatic design, which emphasize the integration of natural elements to enhance human comfort and reduce energy consumption. Pallasmaa's multisensory architecture theory complements this by highlighting how bamboo's tactile qualities and visual appeal create sensory-rich environments that foster emotional connections and well-being among occupants.
- **Aesthetic Enhancement:** Wood carving traditions and the craftsmanship of clay roof tiles (*genting*) contribute significantly to the aesthetic appeal of Javanese houses. These elements reflect local artistic sensibilities and cultural motifs, showcasing a blend of craftsmanship and cultural identity. Gestalt principles of perception underscore how these materials and their intricate designs create holistic visual experiences, where the whole exceeds the sum of its parts. The integration of cultural perspectives, as proposed by Howes' theory, further emphasizes how these aesthetic choices reflect and reinforce cultural narratives, fostering a sense of belonging and identity within the community.
- **Cultural Preservation:** The use of locally sourced materials and traditional construction methods is instrumental in preserving Javanese cultural heritage. By employing indigenous materials and techniques passed down through generations, these houses embody cultural continuity and resilience. This approach resonates with conservation psychology, which advocates for sustainable practices that maintain cultural diversity and heritage. Triangulation methods, combining ethnographic research, architectural analysis, and environmental assessments, provide comprehensive insights into how these materials sustain cultural traditions while adapting to contemporary needs.
- **Comfort and Well-being:** Beyond their functional roles, materials like teak, bamboo, and clay contribute to the comfort and well-being of inhabitants through their tactile qualities and natural aesthetics. These materials create serene living environments that promote physical and psychological well-being, aligning with principles of environmental psychology and human-centered design. By engaging multiple senses and evoking emotional responses, these materials enhance the quality of life and foster a sense of place within traditional Javanese homes.

Thus, the multifaceted roles of construction materials in Javanese Vernacular Houses encompass structural stability, climate adaptation, aesthetic enhancement, cultural preservation, and comfort. The integration of theoretical frameworks such as Gibson's theory of affordances, Pallasmaa's multisensory architecture, Gestalt principles, and Howes' cultural perspectives enriches our understanding of how these materials shape sensory experiences, sustainability practices, and cultural significance in traditional Javanese architecture.

Conclusions

This study delves into the multifaceted roles of construction materials in traditional Javanese vernacular houses in Saradan village, Wonogiri. Guided by theoretical frameworks such as Gibson's theory of affordances, Pallasmaa's multisensory architecture, Gestalt principles, and Howes' cultural perspectives, the research aims to identify these materials, analyze their properties, explore their impact on sensory experiences, sustainability, and cultural significance, and propose theoretical insights based on empirical findings. Key Findings:

1. **Structural Integrity and Functionality:** Teak wood and mahogany serve as primary structural materials due to their high density, durability, and resistance to environmental factors. Traditional construction techniques, including mortise-and-tenon and cathokan joints, ensure stable frameworks capable of withstanding seismic activity, ligning with Gibson's theory of affordances that emphasizes how materials enable specific actions within built environments. Teak wood and mahogany provide robust structural support and durability, reflecting Gibson's concept of stability and functionality in architectural design.
2. **Sustainability:** Locally sourced materials like bamboo and clay roof tiles support sustainable practices. Bamboo's rapid growth and high tensile strength provide natural insulation and ventilation, reducing the carbon footprint. Clay roof tiles, fired at low temperatures from local clay, offer longevity and minimal environmental impact. The use of locally sourced materials and traditional building techniques not only supports sustainability but also preserves cultural continuity and community resilience, echoing Howes' emphasis on sensory ethnography and the embodied experience of material culture.
3. **Enhanced Sensory Experience:** The tactile textures of wood and bamboo, along with the visual appeal of clay roof tiles, enrich the sensory environment of Javanese houses. These materials engage occupants' senses and foster connections to cultural heritage and natural surroundings, aligning with Pallasmaa's multisensory approach to architecture.
4. **Cultural Significance:** Gestalt principles are applied to understand how these materials contribute to spatial coherence and cultural symbolism in Saradan's vernacular houses. Specific woods like Sonokeling and Merbau, used in decorative elements, reflect local appreciation for craftsmanship and cultural heritage. Traditional motifs and techniques in wood carving and bamboo construction embody Javanese values of balance, harmony, and spirituality. Clay roof tiles symbolize tradition and authenticity, reinforcing cultural identity.
5. **Environmental Adaptation:** Wood and bamboo provide natural thermal regulation, enhancing indoor comfort in response to tropical climates. Clay roof tiles contribute to stable indoor temperatures and weather resistance, reflecting an adaptive response to Saradan village's environmental conditions.

Strengths of the study include comprehensive documentation and qualitative insights into the cultural and environmental aspects of Javanese vernacular architecture. By integrating these insights, the research promotes the preservation of indigenous architectural practices and sustainable building techniques. However, limitations include the reliance on qualitative data,

which may limit broader generalizations, and the focus on a single case study in Saradan village, potentially overlooking regional variations in construction practices.

This study contributes theoretical insights into the multifaceted roles of construction materials in Javanese vernacular houses. By integrating theoretical frameworks with empirical findings, it advances our understanding of how these materials shape sensory experiences, sustainability practices, and cultural significance in traditional Javanese architecture. Future research could explore the application of these theories across diverse contexts in Java and promote interdisciplinary collaborations in sustainable architectural practices and cultural heritage.

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