



Strategies and Innovations in Earthquake-Resistant Housing in Indonesia: Systematic Literature Review

Muhammad Dwi Utomo ¹, Puteri Fitriaty ^{2*}, Irdinal Arief ²

¹ Master of Architecture Program, Faculty of Engineering, Tadulako University, Indonesia.

² Department of Architecture, Faculty of Engineering, Tadulako University, Indonesia.

| Received June 8th 2025 | Accepted July 26th 2025 | Published March 31th 2026 |

| DOI <https://doi.org/10.32315/jlbi.v15i1.514> |

Abstract

This study aims to identify strategies and innovations in the development of earthquake-resistant housing in Indonesia during the 2015–2025 period through a Systematic Literature Review (SLR). A total of 20 articles were rigorously selected from 233 initial publications in Google Scholar, based on inclusion and exclusion criteria relevant to the local context in Indonesia. The findings reveal three main approaches: (1) modular prefabricated construction systems such as RISHA, RIKO, and RISBA; (2) improvement of conventional construction in accordance with the latest Indonesian National Standards (SNI); and (3) adaptation of vernacular architecture based on local wisdom. The study also examines the performance of materials such as bamboo, timber, steel profiles, light-gauge steel, and composite materials in enhancing earthquake resilience. Architectural studies in Indonesia generally focus on identifying features and concepts of vernacular architecture that are responsive to seismic conditions; however, they have not yet advanced toward the modernization and generalization of these principles for application in earthquake-resistant housing design. Although various technical and social innovations have emerged, implementation in the field remains constrained by weak technical supervision, disparities in construction and material quality, and low disaster literacy among communities. Therefore, this study recommends strengthening technical regulations, enhancing community capacity, and integrating technology with local values as key strategies toward developing earthquake-resistant housing that is contextual, adaptive, and sustainable in Indonesia.

Keywords : *construction innovation, earthquake-resistant housing, modular construction, vernacular architecture*

Strategi dan Inovasi Rumah Tahan Gempa di Indonesia: Tinjauan Literatur Sistematis

Abstrak

Penelitian ini bertujuan mengidentifikasi strategi dan inovasi pengembangan rumah tahan gempa di Indonesia periode 2015–2025 melalui metode *Systematic Literature Review* (SLR). Sebanyak 20 artikel dipilih secara ketat dari 233 publikasi awal di google cendekia, berdasarkan kriteria inklusi dan eksklusi yang relevan dengan konteks lokal di Indonesia. Hasil kajian menunjukkan tiga pendekatan utama: (1) sistem konstruksi modular prefabrikasi seperti RISHA, RIKO, dan RISBA; (2) perbaikan konstruksi konvensional sesuai SNI terbaru; dan (3) adaptasi arsitektur vernakular berbasis kearifan lokal. Studi ini juga menelaah performa material seperti bambu, kayu, baja profil, baja ringan, dan komposit (gabungan) dalam meningkatkan ketahanan terhadap gempa. Kajian aspek arsitektur di Indonesia umumnya pada identifikasi fitur dan konsep arsitektur vernakuler yang responsif terhadap kegempaan, namun belum mengarah pada modernisasi dan generalisasi prinsip tersebut agar dapat diaplikasikan pada desain rumah tahan gempa. Meskipun terdapat inovasi teknis dan sosial yang berkembang, implementasi di lapangan masih terkendala lemahnya pengawasan teknis, ketimpangan kualitas konstruksi serta material, dan rendahnya literasi kebencanaan masyarakat. Oleh karena itu, direkomendasikan penguatan regulasi teknis, peningkatan kapasitas masyarakat, serta integrasi teknologi dengan nilai lokal sebagai strategi menuju rumah tahan gempa yang kontekstual, adaptif, dan berkelanjutan di Indonesia.

Kata-kunci : arsitektur vernakular, inovasi konstruksi, konstruksi modular, rumah tahan gempa

* Corresponding Author

E-mail: puteri.f@untad.ac.id ; puteri_fitriaty@yahoo.com



Introduction

Housing is a fundamental element of the built environment that reflects the social, cultural, and technological values that develop within a community. The function of a house in Indonesia is not only as a place to live, but also as a symbol of local identity and a space for cultural expression [1]. Despite its geographical beauty, Indonesia is a country with a high risk of earthquakes because it is located at the meeting point of three active tectonic plates. Major earthquakes, such as the one that occurred in Yogyakarta (2006), Padang (2009), Palu and Lombok (2018) have served as reminders of the importance of structural resilience in residential buildings. *“It is not earthquakes themselves, but rather the damage and collapse of houses that are the main killers”* in disaster-prone areas [2].

Many houses in Indonesia especially in rural areas or informal settlements are built without regard for earthquake-resistant structural principles [3]. Extensive damage to buildings caused by various earthquakes highlights gaps in the implementation of building standards. This is exacerbated by limited resources, a lack of technical knowledge, and insufficient dissemination and training related to technical implementation in many post-disaster housing projects [4].

The efforts to design and build earthquake-resistant houses in Indonesia over past decades have shown significant progress, both in terms of community involvement, construction technology, design approaches, public policy, and empowerment. Innovation such as Rumah Instan Sederhana Sehat (RISHA), Rumah Instan Konvensional (RIKO) dan Rumah Instan Baja (RISBA) [5], as well as permanent dwellings based on local wisdom such as wooden stilt houses [6], have become part of this dynamic. At the same time, there are also initiatives from historians, NGOs, the government, and architects communities to design prototypes of earthquake-resistant houses that are more adaptive, efficient, and contextual [7].

However, information and knowledge related to this approach are still scattered across various documents, scientific articles, technical reports, and pilot projects that have not been systematically synthesized. The lack of comprehensive studies covering the development of the Earthquake-Resistant House (RTG) approach in Indonesia over the past ten years has resulted in suboptimal replication and future development efforts. [8]. It is important to have a critical mapping and analysis of various Earthquake-

Resistant House innovations, implementation challenges, and their impact on society.

This study aims to understand the development of RTG in Indonesia between 2015 and 2025 through systematic review. This research not only maps the achievements of research related to architecture, construction systems, and building materials, but also identifies gaps in research that remain open, particularly in architectural design approaches that are relatively rarely the main focus of RTG studies. This study examines the effectiveness of various approaches that have been developed and outlines future development directions based on research published on Google Scholar with a research location restriction in Indonesia. The results of this study are intended to serve as a basis for policy, architectural practice, and community empowerment in earthquake-prone areas, particularly in Indonesia. This study has two research questions (RQs), including:

RQ 1: What construction systems and materials have been developed in RTG design in Indonesia over the past 10 years?

RQ 2: What are the effectiveness, implementation challenges, and development opportunities based on empirical evaluation results in the literature?

Methods

The research method used was a literature review in the form of a Systematic Literature Review (SLR) to discuss the various approaches to construction systems and materials used in the development of RTG in Indonesia and their effectiveness. The stages in this research began with the search and collection of relevant literature, followed by classification based on specific inclusion and exclusion criteria to ensure that only literature relevant to the research focus would be analyzed. Next, proceed with assessing the quality of the literature that will be used as material for the review.

The process of searching for articles in the Google Scholar database using the Publish or Perish tool with the keywords (“rumah tahan gempa” OR “rumah resiliensi gempa” OR “desain rumah tahan gempa”) AND (“perumahan” OR “bangunan tempat tinggal” OR “rumah tinggal”) AND (“kerusakan bangunan” OR “konstruksi tahan gempa” OR “struktur bangunan”), the search results yielded 233 articles.

Table 1. Inclusion and Exclusion Criteria

No	Criteria	Inclusion	Exclusion
1	Article Tyoe	Research article	Book, or chapter of a book, thesis, dissertation
2	Publication period	2015-2025	Before 2015
3	Publication	Open access	Locked access
4	Focus	Residential houses, earthquake-resistant houses	High-rise buildings, public function buildings
5	Location	Indonesia	Outside Indonesia

The next stage was screening through the titles and abstracts based on the inclusion and exclusion criteria in Table 1. Based on this process, 79 articles that met the criteria were selected to proceed to the full-text review stage. At this stage, the articles were reviewed thoroughly in terms of their objectives, methods, and results, while also considering the journal rankings, resulting in 20 articles being selected for further analysis and discussion. This process is illustrated in Figure 1.

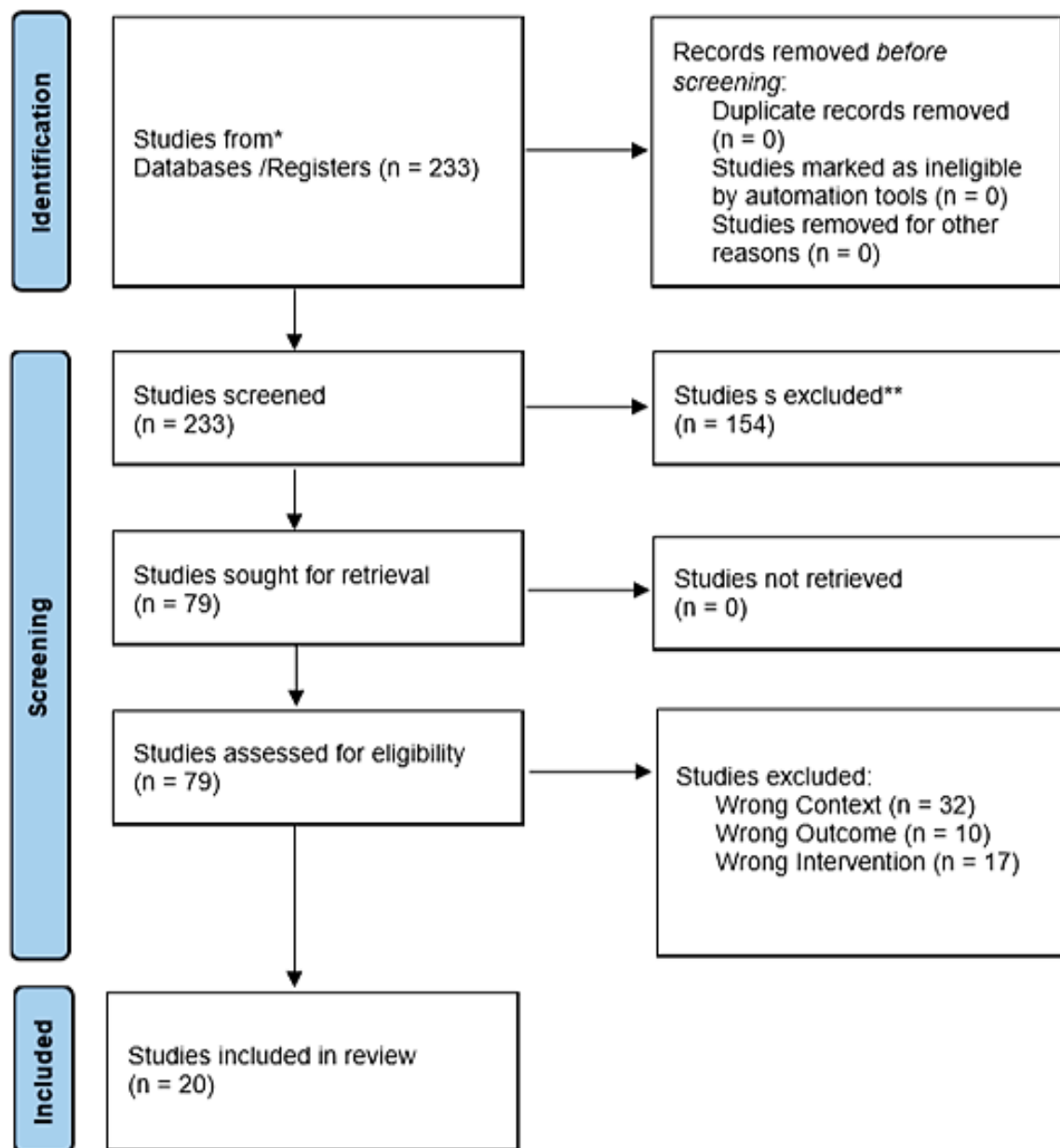


Figure 1. Prism Diagram of Systematic Literature Review (SLR) [33]

Result and Discussion

Earthquakes in Indonesia in recent years have destroyed most of the houses of residents who did not follow standard earthquake-resistant building guidelines. Learning from these events, the evaluation and mitigation of the vulnerability of community buildings/houses has become an interesting topic of research. Most researchers chose topics related to training, education, and assistance on RTG standards, as shown in Figures 2 & 3. Limited information and socio-economic factors often cause communities to ignore technical standards when building homes that are safe from earthquakes.

Based on the results of the 2019 PB-PUPR Task Force report on earthquake disaster management in the Lombok and Palu areas, there are five types/models of RTG construction that have been built and are now inhabited by communities affected by the disaster in those areas, as described in Table 2 [9][10]. RISHA was the most popular choice during the rehabilitation phase following the Palu earthquake, with 7,473 units built [6].

In the Lombok region, RIKO is the top choice [11]. This is because RISHA is constrained in terms of distribution and transportation to reach areas with limited road access, while RIKA is constrained by timber materials with specified strength and durability standards and the legality of timber is difficult to fulfill.

In response to the first research question, the description in Table 2 shows that the RISHA, RIKA, RIKO, RISBA, and ferrocement house construction systems are RTG model options built to provide permanent housing for disaster victims during the rehabilitation and reconstruction phases of disasters in Indonesia.

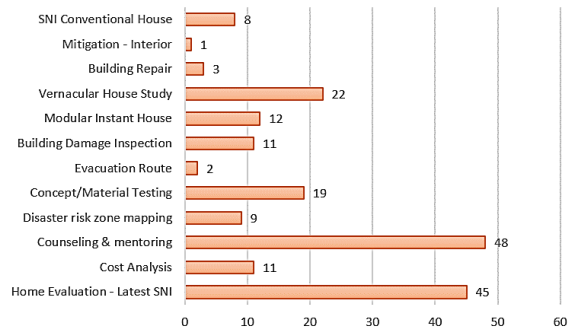


Figure 2. Research Direction for Earthquake-Resistant Houses

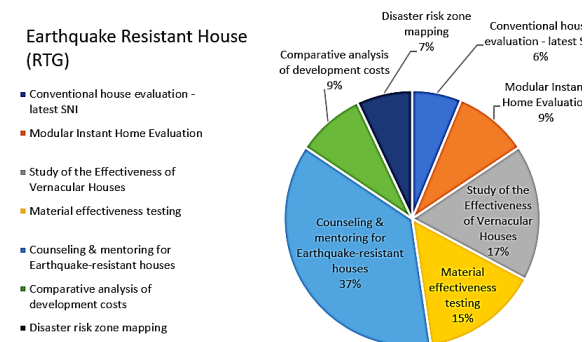


Figure 3. Main Themes of Earthquake-Resistant Housing Research

The results also show that there are other types of RTG that have been recommended by the Ministry of Public Works and Public Housing's Research and Development Center for Housing to support the acceleration of housing development, including: Rumah Cetak Indonesia (RCI), Rumah Bata Ringan (Domus), Rumah Instan Baja Ringan (RISBARI), Rumah Instan Tahan Gempa Al-Ansar (RITA), and Rumah Pracetak Indocement (RAPI) [9]. Based on the specifications of RISHA, RISBA, ferrocement, and other types of materials, it can be concluded that each type of construction combines more than one type of material (composite). For example, the combination of brick walls, ferrocement cladding, and wire mesh results in better seismic performance. [12].

Table 2. Types of Earthquake-Resistant House Construction for the 2018 Palu and Lombok Disaster Rehabilitation Program

No	Construction	Specification	Implementation	Source
1	Rumah Instan Sederhana Sehat (RISHA)	Modular system, precast concrete frame structure with a quality of K.250 - 275 Mpa, lightweight brick/concrete block infill walls	Lombok & Palu	[6] [9] [11]
2	Rumah Instan Konvensional (RIKO)	Structure: stone foundation, concrete sloof, columns, conventional ring beams, cast-in-place construction	Lombok & Palu	[9] [11]
3	Rumah Instan Kayu (RIKA)	The main frame structure uses wood with nail joints, and the wall material is class II wood paneling.	Lombok & Palu	[6] [9] [11]
4	Rumah Instan Baja (RISBA)	Continuous stone foundation structure, combined with conventional concrete sloof, main structure using conventional steel with CNP profile	Lombok	[9] [11]
5	Rumah tembokan balutan ferosemen	House with ferrocement layer application on both sides of the wall, composite structure consisting of a ferrocement layer, wall, ferrocement layer	Palu - Sigi	[6][12]

Table 3. Literature Review Study

No	Title and Author	Aims	Methods	Results
1	Evaluasi terhadap Implementasi Pembangunan Rumah Tahan Gempa Tipikal Tembokan pada Perumahan Bersubsidi di Serang, Banten (M.N Sari & D. Triana, 2019) [25]	Evaluating the extent to which RTG development has been implemented by subsidized housing developers in Serang, Banten.	Qualitative with purposive sampling technique	Only 15% of subsidized houses in Serang, Banten meet the minimum earthquake-resistant construction requirements, while 45% fall short and 40% do not meet the minimum requirements.
2	Analisa Rumah Instan Konvensional sebagai Alternatif Rumah Tahan Gempa sesuai SNI 1726:2019 (J Prasatiawan & A I Makrifa, 2023) [14]	Analyzing the capacity and structural behavior of RIKO under seismic loads in Lombok, Indonesia, according to Indonesian building codes.	Structural modeling using SAP2000 software - pushover analysis	The behavior of the RIKO structure when subjected to seismic loads based on SNI 1726:2019, the resulting displacement limit is = 0.017 m. The displacement capacity level is good, the building performance is concluded to be good and can be occupied immediately. 1. The RISBA method is 17% cheaper than the conventional method. 2. The quality of the builders affects the implementation time. 3. The materials used in the RISBA method are more reliable, the main component being steel that complies with SNI standards.
3	Analisis Perbandingan Biaya dan Waktu Penggunaan Metode RISBA dan Metode Konvensional pada Struktur Bangunan Rumah Tinggal (N.H Crista et al., 2023) [16]	To compare the differences in cost and time between using conventional construction methods and the RISBA method for two-story residential buildings.	Quantitative - calculation of costs and implementation time	Regular wooden beams have a fairly good dynamic response for earthquake-resistant house structures, while light steel composite wooden beams have a better dynamic response than regular wooden beams. However, special attention must be paid to the joints of light steel composite wooden beams to minimize the existing shear forces.
4	Perbandingan Respon Seismik Balok Kayu Biasa dengan Komposit Baja Ringan sebagai Komponen Struktur Rumah Tahan Gempa (P. Simanjuntak, 2021) [22]	Comparing the seismic response of conventional wooden beams and lightweight steel composite beams to determine the most suitable type of beam material for use in earthquake-resistant building structures.	Computer simulation experiment method - ANSYS program	The buildings at the research site did not use earthquake-resistant design principles. The quality of materials, workmanship, and connection details did not meet the minimum requirements for earthquake-resistant buildings.
5	Analisis Ketahanan Gempa Rumah Tembokan Beton Bertulang di Perumahan Graha Arradea (F.S Yoresta, 2018) [26]	To determine whether houses in the Graha Arradea Housing Complex (Phase 3) in Bogor Regency, West Java, were built in accordance with earthquake-resistant design principles.	Qualitative - descriptive (observation and interviews)	The use of bamboo as an alternative material for earthquake-resistant houses is an appropriate solution from an economic perspective, as it is easily available and has elastic properties against seismic forces compared to steel and concrete.
6	Rumah Tahan Gempa Berkonstruksi Bambu sebagai Metode Mitigasi Bencana Masyarakat Garut (M. Ramdani et al., 2022) [17]	Discussing the use of bamboo as a construction material for earthquake-resistant houses is one of the disaster mitigation methods for the people of Garut.	Qualitative - case study	Failures occurred mostly in the columns, affecting other structural components. The main principle of earthquake-resistant buildings is strong columns and weak beams, which was not fulfilled in almost all damaged buildings.
7	Assesmen Kerusakan Rumah Tinggal Pasca Gempa Cianjur November 2022 mengacu kepada Standar PU-PERA (Hutabarat et al., 2023) [27]	Community service activities to assess damage to buildings caused by an earthquake measuring 5.6 on the Richter scale that struck Cianjur Regency, West Java Province, Indonesia on November 21, 2022.	Qualitative (observation and quick assessment)	Based on structural modeling tests of residential houses using bamboo materials, it was concluded that ERBA is capable of withstanding earthquakes. The development of bamboo preservation methods, connection systems, and technical guidance on construction are limitations of this study.
8	Bambu sebagai Material Berkelanjutan ERBA (Earthquake-Resistant Bamboo Architecture) (Bhudi et al., 2024) [18]	Recommending the use of bamboo as a local, affordable, and earthquake-resistant material for building construction as an alternative to the concrete-based RISHA system, which has been rejected by some members of the community.	Combined descriptive qualitative and quantitative methods Computer modeling using SAP2000 software	

Continued from Table 3. No. 9–15

No	Title and Author	Aims	Methods	Results
9	Struktur Rumah Sederhana Ramah Gempa untuk Meminimalisir Kerusakan dan Korban Jiwa (Saputro et al., 2020) [29]	Workshop related to raising awareness and knowledge about earthquake-resistant housing construction to minimize damage and loss of life due to earthquakes.	1) Lectures and discussions about hazards and earthquake-resistant housing. 2) Surveys using Likert scale questionnaires..	Awareness of housing quality is already very good. This is evidenced by the community's response to the importance of building homes that meet standards, even though there is an additional cost of 30% for earthquake-resistant homes compared to ordinary homes.
10	Analisis Perilaku Struktur Bangunan Rumah Metode RISHA dan RIKO Ditinjau Terhadap Gempa Linier Dinamik Respon Spektrum di Kabupaten Minahasa Selatan (N.A Simanjuntak et al., 2024) [15]	Analyzing the structural behavior of residential buildings using the RISHA and RIKO methods based on base shear, displacement, and story drift in South Minahasa Regency, North Sulawesi Province.	Quantitative – computer simulation experiment using ETABS program	The shear force and displacement values using the RISHA and RIKO models still meet the requirements. For floor deflection (story drift) values, the RISHA method meets the requirements, but the RIKO model does not, so the RIKO model has the potential for structural collapse.
11	Analisa Elemen – Elemen Struktur Tahan Gempa Rumah Sederhana pada Arsitektur Nusantara Rumah Gadang (Abidah et al., 2023) [20]	Analyzing the structural elements of Rumah Gadang, a traditional Minangkabau house in West Sumatra, Indonesia, and identifying existing elements to be applied to the design of a simple, modern, earthquake-resistant house without losing local cultural values.	Qualitative-historical method	Selection of a location on hard and stable ground (foundations adapted to soil conditions), symmetrical floor plan (simple), wood and woven bamboo materials (lightweight), dowel and tie connection system (flexible).
12	Efektivitas Pembangunan Rumah RISHA, RIKA dan RIKO (3R) bagi Masyarakat Terdampak Gempa (Kamsuta et al., 2020) [13]	Evaluating the effectiveness of the construction of three house models recommended by the government (RISHA, RIKA, and RIKO) for communities affected by the 2018 Lombok earthquake.	Quantitative – descriptive (questionnaires and interviews)	The RISHA model is more effective than the other models in terms of: a. good material completeness, b. construction time frame, c. appropriate construction costs, d. community group and facilitator involvement, and; e. building size is as expected.
13	Penilaian Bangunan Sederhana di Kawasan Rawan Gempa Bumi (Studi Kasus di Kota Bengkulu dan Kabupaten Bengkulu Tengah) (A. Hamzah et al., 2020) [31]	Summarizing the vulnerability and risk assessment of buildings in earthquake-prone areas in Bengkulu, Indonesia, using a rapid visual assessment tool.	Quantitative – field observations using smartphone software for rapid assessment of simple buildings (ACeBS)	1. The ACeBS application shortens assessment time and provides digital-based data/records. 2. 71% of buildings are at high risk, and 29% of buildings are at moderate risk. 3. The moderate-to-high vulnerability of simple buildings/houses is due to poor building structures, reinforcement, and material quality.
14	Pemeriksaan Material pada Pembangunan Rumah Non-Engineered di Daerah Rawan Gempa Dusun Serut, Palbapang Kabupaten Bantul, Yogyakarta (MH Zulfiar, 2018) [23]	Researching construction practices and the quality of non-engineered housing materials in earthquake-prone areas (simple houses).	Quantitative – observation and laboratory sample testing	Construction practices do not undergo strict planning and supervision. Laboratory test results show that brick materials and concrete quality do not yet meet earthquake-resistant housing requirements, while reinforced concrete does meet the requirements.
15	Perbandingan Biaya Pembangunan Rumah Sederhana dengan Rumah Konsep Aman Gempa Berdasarkan Analisa <i>Benefit Cost Ratio</i> Skenario Gempa 50 Tahun (Z Mirani et al., 2024) [30]	To design earthquake-resistant houses and analyze the cost-benefit ratio and compare it with conventional houses.	Quantitative method – benefit cost ratio	1. Earthquake-resistant houses are more expensive than conventional houses, with a cost difference of IDR 20,370,000 or 5%. 2. The BCR value is > 1, and the value increases until the 50th year. The additional costs of implementing earthquake-resistant features in houses are considered effective.

Continued from Table 3 No 16 - 20

No	Title and Author	Aims	Method	Result
16	Karakter Bentuk Hunian Suku Rejang di Daerah Rawan Gempa (Studi Kasus: Desa Gunung Alam, Kabupaten Lebong) (Prihatiningrum et al., 2020) [21]	Describing traditional Rejang housing in Gunung Alam Village, Lebong Regency, located in an earthquake-prone area, and examining how the design and construction features of these houses make them adaptive to local earthquake risks.	Descriptive qualitative observation and interviews	Building configuration (shape, size, properties, layout of elements) affects the building's response. The adaptability of Rejang tribe housing is demonstrated in the spatial patterns that form simple/symmetrical floor plans and the use of local wood. However, the addition of space behind the original building using brick material poses a new risk to Rejang tribe housing.
17	Penilaian Daya Dukung Daratan Permukiman Sensitif Gempa Panjanglejo, Pundong, Bantul, DIY (F Putri et al., 2022) [32]	To assess the carrying capacity of residential areas in Panjanglejo Village, Pundong Subdistrict, Bantul Regency, which is prone to earthquakes, and to ensure that housing development remains in accordance with its intended use and environmental carrying capacity (DDL).	Quantitative - combining survey and field mapping techniques, as well as carrying capacity evaluation and overlay methods.	Criteria for carrying capacity assessment include: rainfall, soil type, slope, land use, rock type, seismic factors, and distance from faults/fractures. Local-scale carrying capacity and vulnerability maps must be created for each area as they have different characteristics. 1. The analysis produced the same forces and values for medium and soft soil conditions. 2. The analysis of the capacity of the corrected wooden structure shows that some of the structural element values are smaller than the requirements, so that the vernacular house structure is not sufficient to withstand the forces that occur. However, based on the history of earthquakes, the vernacular houses remain standing and there is no damage to their structural elements.
18	Perilaku dan Ketahanan Struktur Rumah Vernakular Desa Gunung Alam Lebong terhadap Gempa Bumi (S Bahri et al., 2022) [24]	To determine the behavior and resistance of structures to earthquakes. The analysis was conducted in accordance with SNI 1726:2019..	Quantitative - computer simulation experiments using SAP2000 software	1. The analysis produced the same forces and values for medium and soft soil conditions. 2. The analysis of the capacity of the corrected wooden structure shows that some of the structural element values are smaller than the requirements, so that the vernacular house structure is not sufficient to withstand the forces that occur. However, based on the history of earthquakes, the vernacular houses remain standing and there is no damage to their structural elements.
19	<i>Local Wisdom as a Sustainable Building Solution: Bamboo Incremental House Design Concept</i> (K Yudhistira et al., 2021) [19]	Presenting an exploration project related to developing the concept of inexpensive disaster-resistant houses, utilizing local wisdom, and accommodating the needs of residents as the number of occupants grows. The proposed design solution stems from the 2018 Lombok earthquake.	Performance-Based Design (PBD) approach, a housing concept with a focus on sustainability and disaster resilience.	1. Proposing a growing house design using bamboo as the main material, which can be expanded gradually. 2. This design utilizes local wisdom and sustainable principles, such as the use of bamboo, stilt foundations, and expandable modular structures.
20	Optimalisasi Mitigasi Bahaya Gempa Bumi melalui Penyuluhan Rumah Tahan Gempa di Kelurahan Rewarangga Selatan, Provinsi Nusa Tenggara Timur (YL Suku et al., 2022) [28]	This Community Service (PkM) program aims to prevent disasters caused by earthquakes by improving the knowledge and skills of the community, especially builders, regarding earthquake-resistant houses.	Community Service (PkM) - technical training and guidance	Technical training and guidance successfully improved the understanding and skills of the community and builders regarding earthquake vulnerability and mitigation in Ende City. Based on the average final test score of 80.67%, compared to the initial test score of only 64.67%, there was a 16% increase in understanding and skills.

Figure 4 shows the trend of research on RTG in Indonesia over the past 10 years, which has been on the rise. In addition to education and training, research in Indonesia has focused on testing local materials or composite/hybrid materials and evaluating their effectiveness in relation to seismic activity.

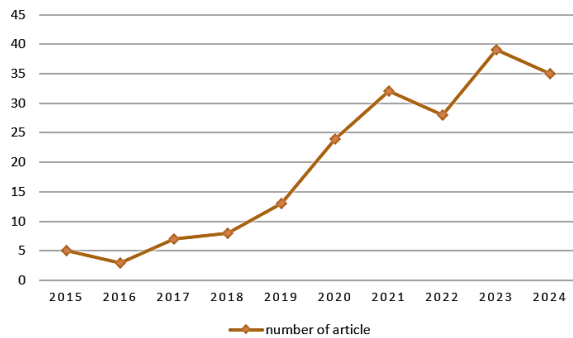


Figure 4. Research Article Trends by Year

The themes in Table 4 are systematically arranged to provide an in-depth overview and understanding to answer the second research question.

Table 4. Overview and Development Formulation

No	Description	Source
1	Diversification of Earthquake-Resistant House Construction Systems	[14], [16], [15], [13]
2	Effectiveness of Local and Composite Materials	[22], [17], [18], [20], [23], [21], [19],
3	The Resilience of Vernacular Architecture Based on Local Wisdom	[20], [21], [24]
4	Challenges in Construction Implementation and Building Quality	[25], [26], [27], [23], [21]
5	The Role of Education, Training, and Public Awareness	[29], [13], [30], [28]
6	Innovations in Risk Assessment and Contextual Planning	[31], [32]

1. Diversification of Earthquake-Resistant House Construction Systems

An in-depth study of 20 articles shows that RTG construction strategies in Indonesia over the past decade have been developed through three main approaches, namely: prefabricated modular systems, reinforced conventional systems, and vernacular architectural approaches based on local wisdom. Modular systems such as RISHA, RIKO, and RIKA have been widely applied in post-disaster reconstruction projects. RISHA is considered superior because it is time and cost efficient, has good structural performance, and is easy for the community to build [13]. On the other hand, numerical simulations of RIKO show that although its lateral displacement is quite good [14], this system fails to

meet the story drift tolerance limit [15], which risks causing collapse during a major earthquake. Meanwhile, the RISBA system, which combines concrete and steel, shows a cost efficiency of 17% compared to conventional construction, with the caveat that technical supervision must be strengthened to maintain building quality [16].

2. Effectiveness of Local and Composite Materials

Bamboo has been extensively studied as the primary material for earthquake-resistant growing houses because it is lightweight, flexible, and inexpensive. Studies show that bamboo structures are resistant to lateral forces [17] [18], especially in the context of bamboo design as a sustainable alternative material [18] reinforced by the idea of a prototype growing house design using bamboo construction [19]. However, this material still faces challenges in terms of connection systems and preservation [17] [18]. Local wood is also still used in traditional house structures due to its flexibility and affordability [20] [21]. Material innovations such as lightweight wood-steel composites show better potential in withstanding dynamic vibrations than ordinary wood, although joint strength remains a critical issue [22]. Conventional concrete and brick, although still widely used, often do not meet technical quality standards and are a source of structural vulnerability [23].

3. The Resilience of Vernacular Architecture Based on Local Wisdom

The vernacular architectural approach has proven to possess historically tested disaster resilience values. Rumah Gadang in West Sumatra uses a platform system and peg joints that allow the structure to respond flexibly to earthquakes [20]. The Rejang Tribe House in Bengkulu [21], research on vernacular wooden houses in Lebong, numerical studies show that some elements of these vernacular houses do not meet internal forces based on modern engineering standards [24], but empirical records show that these houses remained standing during several major earthquakes. These findings indicate that local architecture holds valuable adaptive strategies that require development and modification to be applied in the modern context of earthquake-resistant house design.

4. Challenges in Construction Implementation and Building Quality

The quality of earthquake-resistant housing strategy implementation in the field remains a major challenge. A study in Serang found that only 15% of subsidized houses met earthquake resistance standards [25],

while in Bogor [26] and Bantul [23], the quality of building materials and connections showed many deficiencies. Structural failures most often occur in column elements, even though these elements should be the strongest part of the structure [27]. Modifications and additions that do not comply with regulations actually create new vulnerabilities, as was the case with Rumah Rejang [21]. This reinforces the importance of technical supervision in the construction process, especially for self-help buildings and public housing.

5. The Role of Education, Training, and Public Awareness

Improving the capacity of the community and construction workers greatly influences the successful implementation of RTG. Technical training for builders has been proven to improve skills and awareness of earthquake-resistant construction standards. A training program in Ende, for example, increased builders' knowledge by 16% [28]. Workshops in the Cianjur region succeeded in improving community understanding, although the additional cost of 30% for building earthquake-resistant houses remains a significant obstacle [29]. The additional costs must be explained more clearly to the community. For example, there is an additional cost of 5% for adding earthquake-resistant features to conventional house structures, but the BCR (benefit-cost ratio) is > 1 and its value increases until the 50th year. This means that additional costs at the outset are more effective in preventing greater losses in the future [30]. Other studies confirm that community participation in modular systems such as RISHA greatly helps to accelerate construction and increase a sense of ownership of the house [13].

6. Innovations in Risk Assessment and Contextual Planning

Innovations in risk assessment are also part of the housing resilience strategy. The use of the ACeBS application for rapid assessment in Bengkulu showed that 71% of simple houses were in the high-risk category due to low-quality materials and the absence of structural elements [31]. On the other hand, a geotechnical study in Bantul emphasizes the importance of considering soil bearing capacity in RTG design [32], because the interaction between the structure and the soil greatly determines the success of a building in responding to seismic forces.

Conclusion

The development of RTG in Indonesia for the period 2015–2025 involving various dimensions and complexities. Three main approaches that have been successfully identified include: the use of modular prefabrication systems, improvements to conventional construction in accordance with the latest SNI standards, and the adaptation of vernacular architectural concepts based on local wisdom. Systems such as RISHA have demonstrated good performance in post-disaster reconstruction efforts in Indonesia, although they still require technical and social support to be implemented optimally. The use of local materials such as bamboo, wood, or a combination of materials (composite/hybrid) has promising structural strength potential.

RTG research in the field of architecture in Indonesia generally still focuses on identifying and tracing the features of vernacular buildings that are responsive to seismic conditions, without any systematic efforts to develop or modernize these features. This condition indicates a research gap at the implementation stage, where the principles and techniques of vernacular architecture can actually be adapted, modified, and generalized into contextual modern architectural designs, thereby producing works that are relevant to community needs and comply with applicable standards.

The main obstacle in implementing RTG lies in the lack of supervision of construction quality, resulting in many community housing units not complying with structural safety standards. Therefore, capacity building through training for builders and education for residents is considered very important in supporting the successful implementation of RTG.

Furthermore, the application of software-based building risk/vulnerability assessment methods is considered effective and should be further developed. In addition to earthquake-resistant construction, more detailed mapping of each disaster-prone zone is needed as a basis for RTG planning because each area has unique characteristics such as soil type, land slope, and distance to earthquake faults. Based on the above findings, this study recommends strengthening technical regulations that actively involving the community in the planning process, and combining local values with technological innovations to produce earthquake-resistant housing models that are structurally sound and culturally relevant.

AI Usage Declaration

The authors acknowledge the use of DeepL Translator for language translation from Indonesian to English. While the authors acknowledge the usage of AI, the authors maintain that they (Muhammad Dwi Utomo, Puteri Fitriaty, Irdinal Arief), are the sole authors of this article and take full responsibility for the content therein, as outlined in COPE recommendations and journal policies.

Acknowledgement

We are grateful to Dr. Zulfitriah Massiming for her assistance and suggestions during the completion process of this manuscript.

Funding

This research received no external funding.

References

- [1] D. Widyastomo, "Perubahan Tahapan dan Bentuk Rumah Tradisional Masyarakat Adat Suku Sentani di Pesisir Danau Sentani di Kabupaten Jayapura," *Jurnal Ilmiah Komputer Grafis*, vol. 14, no. 1, 2021.
- [2] D. Hardjito, *Antara Mitigasi Gempa Dan Pendidikan Tinggi*; Cetakan Pe. Lembaga Penelitian dan Pengabdian kepada Masyarakat Universitas Kristen Petra Jl. Siwalankerto 121-131, Surabaya 60236, Indonesia, 2024.
- [3] E. R. Ahadian and E. Tuhuteru, "Evaluasi Bangunan Sederhana Tahan Gempa," *Jurnal Sipilains*, vol. 10, no. 1, pp. 41–52, 2020, [Online]. Available: <https://ejournal.unkhair.ac.id/index.php/sipils/article/view/41-52>
- [4] P. Simanjuntak, "Evaluasi Kerusakan Bangunan Akibat Gempa Di Indonesia," *Jurnal Rekayasa Teknik Sipil dan Lingkungan - CENTECH*, vol. 1, no. 1, pp. 44–53, 2020, doi: 10.33541/cen.v1i1.1425.
- [5] R. Ridha, A. A. Rahmawaty, and H. Santoso, "Strategi Percepatan Rehabilitasi dan Rekonstruksi Pasca Gempa Melalui Zonasi Rumah Tahan Gempa (RTG) di Kabupaten Lombok Utara," *Seminar Nasional Planoeearth #02 Perencanaan dan Pemanfaatan Ruang Berbasis Pengurangan Risiko Bencana*, pp. 33–41, 2021, [Online]. Available: <https://journal.ummat.ac.id/index.php/PRPE/article/view/3987>
- [6] A. Asnudin, A. Ali, and T. Muhtar, "Analisis Alternatif Desain Konstruksi Rumah Tinggal di Wilayah (Palu, Donggala dan Sigi) PASIGALA Pasca Bencana 28 September 2018," *Jurnal Sains dan Teknologi Tadulako*, vol. 9, no. 2, pp. 80–91, 2023.
- [7] S. M. Kaddi, M. I. Yusaputra, and A. P. Melisa, "Desain Pesan Persuasif Yayasan Arsitek Komunitas Indonesia Pada Korban Bencana Alam di Kota Palu," 2022. [Online]. Available: <https://core.ac.uk/reader/11>
- [8] A. Haris, "Tantangan dan Peluang Riset Srstruktur Antisipasi Gempa Tepat Guna Di Indonesia," *Prosiding Seminar Nasional Dmi*, vol. 1, pp. 1–8, 2020.
- [9] R. Thamrin, A. G. G. Akman, and I. S. Gunarta, *Penanganan Pasca Gempa Lombok 2018*. PT. Mediatama Saptakarya, 2019.
- [10] CPMU-CSRRP, "Studi Tematik Kapasitas Pemerintah Daerah Dalam Penanggulangan Bencana (TSLGC)," 2025. [Online]. Available: <https://barenlitbang.malangkota.go.id/wp-content/uploads/2019/03/Lapkir-Penyusunan-Permasalahan-lsu-Strategis-Prioritas-Kebijakan-PMMSB-Kota-Malang-Taun-2017.pdf>
- [11] S. N. Hijah and M. Komarudin, "Rehabilitasi Dan Rekonstruksi Pasca Gempa Lombok Provinsi Nusa Tenggara Barat Tahun 2018," *Prosiding Seminar Nasional Teknik Sipil 2019*, pp. 1–8, 2019.
- [12] T. Boen, H. Imai, and S. E. Suryanto, "Earthquake Resistant Non-Engineered Construction in Developing Countries Utilizing Appropriate Technology," *European Journal of Advances in Engineering and technology*, vol. 7, no. 8, pp. 49–63, 2020.
- [13] Kamsuta, "Efektivitas Pembangunan Rumah Risha, Rika dan Riko (3R) bagi Masyarakat Terdampak Gempa," 2020.
- [14] J. Prasetiawan and A. I. Makrifa, "Analisa Rumah Instan Konvensional Sebagai Alternatif Rumah Tahan Gempa Sesuai Sni 1726: 2019," *Konferensi Nasional Teknik ...*, no. November, pp. 16–17, 2023, [Online]. Available: <https://konteks17.uniba-bpn.ac.id/index.php/konteks/article/download/126/129>
- [15] N. A. Simanjuntak and O. Meilawaty, "Analisis Perilaku Struktur Bangunan Rumah Metode RISHA dan RIKO Ditinjau Terhadap Gempa Linier Dinamik Respon Spektrum di Kabupaten Minahasa Selatan," vol. IX, no. 3, pp. 10106–10114, 2024.
- [16] N. H. Crista, F. Mahmud, H. Purwanti, and K. W. Widiatmoko, "Analisis Perbandingan Biaya dan Waktu Penggunaan Metode Risba dan Metode Konvensional pada Struktur Bangunan Rumah Tinggal," vol. 03, pp. 84–93, 2023.

- [17] Mamur Ramdani, Aulia Nisa Alifah, and Eldi Mulyana, "Rumah Tahan Gempa Berkonstruksi Bambu Sebagai Metode Mitigasi Bencana Masyarakat Garut," *Jurnal Pendidikan Ips*, vol. 12, no. 1, pp. 1–7, 2022, doi: 10.37630/jpi.v12i1.518.
- [18] M. Kusuma Bhudi and P. Studi Arsitektur, "Bambu Sebagai Material Berkelanjutan Erba (Earthquake-Resistant Bamboo Architecture) Fibria Conyatin Nugrahini Zuraida Rofi'i," *Sinektika*, vol. 21, no. 2, 2024, [Online]. Available: <http://journals.ums.ac.id/index.php/sinektika>
- [19] Y. Kusuma, "Local wisdom as a sustainable building solution: Bamboo incremental house design concept," *Journal of Applied Science and Engineering*, vol. 25, no. 1, pp. 119–127, 2022, doi: 10.6180/jase.202202_25(1).0012.
- [20] D. Y. Abidah, M. M. Musthoffa, Ronalmanto, M. Hasanah, and O. Romadhani, "Analisa Elemen – elemen Struktur Tahan Gempa Rumah Sederhana pada Arsitektur Nusantara Rumah Gadang," *G-Tech: Jurnal Teknologi Terapan*, vol. 7, no. 2, pp. 367–376, 2023, doi: 10.33379/gtech.v7i2.2026.
- [21] A. Prihatiningrum, "Karakter Bentuk Hunian Suku Rejang Di Daerah Rawan Gempa (Studi Kasus: Desa Gunung Alam, Kabupaten Lebong)," *Arsitektura*, vol. 18, no. 1, p. 84, 2020, doi: 10.20961/arst.v18i1.40786.
- [22] P. Simanjuntak, "Perbandingan Respon Seismik Balok Kayu Biasa Dengan Komposit Baja Ringan Sebagai Komponen Struktur Rumah Tahan Gempa," *Jurnal Rekayasa Teknik Sipil dan Lingkungan - CENTECH*, vol. 2, no. 1, pp. 30–42, 2021, doi: 10.33541/cen.v2i1.2812.
- [23] M. Heri Zulfiar, "Pemeriksaan Material pada Pembangunan Rumah Non-Engineered di Daerah Rawan Gempa Dusun Serut, Palbapang Kabupaten Bantul, Yogyakarta," *Semesta Teknika*, vol. 21, no. 2, pp. 178–188, 2018, doi: 10.18196/st.212224.
- [24] S. Bahri, M. F. Hanif, A. Prihatiningrum, and M. Islam, "Perilaku dan Ketahanan Struktur Rumah Vernakular Desa Gunung Alam Lebong terhadap Gempa Bumi," *Jurnal Inersia Teknik Sipil*, vol. 14, no. 1, pp. 1–10, 2022, [Online]. Available: <https://ejournal.unib.ac.id/index.php/inersiajournal>
- [25] M. M. Sari and D. Triana, "Evaluasi Terhadap Implementasi Pembangunan Rumah Tahan Gempa Tipikal Tembokan pada Perumahan Bersubsidi di Serang Banten," *Jurnal Infrastruktur*, vol. 5, no. 01, pp. 18–24, 2019.
- [26] F. S. Yoresta, "Analisis Ketahanan Gempa Rumah Tembokan Beton Bertulang di Perumahan Graha Arradea," *Media Komunikasi Teknik Sipil*, vol. 24, no. 1, p. 54, 2018, doi: 10.14710/mkts.v24i1.18097.
- [27] L. E. Hutabarat *et al.*, "Assesmen kerusakan rumah tinggal Pasca Gempa Cianjur November 2022 mengacu kepada Standar PUPERA Assessment of residential house damage after Cianjur Earthquake November 2022 Based on PUPERA Standard," *Abdimas ...*, vol. 6, no. November 2022, pp. 160–169, 2023, [Online]. Available: <https://jurnal.ustjogja.ac.id/index.php/abdimasdewantara/article/view/14777%0Ahttps://jurnal.ustjogja.ac.id/index.php/abdimasdewantara/article/download/14777/6236>
- [28] Y. L. Suku *et al.*, "Optimalisasi Mitigasi Bahaya Gempa Bumi Melalui Penyuluhan Rumah Tahan Gempa Di Kelurahan Rewarangga Selatan Provinsi Nusa Tenggara Timur," *JMM (Jurnal Masyarakat Mandiri)*, vol. 6, no. 2, p. 1030, 2022, doi: 10.31764/jmm.v6i2.6970.
- [29] D. N. Saputro, R. Januardi, and I. Prakoso, "Struktur Rumah Sederhana Ramah Gempa Untuk Meminimalisir Kerusakan dan Korban Jiwa," *Madani : Indonesian Journal of Civil Society*, vol. 2, no. 2, pp. 43–49, 2020, doi: 10.35970/madani.v2i2.247.
- [30] Z. Mirani, M. Natalia, Mafriyal, D. Sari, and R. F. Hanum, "Perbandingan Biaya Pembangunan Rumah Sederhana Dengan Rumah Konsep Aman Gempa Berdasarkan Analisa Benefit Cost Ratio Skenario Gempa 50 Tahun," *Jurnal Ilmiah Poli Rekayasa*, vol. Volume 19, pp. 76–86, 2024.
- [31] A. Hamzah, Mohd. R. Amri, E. Rozita, and R. Yunus, "Penilaian Bangunan Sederhana di Kawasan Rawan Gempabumi (Studi Kasus di Kota Bengkulu dan Kabupaten Bengkulu Tengah)," *Jurnal Dialog Penanggulangan Bencana*, vol. 11, no. 1, pp. 13–21, 2020.
- [32] F. J. R. Putri, J. D. Prasetya, and D. H. Santoso, "Penilaian daya dukung daratan permukiman sensitif gempa Panjangrejo, Pundong, Bantul, DIY," *Jurnal Pengelolaan Lingkungan Berkelanjutan (Journal of Environmental Sustainability Management)*, vol. 6, no. 3, pp. 159–168, 2022, doi: 10.36813/jplb.v6i3.159-168.
- [33] M. J. Page *et al.*, "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," *The BMJ*, vol. 372, 2021, doi: 10.1136/bmj.n71.