

Towards Sustainable Schools: Applying New European Bauhaus Principles in Banda Aceh's Educational Infrastructure

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Abstract. This study assesses the extent to which existing school buildings in Banda Aceh align with the New European Bauhaus (NEB) principles of Sustainability, Inclusiveness, and Beauty. While large-scale reconstruction after the 2004 Indian Ocean tsunami restored access to education, many schools built in the post-recovery phase prioritized speed and basic functionality, with limited consideration for long-term sustainability, cultural relevance, and community integration. Using a tailored assessment framework, the study evaluates energy efficiency, sustainable materials, community engagement, accessibility, and aesthetic quality. The findings reveal significant gaps, particularly in renewable energy adoption, inclusive community spaces, and the integration of local cultural identity. The overall compliance with NEB principles is modest, with Sustainability at 46%, Inclusiveness at 48%, and Beauty at 38%. The results underscore the need to retrofit existing schools and update design practices to fully integrate NEB values, ensuring safer, more resilient, and inspiring educational environments in disaster-prone contexts.

1 Introduction

Safe, functional, and sustainable school buildings are essential for creating conducive learning environments that support student well-being and educational outcomes [1]. Research consistently shows that the quality of school facilities plays a critical role in shaping students' academic performance, emotional development, attendance rates, and overall engagement in learning activities [2]. Schools serve as ideal settings to promote health and well-being, especially because children spend a substantial portion of their developmental years within school environments [3]. Therefore, investing in school infrastructure is not only about providing shelter but also about creating spaces that support holistic development and equitable education.

In disaster-prone regions such as Banda Aceh, Indonesia, the importance of resilient and sustainable school infrastructure becomes even more critical. The 2004 Indian Ocean Tsunami caused unprecedented devastation across Aceh Province, including the destruction

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of thousands of schools. During the post-disaster reconstruction phase between 2005 to 2009, the Indonesian Government established the *Badan Rehabilitasi dan Rekonstruksi Aceh dan Nias* (BRR – Aceh and Nias Rehabilitation and Reconstruction Agency), which led large-scale efforts to rebuild the education sector. According to BRR records [4], 1,759 schools were reconstructed during this period out of a total of 3,415 schools that had been damaged by the disaster. These efforts marked a crucial step in restoring access to education. Reconstruction continued beyond 2009 as part of longer-term development and infrastructure recovery.

As of 2025, data from the Indonesian Ministry of Education’s online portal (*Kementerian Pendidikan Dasar dan Menengah*) show that Banda Aceh currently has 218 existing school buildings across elementary, junior high, and senior high school levels [5]. Despite the substantial progress in physical reconstruction, questions remain about whether these schools were rebuilt with adequate attention to long-term sustainability. Many of the buildings constructed during the early reconstruction phase prioritized speed and basic functionality, and may not reflect current principles of sustainable, adaptive, and human-centered design.

In 2020, sixteen years after the tsunami, the Ministry of Public Works and Public Housing (PUPR) issued updated national guidelines for school design, known as *Petunjuk Teknis Bangunan Gedung Sekolah* (Juknis) [6]. These guidelines introduced new minimum standards for structural safety, accessibility, and spatial functionality. While these updates mark a significant policy step, they largely emphasize technical compliance and operational safety. They do not explicitly integrate broader sustainability concepts such as environmental performance, material reuse, climate responsiveness, and community well-being. As such, there remains a gap between national building codes and emerging global frameworks for sustainable education infrastructure.

The New European Bauhaus (NEB) initiative, launched by the European Commission in 2020, presents a holistic framework that integrates sustainability, inclusiveness, and beauty in the design and use of built environments. The NEB connects the goals of the European Green Deal with everyday spaces, schools for instance, by promoting thoughtful, human-centric design that enhances both environmental quality and quality of life [7]. NEB promotes an innovative and holistic approach to design (see Fig 1) with the aim of creating environments that are not only functional but also enhance well-being and social cohesion [8] [9]. This framework aligns strongly with the goals of resilient and adaptive school infrastructure.

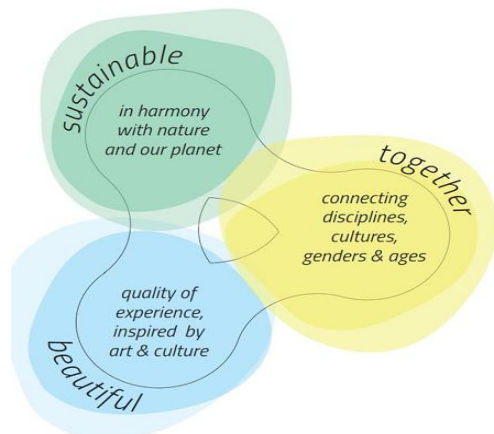


Fig. 1. New European Bauhaus from concept to action [10]

In the NEB framework, sustainability involves designing buildings that minimize ecological impact and are resilient to future challenges. For school buildings, this includes

incorporating energy-efficient technologies, using sustainable materials, and implementing water-saving systems. Features like solar panels, natural ventilation, and rainwater harvesting can reduce energy use and create school environments that are not only safer but more sustainable in the long term.

The NEB “Together” pillar focuses on creating inclusive spaces that strengthen a sense of community. Together or inclusiveness ensures physical access for all, including persons with disabilities, togetherness goes a step further by encouraging interaction, collaboration, and shared experiences. In school settings, this could involve promoting layouts that invite participation and engagement. Schools built with this spirit become not just centres of learning, but places where people connect and belong.

Beauty in the NEB framework is about creating environments that inspire emotional well-being, creativity, and connection. It includes both aesthetic design and what is referred to as “quality of experience.” This broader interpretation of beauty captures critical aspects such as health, safety, accessibility, and resilience to hazards. A beautiful school environment not only integrates elements such as natural light, ventilation, and cultural identity but also promotes functionality and emotional comfort. Beauty is no longer limited to surface-level aesthetics but is deeply connected to how spaces make people feel safe, welcome, and engaged. Schools that are thoughtfully designed with both aesthetics and functionality in mind can foster creativity, emotional well-being, and a sense of pride among students and staff.

This study aims to evaluate the compliance of existing school buildings in Banda Aceh with the three core NEB principles: Sustainability, Togetherness, and Beauty. Through this assessment, the research also seeks to highlight opportunities for improving school infrastructure to become more environmentally responsible, inclusive, culturally rooted, and resilient to future challenges. The findings will provide a clear roadmap for improving the implementation of building codes in Banda Aceh by identifying specific areas of deficiency, such as the lack of renewable energy adoption, cultural relevance, and accessible design for people with disabilities.

2 School Building Assessment Approach

2.1 School buildings data

In this study, the focus is on evaluating how school buildings align with the NEB principles of sustainability, inclusivity, and beauty. Towards this aim, an initial inventory of schools in Banda Aceh was developed using data the Indonesian Ministry of Education’s online portal. This data contains information on three types of schools:

- Elementary Schools (SD/MI): For students aged 6–12 years, covering grades 1 through 6, consisting of 114 schools.
- Junior High Schools (SMP/MTs): For students aged 12–15 years, covering grades 7 through 9, consisting of 53 schools.
- Senior High Schools (SMA/MA/SMK): For students aged 15–18 years, covering grades 10 through 12, consisting of 51 schools.

The following images (Fig 2 to 4) illustrate the three types of school buildings based on PUPR Guideline 2020.



Fig. 2. Elementary school 3D view



Fig. 3. Junior high school 3D view



Fig. 4. Senior high school 3D view

The schools are assessed through comprehensive and detailed visual inspections carried out on-site. Data collected from previous surveys conducted during the INSPIRE Project in 2018 [11] and the AAUI-Maipark research grant in 2021 [12] are re-assessed and added to through further visual inspections. The assessment was conducted on a sample of 69 schools, comprising 119 individual buildings, which were part of previous surveys and were subject to further on-site inspections. The schools assessed include both those that were newly constructed as part of the post-tsunami reconstruction effort and those that were pre-existing facilities. This diverse sample allows for a comprehensive evaluation against modern standards, regardless of their initial design period.

The unit of analysis for this study is the individual school building rather than the entire school complex. Hence, in one complex school area, there are several buildings that can be assessed. This approach allows for a precise evaluation of specific design features and their compliance with NEB principles. In each case, structural design and layout of the buildings is recorded and photographs are taken to document the building’s condition and record architectural elements. Elements such as plumbing and electrical systems are not considered in this study. The distribution of surveyed schools is shown in Fig. 5.

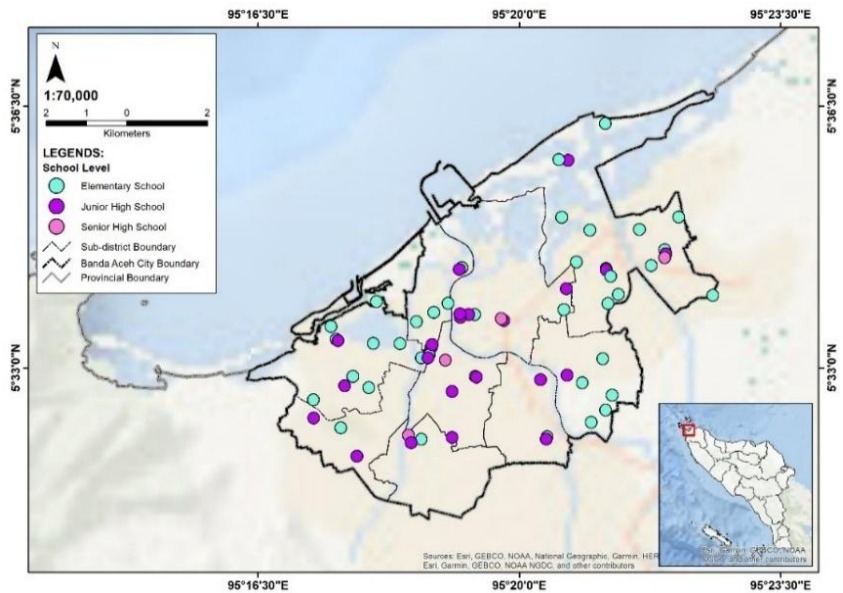


Fig. 5. Distribution of surveyed schools

The process of assessing existing school buildings in Banda Aceh follows a systematic evaluation based on the three core principles of the New European Bauhaus (NEB) framework: Sustainability, Togetherness, and Beauty. The criteria used for this study are adapted from *A Practical Guide to the New European Bauhaus Self-Assessment Method and Tool* [13]. While the original guide provides an extensive list of indicators for each principle, these are highly detailed and primarily intended for the design phase of individual projects. Applying them directly to a large population of existing buildings, such as schools, would be impractical.

To address this, the assessment was optimized by selecting the most relevant and measurable parameters that align with the environmental conditions and local context of Banda Aceh. These parameters serve as practical indicators to represent each NEB principle while ensuring that the evaluation remains applicable and focused on the realities of existing school infrastructure.

As illustrated in Fig. 6, each NEB principle is represented by three carefully chosen assessment criteria, providing a clear and manageable framework for evaluating how the principles are reflected in the design, function, and experience of school buildings. These criteria were adapted from the NEB practical guide but simplified to suit the evaluation of an existing building stock, rather than being applied during the design phase. For Sustainability, the selected criteria focus on *energy efficiency*, *sustainable materials*, and *water conservation*. For Togetherness, the assessment considers *community engagement*. The Beauty principle is divided into five aspects such as *design appeal*, *cultural relevance*, *environmental harmony*, *accessibility*, and importantly, *health and safety*.

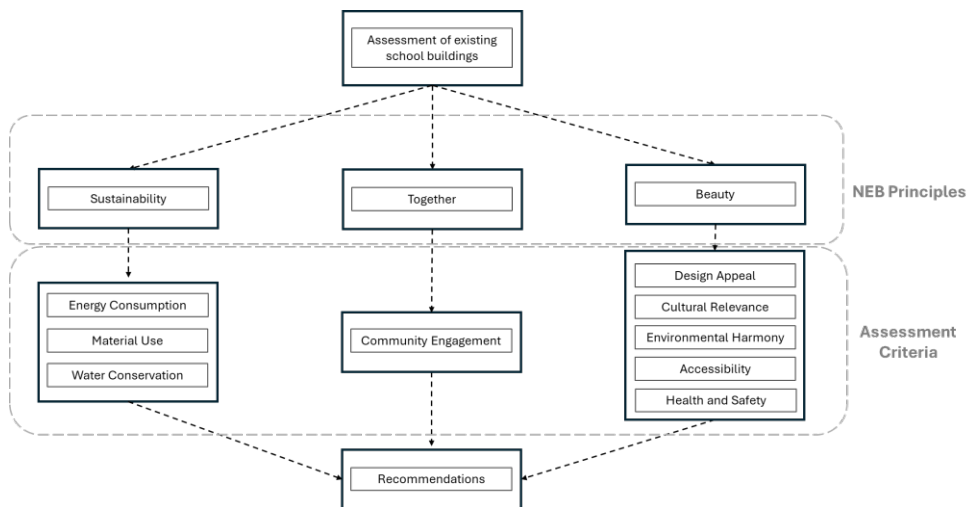


Fig. 6. The flowchart of school buildings assessment according to NEB principles

The flowchart illustrates how each NEB principle is linked to its respective measurable criteria, ensuring a consistent and transparent method for assessing the extent to which Banda Aceh’s schools align with the NEB vision. This approach also allows for a more balanced comparison across principles and helps identify targeted areas for improvement.

For the evaluation process, each surveyed school building is assessed against the selected NEB parameters. Compliance is recorded when a building meets the specified guideline (assigned a value of 1). Non-compliance is recorded when a building does not meet the requirement (assigned a value of 0), with specific justifications noted for each case. This method ensures that the results highlight both strengths and deficiencies, providing a clear basis for recommendations, whether through retrofitting, redesign, or future construction improvements.

2.2 Application of NEB principles in building assessment

The NEB framework offers a holistic approach that connects the goals of the European Green Deal with everyday spaces, promoting thoughtful, human-centric design. This differs from the local Juknis guidelines and building codes, which focus more on technical and operational safety. This study justifies the use of the NEB framework by arguing that it aligns strongly with the goals of resilient and adaptive school infrastructure, especially in a disaster-prone region like Banda Aceh.

This study adapted the New European Bauhaus (NEB) Self-Assessment Guide to evaluate existing school buildings in Banda Aceh. Because the original framework was developed for a European context, several items were excluded as they were either irrelevant in a tropical climate or not feasible for existing infrastructure.

For Sustainability, insulation measures (foam, double glazing) and heating systems were excluded as they address temperate-climate needs. Renewable energy was noted but not scored, since no schools had installed such systems. For Inclusiveness, housing-related indicators (affordability, rent regulation, de-commodification) were excluded as they apply to residential projects, not schools. The focus instead was on community engagement, such as shared spaces and programmes. For Beauty, the original NEB guide contains indicators for "aesthetic pioneering" and advanced design styles like deconstructivism and regionalism.

For a post-disaster context where functional and culturally relevant design is a more urgent priority, these advanced aesthetic concepts were considered less applicable.

2.2.1 Sustainability

Sustainability within the NEB framework focuses on minimizing environmental impact through energy efficiency, the use of sustainable materials, and water conservation. The sustainability assessment helps ensure that school buildings contribute to a lower environmental footprint. To assess sustainability, the evaluation looks at several factors in the following Table 1.

Table 1. NEB Parameter for Sustainability

Aspect	Criteria	Practical Implementation
Energy Consumption	Uses LED or energy-efficient lighting	LED bulbs
	Classrooms have sufficient windows for natural daylight	Large windows, skylights
	Has energy-efficient heating or cooling systems	Natural ventilation
	Building insulation in walls, roof, and windows present	Foam insulation, double-glazed windows
	Uses renewable energy sources (solar panels, etc.)	Solar PV panels on roof
	Energy consumption is monitored or managed	Energy meters, smart energy systems
Material Use	Uses locally sourced construction materials	Bamboo, local stone, clay bricks
	Incorporates recycled or reused materials	Recycled steel, reclaimed wood
	Uses low-toxicity paints and finishes	Water-based paints
	Materials are durable and require low maintenance	Concrete, treated timber
	Building materials can be recycled or reused after use	Steel frames, modular panels
Water Conservation	Has low-flow faucets and toilets	Dual flush toilets, sensor taps
	Rainwater harvesting system installed	Rooftop rainwater tanks
	Greywater reuse or recycling system in place	Greywater from sinks reused for irrigation
	Efficient irrigation for plants	Drip irrigation
	School promotes water conservation awareness	Signage, student programs

2.2.2 Together / Inclusiveness

The Together principle in the NEB framework focuses on strengthening social cohesion and fostering meaningful connections between the school and the wider community. In this study,

the evaluation of inclusiveness is limited to community engagement. This principle also examines how well the schools foster a sense of belonging and engagement by involving local communities in the design process and ensuring the spaces are used collectively. The aim is to create schools that serve not only as educational facilities but also as vibrant community hubs. Key aspects of this evaluation can be shown in the following Table 2.

Table 2. NEB Parameter for Inclusiveness

Aspect	Criteria	Practical Implementation
Community Engagement	Spaces available for community events or meetings	Multipurpose halls, outdoor amphitheatre
	School runs programs that involve local community	After-hours classes, local workshops
	Facilities accessible outside school hours	Community centres, library access
	Evidence of community involvement in building upkeep	Volunteer groups, parent associations
	Multipurpose halls or shared spaces	Gymnasiums, auditoriums

2.2.3 *Beauty*

Beauty in the NEB framework is not just about aesthetic appeal but about creating spaces that foster emotional well-being, creativity, and connection with nature. The beauty of a building can significantly impacts the learning experience and social interactions. In the context of school buildings, this principle includes both aesthetics and quality of experience. The aesthetic aspect considers harmonious design, cultural relevance, and integration with the natural environment. While quality of experience, which covers physical accessibility, health, and safety. Accessible designs ensure that all students, including those with disabilities, can navigate the school environment with ease. Health and safety further enhance the overall quality of the learning experience. By focusing on beauty, schools can become not only functional spaces but also emotionally supportive environments that promote creativity and well-being. Key factors in this core include in the following Table 3.

Table 3. NEB Parameter for Beauty

Aspect	Criteria	Practical Implementation
Design Appeal	Building has pleasant and inspiring interior design	Colourful walls, murals, natural materials
	Use of colour, art, or murals to enhance learning spaces	Student artwork, cultural motifs
	Layout promotes openness and calmness	Open-plan spaces, natural light
	Exterior design fits well within its surroundings	Harmonizes with neighbourhood style
Cultural Relevance	Design incorporates local architectural styles	Traditional roof shapes, carved woodwork
	Use of traditional materials or motifs	Bamboo, terracotta tiles
	Dedicated spaces for cultural or traditional activities	Community halls, ritual spaces

Aspect	Criteria	Practical Implementation
	Design considers local climate and environment	Shading devices, cross ventilation
Environmental Harmony	Presence of landscaped gardens or green spaces	School gardens, playground trees
	Use of native plants in landscaping	Local flowers, shrubs, and trees
	Design allows connection with nature (views, outdoor spaces)	Outdoor classrooms, nature trails
	Sustainable landscaping practices employed	Rain gardens
Accessibility	Ramps or elevators for wheelchair access	Concrete ramps, electric lifts
	Doors and corridors wide enough for mobility aids	Minimum 90 cm door width
	Accessible toilets and washrooms	Grab bars, wide stalls
	Clear signage for visually or hearing-impaired students	Braille signs, auditory signals
	Handrails and non-slip surfaces on stairs and ramps	Textured tiles, sturdy handrails
	Inclusive design of classrooms and common areas	Adjustable desks
Health and Safety	Good ventilation and fresh air circulation	Operable windows, HVAC systems
	Natural daylight in classrooms	Large windows, light wells
	Noise reduction measures implemented	Acoustic panels, landscaping buffers
	Use of non-toxic materials and finishes	Low-VOC paints
	Safety protocols and regular emergency drills	Fire drills, evacuation plans

3 Results and Discussion

3.1 NEB Compliance

The NEB framework encompasses three core principles: Sustainability, Togetherness, and Beauty, each representing essential aspects of high-quality, future-ready school infrastructure. The evaluation results for the surveyed schools in Banda Aceh reveal notable gaps in meeting these standards.

As shown in Fig. 7, overall compliance is relatively modest, with Sustainability scoring 46%, Togetherness 48%, and Beauty 38%. The result indicates that less than half of the surveyed schools meet the selected criteria for each principle. The low compliance rates suggest that current school designs, while functional, often do not fully consider environmental sustainability, community involvement, and attractive, healthy learning environments.

The near-similar values for sustainability and togetherness suggest that while some initiatives, such as basic energy efficiency measures and occasional community involvement, are present, they are not yet consistently incorporated across the school stock. The lowest

score in the beauty category highlights a persistent gap in design elements that enhance user experience, cultural relevance, accessibility, and health and safety.

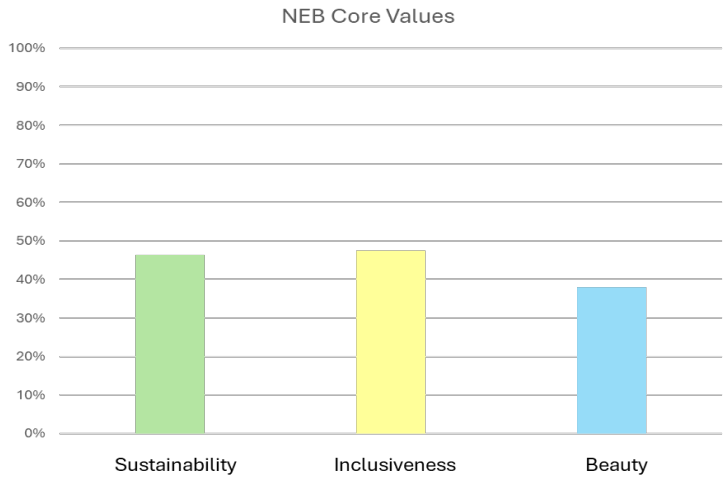


Fig. 7. The compliance of NEB concepts

3.1.1 Sustainability

The Sustainability principle of the New European Bauhaus (NEB) emphasizes reducing the environmental footprint of buildings by improving energy efficiency, using sustainable materials, conserving water, and enhancing climate resilience. In this study, the assessment of existing school buildings in Banda Aceh considered multiple sustainability aspects, including energy consumption patterns, the type and sourcing of construction materials, and the implementation of water-saving measures. The overall compliance for sustainability is illustrated in Fig. 8, while Fig. 9 provides examples of observed field conditions from the surveyed schools.

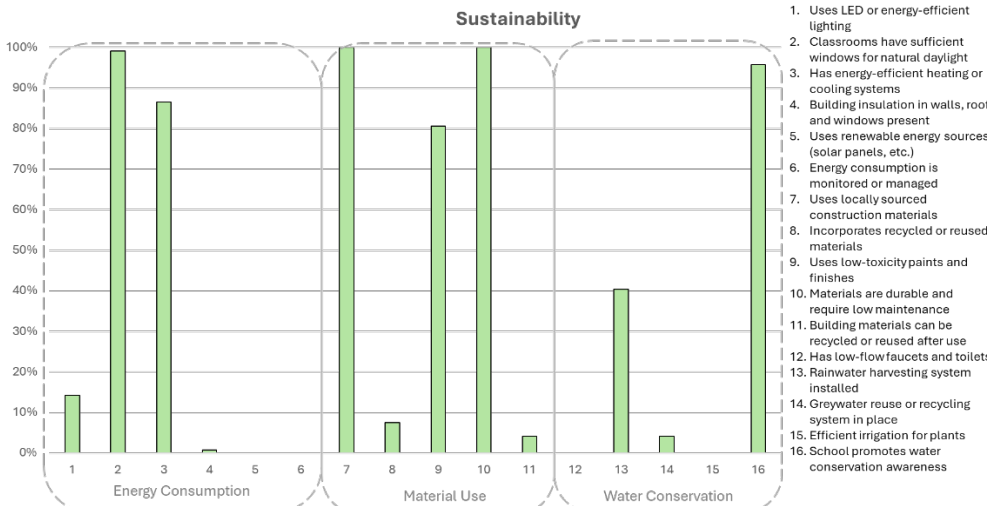


Fig. 8. Compliance of surveyed schools with NEB Sustainability criteria

a. Energy consumption

The majority of surveyed schools (99%) had classrooms with sufficient windows for natural daylight, which supports passive energy use by reducing reliance on artificial lighting. However, only 14% of the buildings implemented LED or energy-efficient lighting systems, and a small fraction (1%) incorporated building insulation in walls, roofs, and windows. Additionally, none of the buildings utilized renewable energy sources, such as solar panels. Energy consumption management systems were also not commonly in place.

b. Material use

Regarding material use, 100% of the schools utilized locally sourced construction materials, with clay bricks. Recycled or reused materials were incorporated in 8% of the schools, and 81% used low-toxicity paints and finishes. However, only 4% of the schools used materials that could be recycled or reused after the building's lifecycle. Furthermore, while 100% of the schools used durable materials like concrete, only a small percentage implemented low-maintenance building materials such as steel frames and modular panels.

c. Water conservation

Water conservation was a significant concern in the surveyed schools. Only 40% of the schools had rainwater harvesting systems installed, and 4% had greywater reuse or recycling systems. Moreover, no schools had efficient irrigation systems for plants, though 96% of schools actively promoted water conservation awareness through signage and student programs. Additionally, none of the schools featured dual-flush toilets and sensor taps to reduce water consumption.



Fig. 9. Field examples of Sustainability criteria implementation in surveyed schools

3.1.2 Together / Inclusiveness

The “Together” principle in the New European Bauhaus (NEB) framework focuses on fostering community engagement and social cohesion, ensuring that schools serve as shared spaces for interaction, collaboration, and collective activities. This principle emphasizes the

active participation of local communities in school life. As shown in Fig. 10, compliance with community engagement indicators varies widely across the surveyed schools. The detailed breakdown is presented in Fig. 11.

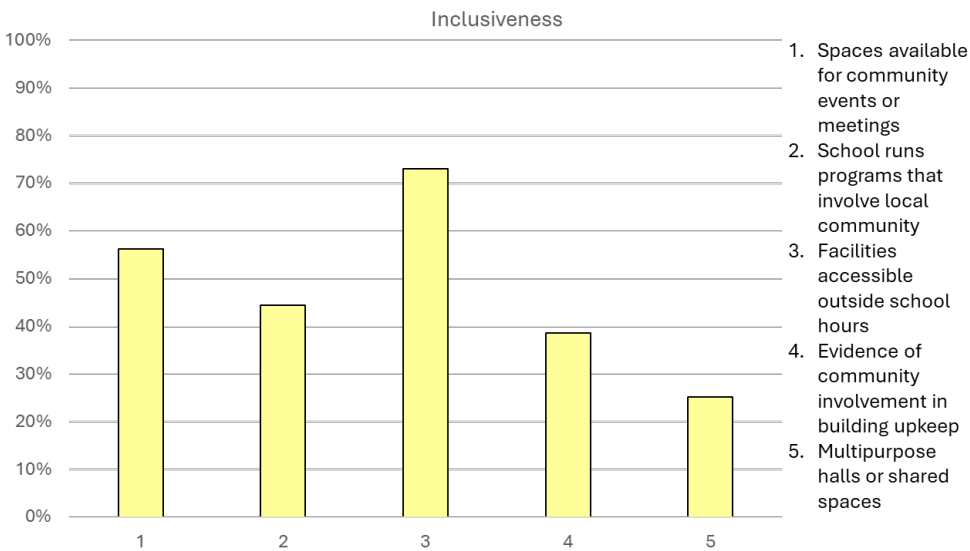


Fig. 10. Compliance of surveyed schools with NEB Inclusiveness criteria



Fig. 11. Field examples of Inclusiveness criteria implementation in surveyed schools

Facilities accessible outside school hours scored the highest (73%), indicating that a significant proportion of schools provide spaces such as community centres or libraries for public use beyond regular school activities. Spaces available for community events or meetings also showed relatively strong performance (56%), often in the form of multipurpose halls.

However, only 45% of schools run programs that actively involve the local community, such as after-hours classes or local workshops, highlighting a missed opportunity for deeper engagement. Community involvement in building upkeep, such as through volunteer groups or parent associations, was recorded in 39% of schools, suggesting that maintenance and improvement efforts could benefit from stronger community participation. The availability of multipurpose halls or shared spaces, including gymnasiums and auditoriums, was the lowest (25%), showing that facilities specifically designed for collective activities remain limited.

3.1.3 Beauty

The Beauty core value in the New European Bauhaus (NEB) framework goes beyond aesthetics. It encompasses functionality, accessibility, and health and safety to create environments that inspire, support well-being, and foster meaningful connections between people and their surroundings. In the context of school buildings, this means integrating visually appealing design with practical features that ensure comfort, inclusivity, and safety for all users. The compliance results for each aspect are shown in Fig. 12, with examples from the surveyed schools in Fig. 13.

- *Design appeal*

Design appeal considers how the overall appearance and spatial arrangement of the school contribute to an inspiring and pleasant learning environment. Elements such as colourful walls, murals, natural materials, and student artwork can enhance engagement and creativity. The survey results show that 49% of schools have colourful walls, murals, and natural materials, while 35% incorporate student artwork or cultural motifs. Notably, 92% of schools feature open-plan layouts that promote openness and natural light, which supports a calm and engaging learning atmosphere. However, exterior design integration with the surrounding neighbourhood remains absent (0%).

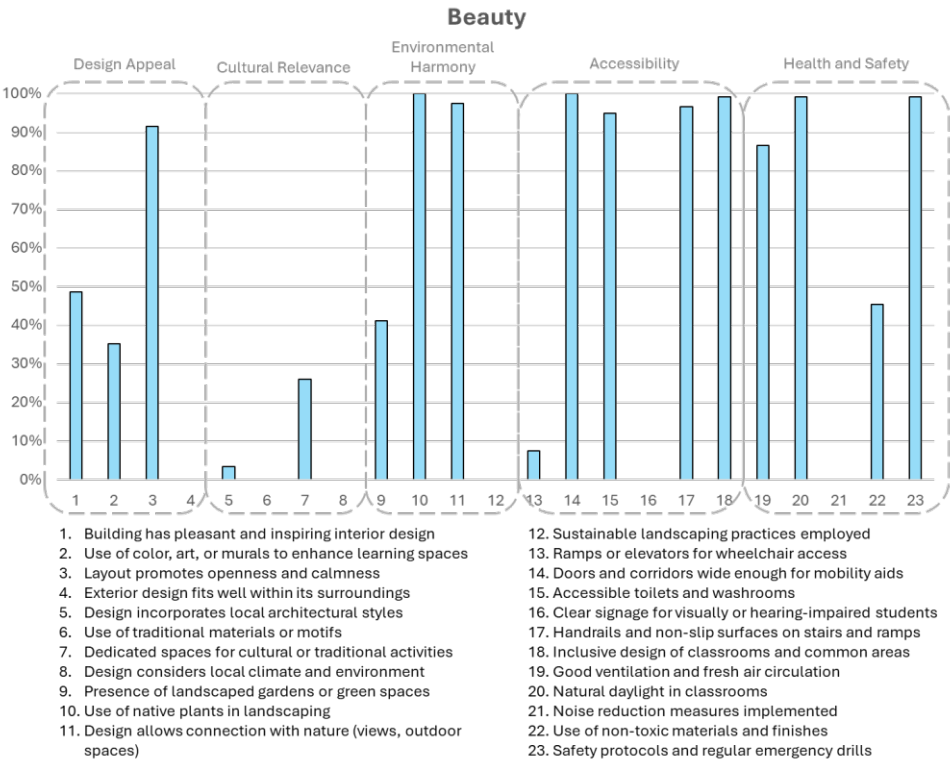


Fig. 12. Compliance of Surveyed Schools with NEB Beauty Criteria

- *Cultural Relevance*

Cultural relevance ensures that school buildings reflect and celebrate the local identity, traditions, and community values. This could involve using traditional materials, motifs, architectural styles, or providing dedicated spaces for cultural activities. The survey reveals very low integration of cultural relevance, with no schools using traditional materials (0%),

only 3% incorporating local architectural styles, and 26% providing dedicated spaces for cultural or traditional activities. Additionally, no schools were found to consider local climate in the cultural design approach (0%), highlighting a significant gap in integrating local heritage into school design.

• *Environmental Harmony*

Environmental harmony focuses on connecting the built environment with nature. It includes landscaped gardens, the use of native plants, and sustainable landscaping practices. The findings show strong compliance in some areas: all surveyed schools (100%) use local flowers, shrubs, and trees, and 97% allow for direct connection with nature through outdoor classrooms. However, only 41% have landscaped gardens or green spaces, and none implement sustainable landscaping practices such as rain gardens (0%).



a. Colorful murals



b. Local flowers



c. Praying room



d. Outdoor classroom



e. Student artwork



f. School garden



g. Ramp



h. Sturdy handrails



i. Evacuation plan

Fig. 13. Field examples of Beauty criteria implementation in surveyed schools

- *Accessibility*

Accessibility in the NEB framework ensures that school facilities are usable by all, including students with disabilities. The assessment reveals high compliance in basic accessibility features: 100% of schools have doors and corridors wide enough for mobility aids, 95% have accessible toilets, and 97% have handrails and non-slip surfaces. However, ramps or elevators for wheelchair access are present in only 8% of schools, and no schools provide clear signage for visually or hearing-impaired students (0%). Additionally, while 99% offer inclusive classroom layouts, adjustable desks and quiet zones for students with specific needs are available in only 56% of the buildings.

- *Health and Safety*

Health and safety are crucial for creating secure and supportive learning environments. The survey shows that 99% of schools follow safety protocols and conduct regular emergency drills, an essential practice in a disaster-prone area like Banda Aceh. Natural daylight is available in almost all classrooms (99%), and 87% of schools have good ventilation systems. However, noise reduction measures are entirely absent (0%), which could affect concentration and comfort. Furthermore, only 45% of schools use non-toxic materials and finishes, leaving room for improvement in ensuring healthier indoor environments.

3.2 The Link to Disaster-Resilience

The connection between the NEB principles and disaster resilience is a central theme of this research. In a region like Banda Aceh, which is highly prone to natural disasters, the NEB principles offer a framework for building schools that are not only structurally sound but also contribute to a community's overall resilience. For example, the Sustainability principle, through its focus on energy independence and water conservation, can ensure schools remain functional even when public utilities are disrupted. The Togetherness principle promotes schools as community hubs with spaces for meetings and emergency shelters, while the Beauty principle, which includes aspects of health and safety, ensures that evacuation routes and safety protocols are part of a thoughtful and human-centric design. In the future, Banda Aceh can build school infrastructure that serves as a foundation for a safer and more resilient future for the entire community by adapting these principles.

3.3 Recommendations

Based on the survey data and findings, several key recommendations can be made to enhance the resilience, safety, and sustainability of school buildings in Banda Aceh, particularly alignment with the New European Bauhaus (NEB) principles. These recommendations are intended for stakeholders, policymakers, and decision-makers involved in future school construction and renovation projects in Banda Aceh.

Additionally, the recommendations can guide updates to the current school building guidelines, ensuring they better account for multi-hazard risks and sustainability while incorporating NEB principles. As emphasized by the World Bank's 2025 Global Assessment of Building Codes [14], it is important to focus on integrating green, resilient, and inclusive building strategies, which should be taken into consideration when developing or updating building codes for school infrastructure. Several recommendations can be implemented:

3.3.1 Sustainability:

- **Energy efficiency:** introduce solar panels and energy-efficient lighting systems (e.g., LED lights) in all schools to minimize energy consumption. Furthermore,

incorporate natural ventilation in classrooms to reduce reliance on air conditioning and decrease energy use.

- Water management: implement rainwater harvesting systems and low-flow toilets in all school buildings. Schools should also consider greywater recycling systems to reduce water consumption and increase self-sufficiency in water management.

3.3.2 *Together:*

- Community engagement: design spaces that foster community engagement, such as multipurpose halls, outdoor amphitheatres, and community gardens. Schools should also encourage local participation in school upkeep and community activities.

3.3.3 *Beauty:*

- Aesthetic and emotional well-being: schools should incorporate colourful murals and use natural materials in interiors to enhance the emotional well-being of students.
- Cultural integration: reflect local cultural identity by incorporating traditional materials and architectural styles that resonate with the community. This could also include the creation of dedicated spaces for cultural and traditional activities that align with the local context.
- Environmental harmony: encourage the integration of green spaces such as school gardens, playgrounds, and outdoor classrooms. Native plants should be prioritized to foster a harmonious relationship between the built environment and nature.
- Universal design features: ensure accessibility for people with disabilities, such as ramps, wheelchair-friendly toilets, and adjustable desks. This would ensure inclusivity in all aspects of school design, promoting equal access to education for all students.

While there has been substantial progress in physical reconstruction (not only schools but also several structures) since the 2004 tsunami, the findings of this study suggest that the quality of buildings, has not improved significantly in terms of long-term sustainability, cultural relevance, and community integration. A key reason for this is that much of the post-disaster reconstruction prioritized speed and basic functionality over comprehensive, long-term sustainable design. The national guidelines and building codes emphasize technical compliance and operational safety, but they do not explicitly integrate broader sustainability or community-focused concepts. This creates a gap where buildings can be structurally safe but still fail to meet the standards of modern, resilient, and human-centered design.

The findings of this research provide a clear roadmap for improving the implementation of building codes in Aceh by highlighting specific areas of deficiency. The low compliance scores in key areas, such as renewable energy adoption, cultural relevance, and accessible design for people with disabilities, indicate where current guidelines fall short and where future policy interventions should be focused.

For instance, this study reveals that no schools utilized renewable energy sources or incorporated noise reduction measures, and only a small percentage had features like wheelchair ramps. By specifically identifying these gaps, policymakers can be guided to revise the *Petunjuk Teknis Bangunan Gedung Sekolah (Juknis)* to include these criteria as mandatory standards for all new and retrofitted school buildings. This will ensure a better integration of green, resilient, and inclusive building strategies, consistent with global recommendations. The NEB framework provides a useful model for how to move beyond

basic safety and functionality towards a more holistic approach that considers environmental, social, and aesthetic factors.

3.4 Future Research

Future research should address key gaps identified in this study to further enhance the resilience, functionality, and sustainability of school infrastructure in Banda Aceh. The following areas are proposed for deeper investigation:

3.4.1 Multi-hazard vulnerability assessment

Given that Banda Aceh is highly prone to natural disasters such as earthquakes, tsunamis, and liquefaction, future studies should conduct detailed vulnerability assessments of existing school buildings against multiple hazards. This includes structural integrity analysis, evacuation route safety, and disaster preparedness measures. Such assessments can guide the development of targeted retrofitting strategies and disaster-resilient designs tailored to the local hazard profile.

3.4.2 Functionality compliance with updated building guidelines

An in-depth review is needed to evaluate whether schools constructed after the 2004 tsunami meet the latest Ministry of Public Works and Public Housing (PUPR) Building Guidelines in 2020. This includes assessing classroom size, circulation spaces, accessibility, structural elements, lighting, and other functional requirements. The study should also examine whether the 2020 guidelines themselves require revisions to better address the evolving needs of educational infrastructure in disaster-prone areas.

In addition, future research should also be considered more comprehensive justification of a comparative matrix highlighting the key differences between the NEB and the local guidelines, such as ministerial regulations (*Peraturan Menteri*), and/or suitable building codes that consist of the infrastructure regulations.

3.4.3 Integrated design recommendations

Future work should develop prototype school designs that integrate three critical aspects:

- **Safety:** Compliance with multi-hazard resilience standards for earthquakes, tsunamis, and liquefaction.
- **Functionality:** Alignment with the most recent building codes and functional requirements for educational facilities.
- **Sustainability:** Application of the NEB principles to promote energy efficiency, environmental harmony, and community inclusiveness.

These integrated designs could serve as a reference model for policymakers, architects, engineers, and other stakeholders, providing a practical blueprint for constructing safe, functional, and sustainable schools in disaster-prone regions.

4 Conclusions

The assessment of school buildings in Banda Aceh reveals key gaps in the integration of the New European Bauhaus (NEB) principles into existing infrastructure. While many schools have made progress in accessibility and community engagement, the application of

sustainability and aesthetic principles remains limited. Natural lighting and some use of locally sourced materials are common, yet there is significant scope for improvement in energy efficiency, renewable energy adoption, and water conservation.

Although inclusiveness is partially achieved through community engagement, the integration of beauty requires greater attention. The beauty aspects ensure schools inspire creativity, emotional well-being, and a sense of belonging. Cultural relevance and overall aesthetic quality should be strengthened to reflect local identity and enhance the learning environment.

To fully align with the NEB framework, future efforts should prioritize rehabilitation school buildings with energy-efficient technologies, sustainable materials, and improved water management systems. These enhancements will not only improve the resilience of schools in Banda Aceh but will also foster long-term sustainability and social inclusivity, creating environments that are functional, inspiring, and well-adapted to the community's needs.

Consistent with the World Bank's 2025 Global Assessment of Building Codes, school infrastructure policy in Banda Aceh must evolve to integrate green, inclusive, and resilient building strategies. Future projects should emphasize multi-hazard-resistant structures, renewable energy integration, sustainable materials, and effective water management, ensuring that schools are prepared to meet both current challenges and the long-term impacts of climate change and natural disasters.

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