Factors Influencing Earthquake Resistance in Vernacular Architecture: A Systematic Literature Review of Architecture Indigenous Knowledge

Riza Aulia Putra[1], Dewi Larasati[2]*, Aswin Indraprastha[3], Hanson E Kusuma[4]
[1] Doctor Study Program of Architecture, School of Architecture, Planning, and Policy Development, Institut Teknologi Bandung, Indonesia
[2] Building Technology Research Group, Department of Architecture, School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Indonesia
[3,4] Architectural Design Research Group, Department of Architecture, School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Indonesia

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Corresponding Author:
Riza Aulia Putra
Doctor Study Program of Architecture, School of Architecture, Planning, and Policy Development, Institut Teknologi Bandung, Indonesia
Email: dewizr@ar.itb.ac.id

Abstract

Vernacular architecture in seismic-prone regions often reflects generations of knowledge embedded in local building practices. This knowledge contributes significantly to the earthquake resilience of traditional structures through context-specific design strategies and materials. This study presents a systematic literature review to identify the critical factors that influence the seismic resistance of vernacular buildings. A summative content analysis method was employed, emphasizing the elements that affect the seismic performance of these structures. The review identifies six key factors contributing to the earthquake resistance of vernacular buildings, categorized into two primary domains: explicit knowledge, which includes building typology, structural systems, construction methods, and building materials, and implicit knowledge, encompassing community involvement and risk management. The findings underscore the significance of local architectural knowledge as a fundamental basis for developing more effective and sustainable construction strategies to enhance earthquake resilience in earthquake-prone areas.

INTRODUCTION

Indigenous knowledge, also referred to as local knowledge, represents a body of knowledge that emerges and evolves within specific spatial and cultural contexts, characterized by its holistic and adaptive nature (Abebe & Gatisso, 2023; Mistry, 2009). This knowledge is primarily transmitted orally and through practice, passed down across generations within communities (Hărmănescu & Enache, 2016; Meutia et al., 2017). Indigenous knowledge enables communities to adapt and thrive within particular environmental conditions, encompassing various domains of human activity (Dhungana et al., 2023; Kurnio et al., 2021; Mikulecký et al., 2023). In international discourse, terms such as local knowledge, folk knowledge, traditional wisdom, traditional science, traditional knowledge, and technical knowledge are often used interchangeably to refer to this concept (Abebe & Gatisso, 2023; Hadlos et al., 2022).

The scope of knowledge is diverse, encompassing a wide range of domains and expressions. It may take the form of stories, proverbs, cultural values, legal systems, community norms, agricultural practices, and architectural traditions (Hărmănescu & Enache, 2016). Within the field of architecture, knowledge evolves in response to community needs for shelter, resulting in architectural traditions that are specifically designed to accommodate and adapt to local environmental conditions.

The architectural traditions of communities represent an accumulation of knowledge about building practices, embodied in architectural forms. Architecture that emerges from these traditions is often referred to as vernacular architecture (Oliver, 2006). A distinctive feature of vernacular architecture is its responsiveness to the surrounding physical environment, which includes climate, weather, and seismic conditions. This responsiveness is a result of the long-standing tradition of building that is passed down across generations, particularly in construction techniques and material usage (Ortega et al., 2019). Through this extensive building tradition, vernacular architecture integrates local knowledge related to construction practices that are adapted to environmental conditions.

The study of building traditions in vernacular architecture has the potential to inform contemporary construction practices, especially in the areas of engineering systems and seismic performance. By examining the seismic resilience of vernacular architecture, it is possible to derive valuable insights for future sustainable development. Therefore, a comprehensive study is required to explore the engineering and seismic systems within vernacular architecture to fully understand the potential of knowledge.

This study takes a global perspective to understand broader patterns and principles in earthquake-resistant vernacular design. Despite the diversity of climatic and cultural contexts, vernacular architecture in various seismic-prone regions often reflects similar design strategies. These include the use of flexible materials (e.g., timber, bamboo), energy dissipation mechanisms (e.g., joinery that allows controlled movement), and adaptive structural typologies (e.g., low-rise, symmetrical forms). Such recurring features suggest that communities worldwide, through empirical knowledge and generational experience, have developed universal strategies to mitigate seismic risks (Ortega et al., 2014, 2017; Varum et al., 2015).

However, despite the growing recognition of vernacular architecture's value, research in this area remains underexplored from a systematic and technical perspective. While existing studies have examined the seismic behavior of vernacular buildings and the factors contributing to their resilience, most are region-specific and lack comparative synthesis. This underscores the pressing need to bridge the significant research gap in understanding the common seismic principles embedded in traditional architecture across different geographic and cultural contexts. Bridging this gap is essential to elevate knowledge from a localized practice to a valuable resource for global disaster-resilient design.

To address this gap, the present study sets out two primary objectives: (1) to conduct a literature review on architectural knowledge in the context of earthquake-resistant vernacular buildings and (2) to identify the key factors in vernacular architecture that influence earthquake resistance. The ultimate goal is to uncover how knowledge systems embedded in vernacular architecture can inform the development of more sustainable and seismically robust built environments, especially in vulnerable regions like Indonesia.

Local Knowledge in the Context of Earthquake-Resistant Buildings

Communities in earthquake-prone regions have long developed architectural and construction techniques tailored to withstand seismic shocks. Often derived from knowledge, these methods result from empirical processes involving observation, experimentation, and adaptation over generations. Several studies have demonstrated that local knowledge of architecture has proven resilient in mitigating the impact of earthquakes (Sari et al., 2020; Triyadi et al., 2010). Knowledge related to earthquake-resistant construction and architecture is the product of trial and error, resulting in techniques that enhance the durability of buildings against seismic forces. The construction practices of traditional communities reflect their knowledge and creativity in responding to environmental challenges and addressing the need for shelter (Ortega et al., 2019; J. Wang & Ng, 2023).

During the 2004 Aceh earthquake, when most modern structures were destroyed, some vernacular buildings withstood devastation (Figure 1). This outcome highlights that construction knowledge includes practical mechanisms for seismic resilience, reflecting structural ingenuity and cultural adaptation to recurring environmental hazards.

(a) (b) (c)

Fig. 1. Several vernacular buildings demonstrated resilience and survived the 2004 Aceh earthquake: a) Masjid Tgk Di Pucok Krueng in Pidie Jaya (Pidie Jaya earthquake in 2016, b) Masjid Tuha Ulee Kareng in Banda Aceh (Banda Aceh and Aceh Besar earthquake in 2004 and 2012), c) Masjid Tuha Indrapuri in Aceh Besar (Banda Aceh and Aceh Besar earthquake in 2004 and 2012)

This study reviews 40 scientific articles published between 2016 and 2024 that examine knowledge in the context of earthquake-resistant architecture to identify the factors of local knowledge associated with the earthquake resistance of vernacular buildings.

METHODS

This study aims to identify factors that affect earthquake resistance in vernacular buildings. A comprehensive Systematic Literature Review (SLR) focused on scholarly articles about knowledge in the realm of vernacular building, particularly in the framework of earthquake-resistant building. The SLR was conducted to synthesize knowledge from various studies that could be replicated or critically examined as part of an academic learning process (Neuman, 2014). This method followed a transparent and replicable process, guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, which is a widely recognized standard for reporting in systematic reviews and contributes to methodological rigor and clarity (Page, McKenzie, et al., 2021; Page, Moher, et al., 2021).

Research Scope and Data Sources

The primary objective of this review is to identify and classify the factors that contribute to earthquake resistance in vernacular buildings, with emphasis on the contribution of knowledge systems in architecture and construction. The review focuses on scholarly works published between 2016 and 2024, representing the most recent academic developments and discourses in the field of vernacular seismic resilience (Figure 2b).

The **Scopus database** was selected as the primary source for its extensive repository of peer-reviewed scientific literature. The literature search was conducted via the **ScienceDirect platform**, using the following keyword combinations: *"architecture Indigeonus knowledge"*, *"traditional earthquake resistant"*, and *"vernacular earthquake resistant"*. Boolean operators such as **AND** and **OR** were employed to expand and refine search results to ensure comprehensive coverage of terms related to vernacular architecture and seismic performance. This strategy aimed to capture a wide spectrum of studies dealing with cultural, architectural, and engineering aspects of traditional earthquake-resistant design.

Inclusion and Exclusion Criteria

To ensure that only high-quality and contextually relevant studies were included in the systematic review, a clear set of inclusion and exclusion criteria was applied during the selection process. Studies were considered eligible for inclusion if they were published between 2016 and 2024, representing the most current developments in the field. Only peer-reviewed journal articles or papers from reputable international conference proceedings were included, to ensure the academic rigor and credibility of the data. Furthermore, the articles had to be written in English to allow for consistent analysis and interpretation. The scope was limited to studies that focused on vernacular or traditional architecture specifically within the context of earthquake resilience. Additionally, the presence of or local construction knowledge as part of the research focus was deemed essential, as the study aimed to explore how traditional practices contribute to seismic resistance.

Conversely, studies were excluded if they did not directly address themes related to earthquake resistance or vernacular architecture. Publications that had not undergone peer review, such as theses, dissertations, or news articles, were also omitted due to concerns about consistency and academic validity. Furthermore, studies that focused solely on modern seismic engineering or technology without reference to cultural, historical, or contexts were excluded, as they fell outside the scope of this review. Finally, articles for which full texts could not be accessed were also eliminated from consideration, to ensure that all reviewed material could be critically appraised in full.

Article Selection Process

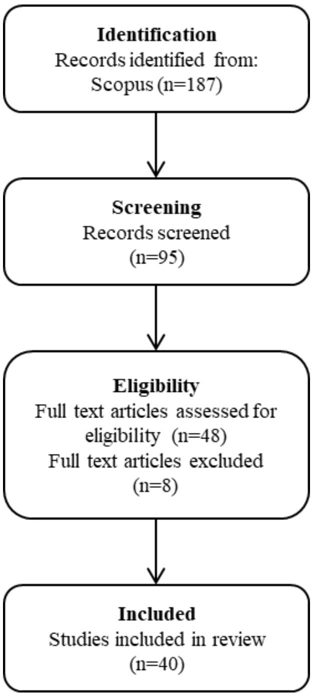
The article selection process in this study adhered to the four sequential phases outlined in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to ensure transparency, consistency, and academic rigor. The process began with the identification phase, during which a keyword-based search was conducted across the Scopus database, yielding 187 articles. This initial pool represented a wide array of publications related to vernacular architecture, knowledge, and earthquake resistance.

The screening phase involved a preliminary evaluation of each article's title and abstract to determine its relevance to the research objectives. Through this process, 95 articles were retained for further examination. These were selected based on their potential alignment with the inclusion criteria and thematic relevance.

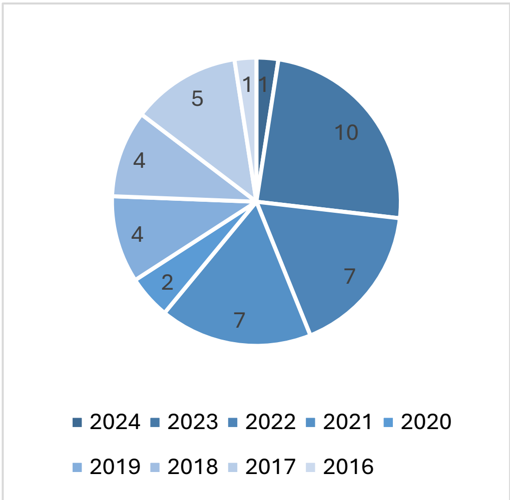
In the eligibility phase, full-text reviews were conducted on the shortlisted articles. Each study was carefully assessed according to the established inclusion and exclusion criteria to ensure methodological robustness and topical appropriateness. As a result of this rigorous evaluation, 48 articles were deemed eligible for potential inclusion in the final synthesis.

In the final phase, inclusion, 40 articles were selected that met all criteria and were considered most relevant and credible for in-depth analysis. This final dataset comprised 35 peer-reviewed journal articles, most published in top-tier Scopus-indexed journals (Q1), and five papers from reputable international conference proceedings. These articles formed the foundation for analyzing factors influencing earthquake resistance in vernacular architecture.

This process is visually illustrated in the PRISMA flow diagram in Figure 2 (a), which systematically depicts how articles were filtered at each stage. Figure 2 (b) shows the distribution of the publication years for the selected articles.



(a)



(b)

Fig. 2. (a) PRISMA flow diagram of study, and (b) Distribution of publication years of selected articles

Data Extraction and Content Analysis

The selected articles were systematically cataloged using Microsoft Excel to facilitate an organized and comprehensive tabulation of metadata. This included key bibliographic and contextual information such as authorship, year of publication, geographic focus of the study, methodological approaches employed, and major findings relevant to earthquake resilience in vernacular architecture. The structured catalog enabled comparative referencing and cross-thematic mapping throughout the review process.

To derive meaningful interpretations, the study employed summative content analysis, a qualitative technique that allows for both thematic identification and quantification of recurring concepts. The analysis focused specifically on aspects influencing the earthquake-resistant performance of vernacular buildings, particularly those informed by construction knowledge and cultural practices.

The content analysis was conducted in two sequential stages: open coding and focused coding with quantification. In the open coding stage, the abstracts, results, and discussions from each article were closely reviewed to extract textual elements containing significant insights on seismic resilience. These texts were broken down into discrete units of meaning and systematically labeled. The resulting data fragments were then clustered into sub-factors (i.e., recurring construction elements, spatial principles, material strategies) and further grouped under broader thematic categories or factors, such as structural form, material behavior, and cultural adaptation.

The second stage involved coding quantification, where the frequency and relative proportion of each identified factor and sub-factor were calculated across the reviewed literature. This quantification process served to determine the prominence and consistency of each factor in the academic discourse, enabling the identification of dominant themes and underrepresented dimensions in the field. The combination of qualitative coding and numerical analysis provided a robust foundation for the subsequent thematic synthesis and interpretation.

Synthesis of Results

The synthesized results from this systematic literature review reflect a convergence of key insights and emergent patterns related to the earthquake resilience of vernacular architecture. The integration of coded data was carried out through an interpretative synthesis, aimed at identifying not only individual components of traditional building systems, but also their interconnected roles within knowledge frameworks.

The synthesis revealed a range of thematic constructs—such as flexible structural joints, the use of lightweight and ductile materials, symmetrical spatial configurations, and context-responsive site planning—that have been consistently cited as contributing to earthquake resistance. These findings suggest that resilience in vernacular buildings is not solely a product of material composition or construction technique, but also of culturally embedded design logic, passed down through generations and continuously adapted to local environmental conditions.

Furthermore, the synthesis brought to light contextual variations in how communities interpret, apply, and maintain their architectural practices in relation to seismic risk. This points to a broader understanding of resilience not merely as physical robustness, but as a holistic interaction between material, spatial, and socio-cultural systems.

The outcomes of this synthesis serve as the basis for the discussion and conclusion sections that follow, offering a conceptual lens through which contemporary design practices, heritage preservation, and disaster risk reduction policies can be reimagined by drawing from time-tested vernacular traditions.

RESULTS AND DISCUSSION

This literature review critically assesses 40 scholarly articles concerning knowledge and seismic resilience within the context of vernacular architecture. The findings indicate that these articles are being examined across diverse geographical regions globally. Notably, the research sites are predominantly located in areas susceptible to seismic activity. Among the examined publications, Indonesia, Portugal, India, and Iran emerge as the nations with the highest concentration of study locations. Figure 3 depicts the distribution of these research sites.

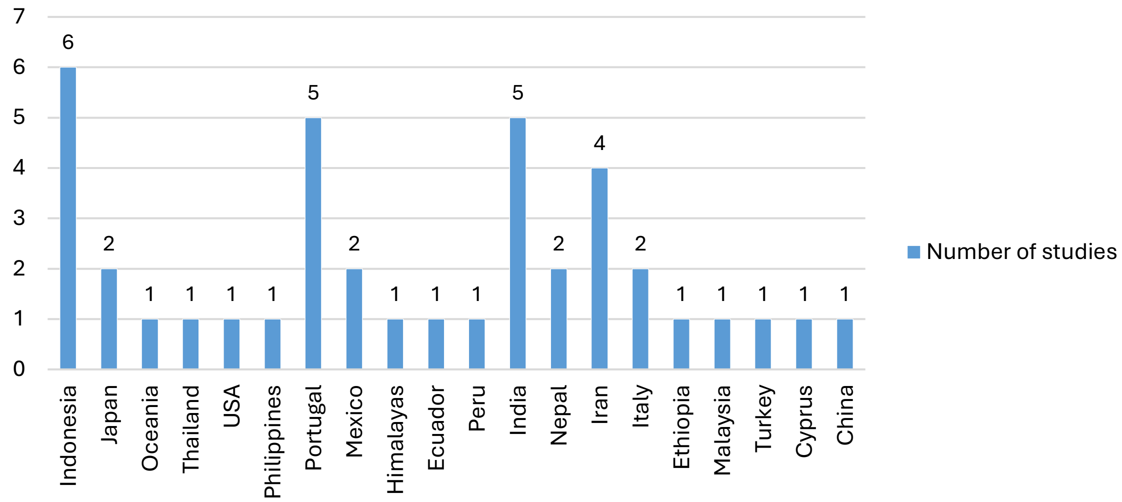


Fig. 3. Distribution of study locations

The map in Figure 4 illustrates the number of studies related to earthquakes across various regions, particularly in countries situated in seismically active zones. The shading intensity indicates the concentration of studies, transitioning from lighter shades for fewer studies to darker shades for higher concentrations. While many of the highlighted countries are located within or near the Pacific Ring of Fire—such as Indonesia, the Philippines, Oceania (such as Papua New Guinea, New Zealand, and parts of the Pacific Islands), and other Southeast Asian nations—the map also includes regions beyond this zone, including South Asia and parts of the Middle East. This visualization highlights the global distribution of earthquake-related research rather than exclusively focusing on the Pacific Ring of Fire.

Based on the analysis, six primary factors influencing the seismic resilience of vernacular architecture were identified and grouped into two broad categories: *explicit knowledge* and *implicit knowledge*. The term explicit knowledge refers to observable and tangible aspects of vernacular buildings that can be directly identified through visual inspection or physical analysis. This category includes building typology, structural systems, building construction, and building materials. In contrast, implicit knowledge refers to intangible elements not directly visible in the physical structure but embedded in the cultural and social practices surrounding the building process. These include risk management and community engagement, which are typically understood through historical context, local customs, or interviews with knowledge holders. The classification helps to distinguish between what is physically present in the built form and what is culturally or socially embedded in the construction process. The factors identified in the analysis are illustrated in Figure 5.

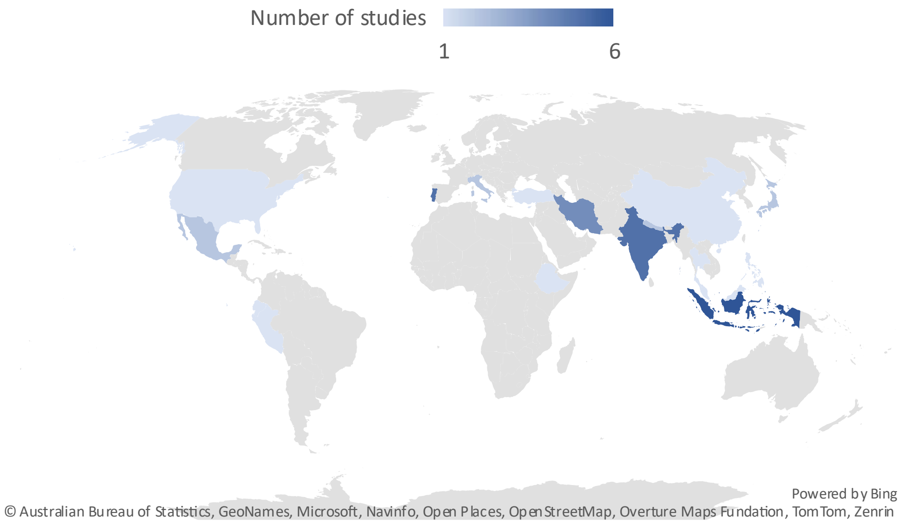


Fig. 4. Geographical dispersion of study

Building construction, structural systems, and building typology are three interrelated factors that significantly influence the seismic performance of a structure(Ahmad et al., 2017; Ortega et al., 2019; Surana et al., 2022). Their combined effects on earthquake resilience have been well-documented in numerous studies. In particular, the building's capacity to withstand and adapt to seismic forces is largely determined by the configuration of its structural system and building typology (Bothara et al., 2022). This statement is also supported by the result of the analysis, which show that building construction, structural systems, and building typology account for the highest percentage among the factors influencing building resistance to earthquakes. These are followed by building materials, risk management, and community engagement.

As illustrated in Figure 6, 24% of the reviewed studies stated that building construction is the main factor that affects the building's resistance to earthquakes. The significant influence of building construction on the seismic performance of structures is fundamentally attributed to the building construction system, which constitutes the primary factor that dictates the structural integrity of the edifice in managing the imposed loads (Abebe & Gatisso, 2023; Biglari et al., 2022; Bothara et al., 2022; Kurnio et al., 2021). This factor encompasses the use of vernacular construction techniques, construction methods and building technology as subfactors. These practices often exhibit flexibility, redundancy, and energy dissipation characteristics crucial for earthquake resistance. For example, the use of timber frame systems with mortise-tenon joinery in vernacular structures has been shown to provide both structural ductility and modular repairability.

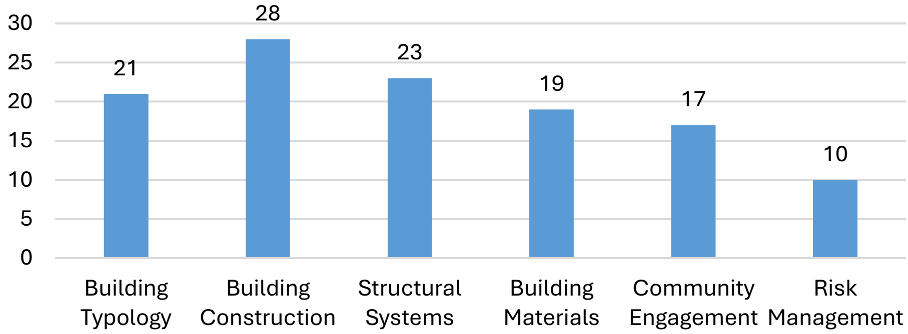


Fig. 5. Factors influencing earthquake resistance in vernacular architecture

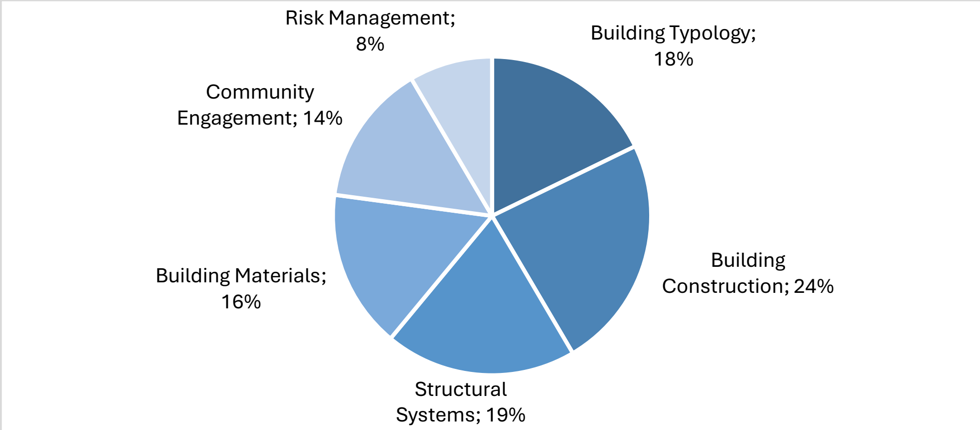


Fig. 6. Percentage factors influencing earthquake resistance in vernacular architecture

The subsequent factor pertains to structural system that constitutes 19% of the factors influencing the seismic performance of the building. These structural system factors are intrinsically linked to the building construction factors. However, while construction methods primarily address *how* buildings are assembled, structural systems focus on *what* structural logic underpins the overall form and behavior of the structure. It is essential to acknowledge that evolutionary adaptations in structural systems may occur in response to the specific seismic characteristics of a given region. Within this factor, subfactors such as jointing system and structural components play a crucial role in determining how seismic loads are distributed, absorbed, and transferred throughout the building during an earthquake.

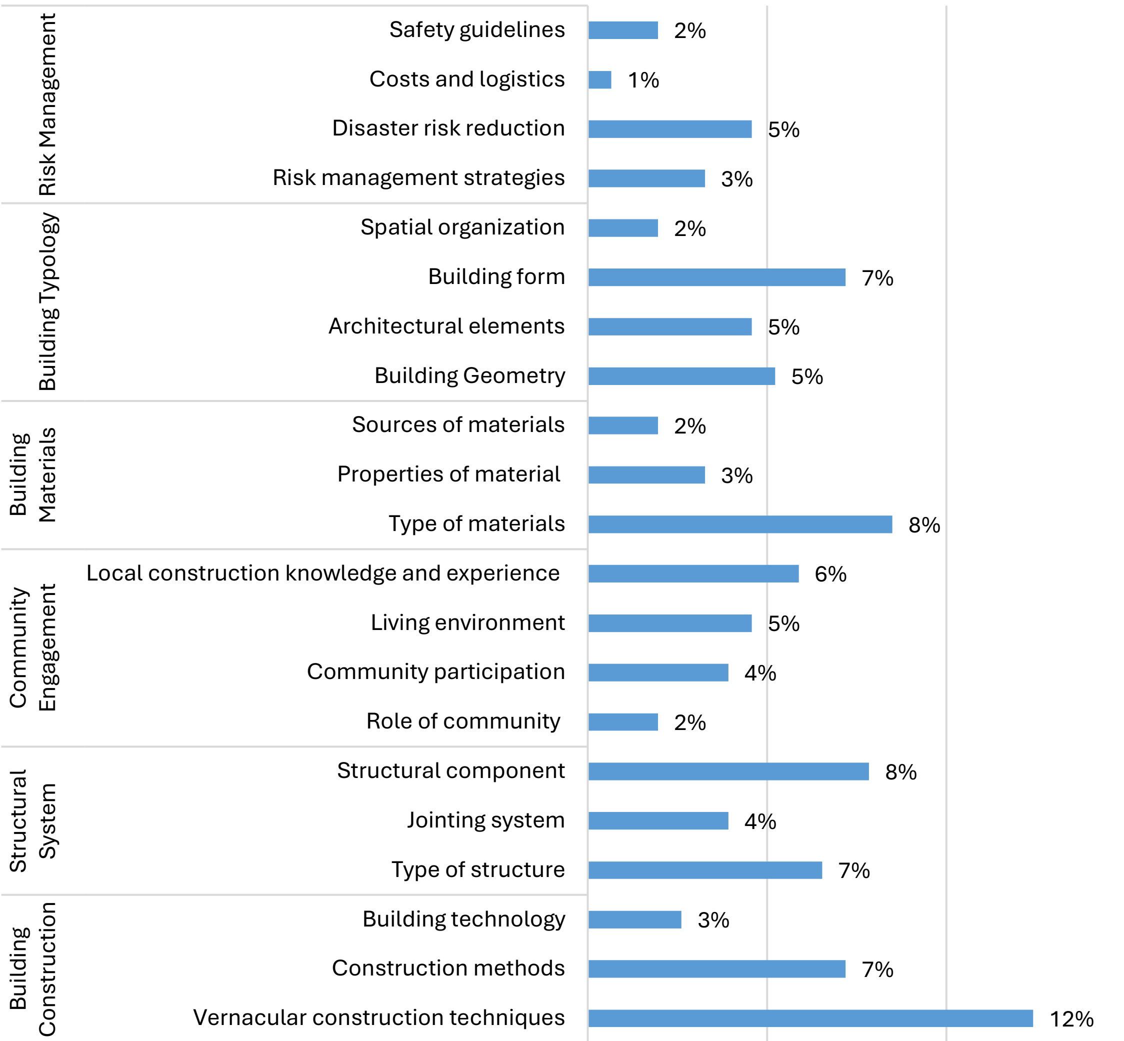


Fig. 7. Percentage subfactors (variables) influencing earthquake resistance in vernacular architecture

Moreover, building typology accounts for 18% of the factors influencing the seismic performance of vernacular buildings. This factor plays a significant role through aspects such as the geometric configuration of the floor plan, building dimensions, and the presence of architectural elements, all of which collectively affect the distribution of seismic loads (Bothara et al., 2021; Daly et al., 2023; Feizolahbeigi et al., 2021; García et al., 2023). For instance, square or rectangular floor plans with low height-to-base ratios have been reported to perform better during seismic activity due to balanced inertia distribution. Based on the analysis, four subfactors were identified that influence the efficacy of building typology factors in seismic resilience, specifically building geometry, architectural elements, building form and spatial organization.

Table 1. List of bibliography of factors and subfactors that influence earthquake resistance in vernacular buildings

No.	Factors	Subfactors	Authors
1	Building Typology	Building Geometry	(Feizolahbeigi et al., 2021; García et al., 2023; Hendriks & Opdyke, 2021; Juwita et al., 2017; Murano et al., 2019; Ramírez Eudave et al., 2022)
		Architectural Elements	(Daly et al., 2023; Feizolahbeigi et al., 2021; Mazraeh & Pazhouhanfar, 2018; Surana et al., 2022; Tosto et al., 2023)
		Building form	(Bothara et al., 2021; Feizolahbeigi et al., 2021; Jia et al., 2023; Mahayuddin et al., 2017; Mikulecký et al., 2023; Ortega et al., 2017; Tosto et al., 2023)
		Spatial organization	(García et al., 2023; Georgiou et al., 2022; Jia et al., 2023; Ortega et al., 2017)
2	Structural Systems	Type of structure	(Georgiou et al., 2022; Mazraeh & Pazhouhanfar, 2018; Nguyen et al., 2019; Ramírez Eudave et al., 2022; Tosto et al., 2023)
		Jointing System	(Ahmad et al., 2017; Aktaş, 2017; Chand et al., 2020; Chmutina & Rose, 2018; Mikulecký et al., 2023; Surana et al., 2022)
		Structural component	(García et al., 2023; Ortega et al., 2018)
3	Building Construction	vernacular construction techniques	(Biglari et al., 2022; Bothara et al., 2022; Chand et al., 2020; Feizolahbeigi et al., 2021; García et al., 2023; Hu et al., 2023; Juwita et al., 2017; Kodai Kaje et al., 2023; Kurnio et al., 2021; Mahayuddin et al., 2017; Murano et al., 2019; Ortega et al., 2018, 2019; Wang & Ng, 2023)
		construction methods	(Abebe & Gatisso, 2023; Bothara et al., 2022; Hu et al., 2023; Kurnio et al., 2021; Ortega et al., 2017)
		building technology	(Ahmad et al., 2017; Chmutina & Rose, 2018; Hu et al., 2023; Jia et al., 2023; Ortega et al., 2017)
4	Building Material	Type of material	(Abebe & Gatisso, 2023; Bothara et al., 2022; Chand et al., 2020; Georgiou et al., 2022; Hendriks & Opdyke, 2021; Idham, 2018; Kodai Kaje et al., 2023; Mahayuddin et al., 2017; Okubo, 2016; Ortega et al., 2017, 2019)
		Properties of material	(Greco & Lourenço, 2021; Ramírez Eudave et al., 2022)
		Sources of material	(Ahmad et al., 2017)
5	Risk Management	Risk management strategies	(Ahmad et al., 2017; Cuaton & Su, 2020; Hu et al., 2023; Okubo, 2016)
		Disaster risk reduction	(Cuaton & Su, 2020; Hadlos et al., 2022; Juwita et al., 2017; Koopman, 2023; Mikulecký et al., 2023)
		Costs and logistics	(Daly et al., 2023)
		Safety guidelines	(Hendriks & Opdyke, 2021; Pribadi et al., 2021)
6	Community Engagement	role of community	(Cuaton & Su, 2020; Kodai Kaje et al., 2023)
		Community participation	(Cuaton & Su, 2020; Hadlos et al., 2022)
		living environment	(Hadlos et al., 2022; Idham, 2018; Koopman, 2023; Kurnio et al., 2021; Mazraeh & Pazhouhanfar, 2018)
		Local construction knowledge and experience	(Abebe & Gatisso, 2023; Biglari et al., 2022; Chmutina & Rose, 2018; Hadlos et al., 2022)

The fourth factor that further affects the building's earthquake resistance is building materials by 16%. In general, building materials will affect the seismic performance of buildings in terms of the type of materials, properties of material and the sources of the building material. From the perspective of implicit knowledge, there exist factors pertaining to community engagement and risk management. The factor of community engagement serves as a determinant that affects the seismic performance of structures by 14%, encompassing elements such as role of community, community participation, environmental conditions, and the construction experience from the local community. The last factor that influences the seismic performance of vernacular buildings is the risk management aspect of 8%. This factor includes risk management strategies, disaster risk reduction, costs and logistics and safety guidelines. These findings suggest a strong correlation between social knowledge systems and structural resilience, emphasizing that vernacular architecture should be understood not merely as a material artifact, but as a socio-technical system shaped by collective knowledge and lived experience.

This analysis reveals that the effectiveness of each Subfactor in contributing to seismic resilience is highly interdependent. For example, a compact and symmetrical building typology enhances load distribution, but its performance is closely linked to the structural system and construction methods that support it. Traditional jointing systems such as mortise-tenon joint, when paired with flexible materials like timber, enable both energy dissipation and repairability. Conversely, heavier materials may offer strength but reduce flexibility, requiring compensatory design strategies. These correlations highlight that vernacular seismic resilience emerges not from isolated attributes, but from the integrated synergy between physical design, construction logic, and socio-cultural knowledge.

The percentage of Subfactors that affect the seismic resilience of vernacular building are presented in Figure 7 and comprehensive bibliography of factors and subfactors that influence earthquake resistance in vernacular buildings are presented in Table 1.

Local Knowledge in Vernacular Architecture

Local knowledge holds a critical significance in mitigating the adverse effects induced by natural catastrophes. Local knowledge possesses considerable worth in relation to the preservation of human lives and assets in the face of natural disasters (Cuaton & Su, 2020; Dhungana et al., 2023). In region where natural disasters frequently occur, peoples have developed stories and practices from generation to generation based on past experiences. This knowledge allows them to reduce the risks associated with natural phenomena such as earthquakes and tsunamis that have the potential for enormous damage (Mikulecký et al., 2023). This method of adaptation and response to disasters is a potential that can be explored in local knowledge to be enhanced and applied in forthcoming developmental initiatives. (Kodai Kaje et al., 2023).

In vernacular buildings, structural systems with lightweight materials, such as bamboo and wood, are generally used. The connections between beam and column elements are also made flexible using wooden dowel locks (Aktaş, 2017; Kurnio et al., 2021; Ortega et al., 2019). And the use of a flexible foundation system also has an effect on reducing the earthquake load that occurs (Chmutina & Rose, 2018). This building structure system is not rigid and has a level of flexibility which can be the reason why vernacular buildings have good resistance to earthquake loads.

Furthermore, the building typology which includes the geometric configuration of the building, architectural elements and building form of the space in the building also has a significant impact on earthquake resistance (Surana et al., 2022; Tosto et al., 2023). The geometric configuration of the layout or building plan includes the size or dimensions, shape and proportions which will affect the building structure in responding to earthquake loads (García et al., 2023; Ortega et al., 2019; Ramírez Eudave et al., 2022).

This assertion is highly justifiable as the shape of the building geometry will certainly be one of the factors in distributing the building load during an earthquake. he shape of the floor plan with a square, rectangular, circular, hexagonal or other geometric shapes will certainly have a different response when an earthquake occurs.

Buildings with square and symmetrical geometric shapes are good and safe shapes in responding to earthquake loads (Hendriks & Opdyke, 2021; Juwita et al., 2017). The square shape allows the application of a rigid frame structure system configuration so that structural components such as columns and beams can be connected properly as a whole. The connection between columns and beams is also one of the principles for earthquake-resistant buildings.

Furthermore, the ability of a building to withstand earthquakes is also influenced by the materials and technology used in these materials (Ahmad et al., 2017; Ortega et al., 2018). Vernacular buildings generally have structures made from natural materials such as wood, bamboo and stone which are locally available (Ramírez Eudave et al., 2022; Wang & Ng, 2023). The application of this material is also adjusted to its respective functions. Stone material is generally used as foundation material while wood and bamboo become the main structure of the building. The use of wood materials in building construction can increase the building's ability to adapt and respond to the risk of earthquake disasters (Hariyanto et al., 2023; Kodai Kaje et al., 2023).

Local Knowledge in the Context of Disaster Risk Reduction

In recent years, disaster management has shifted from a reactive focus on post-disaster recovery to a more proactive orientation centered on risk prevention through Disaster Risk Reduction (DRR) strategies (Mikulecký et al., 2023). Within this evolving framework, local and indigenous knowledge plays a critical role in mitigating the impacts of natural disasters, offering valuable insights for saving lives and protecting property (Cuaton & Su, 2020; Dhungana et al., 2023). In regions frequently affected by natural hazards, communities have developed practices and narratives passed down through generations based on their experiences with past events. This knowledge enables them to reduce the risks posed by natural phenomena, such as earthquakes and tsunamis, which can potentially cause widespread destruction (Mikulecký et al., 2023). The adaptive strategies embedded in local knowledge present significant opportunities for further exploration, development, and integration into contemporary disaster management practices (Kodai Kaje et al., 2023).

Local knowledge is reflected in the construction of vernacular buildings, which have evolved to adapt to environmental conditions (Kurnio et al., 2021c). Given Indonesia's high seismic activity, communities have developed architectural traditions that consider seismic factors. Repairs are undertaken immediately when buildings are damaged during earthquakes, incorporating improvements and new knowledge. This reinforces a culture of community participation in construction and risk management, fostering a sense of ownership and collective responsibility. (Mikulecký et al., 2023).

Moreover, the integration of local construction knowledge and experience, including traditional joinery, lightweight materials, and modular layouts, into daily building practices underscores the practical intelligence of these communities. Thus, the living environment becomes not only a place of residence but also a dynamic reflection of localized resilience strategies. The community's role is essential in preserving these practices and innovating them across generations in response to emerging threats.

The value of traditional building practices embedded in vernacular architecture is increasingly recognized as a critical component of Disaster Risk Reduction (DRR) strategies (Cuaton & Su, 2020). The Sendai Framework for Disaster Risk Reduction 2015–2030 underscores the importance of leveraging local knowledge to enhance disaster resilience (UNDRR, 2015; J. Wang & Ng, 2023). There is growing recognition of the need to integrate indigenous knowledge systems into scientific disciplines and formal disaster management frameworks (Kurnio et al., 2021c). Local knowledge thus plays a central role in enriching DRR strategies by incorporating the architectural traditions of local communities. Integrating local knowledge into DRR fosters innovation in the development of knowledge-based solutions and contributes to the preservation of this valuable cultural resource.

CONCLUSION

Based on the comprehensive literature review undertaken, it can be inferred that there exist six factors and their corresponding sub-factors that significantly influence the seismic resistance of vernacular building. These factors are systematically categorized into two distinct classifications: the explicit knowledge factor category and the implicit knowledge factor category.

First, the factors of the explicit knowledge category are factors that are directly related to the physical aspects of the building that can be seen through direct observation of the vernacular building. These factors encompass:

a. Building Typology, with subfactors including building geometry, architectural elements, building form dan spatial organization.
b. Structural System, with subfactors including type of structure, jointing system dan structural component.
c. Building Construction, with subfactors including vernacular construction techniques, construction methods and building technology.
d. Building material, with subfactors including type of material, properties of material and sources of material.

Second, the factors of the implicit knowledge category are factors related to aspects that cannot be seen directly in the building but require in-depth study, whether through historical studies or in-depth interviews with experts. These factors encompass:

a. Risk Management, with subfactors including risk management strategies, disaster risk reduction, sosts and logistics and safety guidelines.
b. Community Engagement, with subfactors including role of community, community participation, living environment and local community construction experience

These findings underscore that seismic resilience in vernacular architecture is not attributable to a singular factor, but rather emerges from the synergistic interplay of multiple elements, encompassing both technical construction strategies and embedded socio-cultural knowledge systems that have evolved and been refined across generations. This multidimensional nature of vernacular resilience offers critical implications for contemporary architectural and engineering practices, particularly in regions characterized by high seismic risk. The integration of vernacular principles into modern design frameworks holds considerable potential in enhancing the sustainability and resilience of the built environment. Architectural features commonly found in traditional structures—such as modular and flexible construction systems, low height-to-base ratios, the use of locally available materials, and community-centered construction practices—present empirically grounded models that align closely with the goals of disaster risk reduction and ecological sustainability.

Moreover, these insights support the development of hybrid design methodologies that strategically combine traditional knowledge with contemporary engineering principles. Such an approach improves the structural performance of buildings in seismic zones and strengthens community preparedness and engagement, which are essential components of long-term resilience. Consequently, future strategies to enhance earthquake resilience should extend beyond technical reinforcement alone. They must also prioritize the revitalization of local construction traditions, the preservation of cultural knowledge, and the empowerment of communities as active stakeholders in risk mitigation and adaptive spatial planning. Recognizing the value of knowledge within the formal discourse of resilient architecture is thus imperative for developing contextually responsive and socially inclusive built environments.

The scope of this study is limited to identifying and classifying influencing factors based on their frequency in existing literature through content analysis. It does not assess these factors' structural performance or effectiveness in real seismic conditions. Future research should include empirical investigations—such as field studies, structural simulations, or performance-based analyses—to validate and refine the framework proposed in this study.

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