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Analysis of design criteria for post-disaster schools using prefabricated architecture concepts

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ABSTRACT

Indonesia's location in the ring of fire and between three continental plates makes it vulnerable to disasters. As a result, school buildings are damaged and require time and resources to be repaired or enhanced. It emphasizes the need for building designs that can be constructed quickly. As a result, the country's educational system is still developing slowly compared to other countries. The study methodology will involve two forms: gathering data and writing it properly. The writing approach will compare and analyze prefabricated variables among selected prior items. A comparison of data on school buildings constructed after a disaster or prefabricated methods of construction appropriate for application in these types of circumstances is the result of this study. To maintain a balance in the speed of school procurement that can continue as permanent buildings without the need for emergency or temporary schools, the research aims to ascertain the design criteria for post-disaster schools using prefabricated methods and to determine the correlation between speed and comfort.

Introduction

Natural disasters are prevalent in Indonesia; earthquakes are the most frequent natural disaster. From 1600 to 2000, there were 105 tsunami incidents; 90% of them were caused by earthquakes, 9% by volcanic eruptions, and 1% by landslides, which remain a hazard (BPBD Kabupaten Mojokerto 2020). In the 2004-2018 data in Indonesia, damage to school buildings due to disasters was 47,568 or 18% of the total schools in Indonesia and this number is very likely to increase, then from World Bank data, 75% of existing school locations are currently threatened by natural disasters (Kemendikbud 2018). According to international standards, 6 basic needs must be met for people affected by natural disasters, namely: clean water, shelter, food and drink, health, education, and protection of rights. human rights. The completion of children's ideal education is contingent upon schools serving the fundamental needs of various child-bearing groups within the framework of society (IASC, 2021). In addition to causing damage to already-existing buildings, natural disasters have a long-lasting effect on psychological health, particularly for women and children in vulnerable populations. One way to address (Kementerian Pemberdayaan Perempuan dan Perlindungan Anak Republik Indonesia, 2020) the psychosocial needs of traumatized children is to establish schools (Kementerian Pemberdayaan Perempuan dan Perlindungan Anak Republik Indonesia, 2020).

Prefabrication is one of the many techniques employed to advance civilization, and it is one of the topics that is still being developed. Aside from the primary need to provide adequate housing for impacted communities, prefabrication is essential to the completion of post-disaster buildings, particularly in school buildings.

This paper aims to analyze not only the requirements for prefabricated buildings, such as those needed to build schools but also how these structures can be used for a long time to come. Several alternatives to temporary building procurement should be discussed, particularly for schools that can accelerate development by meeting current standards and accelerating classroom learning. This will allow for the construction of schools more quickly and in better condition than those destroyed by natural disasters.

Architectural prefabrication

Prefabrication in its relevance in the industrial world needs to be analyzed following large needs so that its needs can be supported by a development process that does not only look at the form of design, 3 variables that become measuring instruments in determining the appropriate prefabrication needs:

- *Environment*: Market needs, available infrastructure, and location context.
- *Organization:* Conformity to the work system, communication, and collaboration responsibilities between jobs
- *Technology:* Adjustment to the real conditions and characteristics of the technology used in the design.

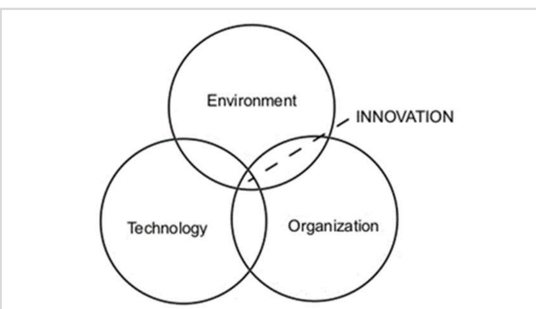

Figure 1. Three basic criteria in finding innovative prefabricated systems
Source: The Process of Technological Innovation, (L. G. Tormatzky and M. Fleischer 1990)

The correlation of criteria to find more particular technical advances and developments is depicted in figure 1. The requirement for technology to accelerate development in post-disaster settings necessitates specific criteria in selecting what type of prefabricated system to utilize.

Standard school needs

Different modifications are required for the provision of education in catastrophe situations, such as the limited availability of building facilities devastated by natural disasters and the traumatized workforce or teachers resulting from such events. The UNICEF agency has specified this standard provision to help determine what kind of school criteria are appropriate. It includes the following points, particularly in terms of design (UNESCO 2011):

- Site Selection: securing disaster-safe areas is determined by the availability of land with flat surfaces and away from hazards.
- Basic Planning: adjusting the standard area in one classroom unit, providing clean water for sanitation needs, and opening areas as evacuation points.
- Comfort: comfort emphasizes on the utilization of daylight, air, and acoustics and has protection from climatic conditions.
- Land, Site, and Service: Site and Service: provision of drainage, easy maintenance planning, and can last for a longer period.

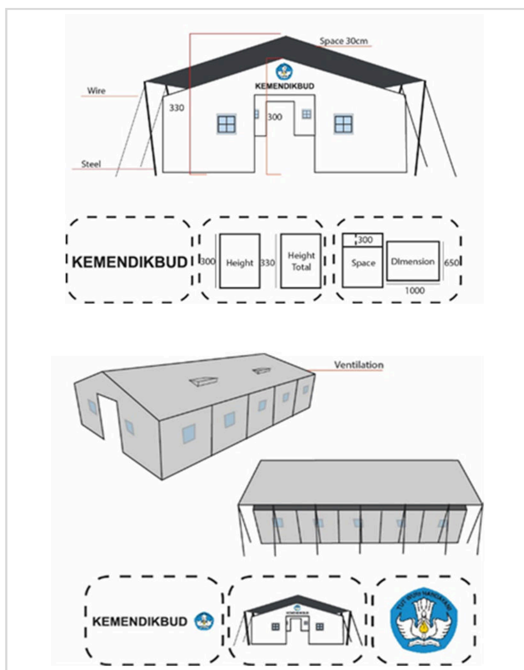

Figure 2. Design of tents as temporary schools in emergency conditions
Source: Pedoman penyelenggaraan Pendidikan dalam situasi darurat (Kemendikbud 2018)

Figure 3. The real condition of emergency schooltents Source: Pedoman penyelenggaraan Pendidikan dalam situasi darurat (Kemendikbud 2018)

Children impacted by natural disasters can have their educational needs fulfilled with a tent, as demonstrated in figure 3, which has 48 m^2 of space to house two study groups. In situations where conditions are not yet safe from future disasters, a lightweight, quick-to-assemble structure, as illustrated in figure 3, is taken into consideration. However, prolonged use of this structure may have negative effects on comfort.

Methods

In this study, three study objects that were selected based on characteristics such as school building functions, prefabricated construction methods, and natural disaster-affected backgrounds are compared using a deductive qualitative method. Afterward, it aims to formulate school buildings that comply with safety standards in disaster conditions and can be used directly as schools with standards without having to use temporary emergency schools. It is achieved by using the UNICEF emergency school standards and the prefabrication theory of Tomartzky and Fleischer with adjustments to post-disaster conditions as measuring tools.

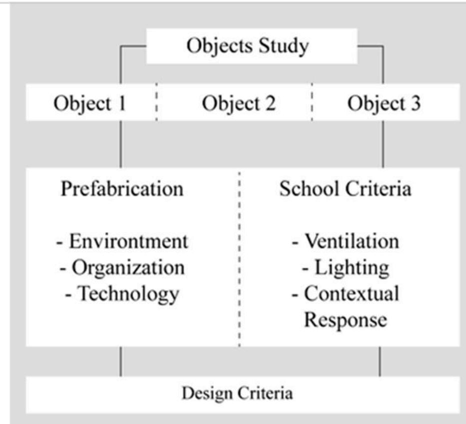

Figure 4. Systematic object analysis

To ensure that the study object is taken in a tropical climate, relevance to the place in Indonesia is considered during the selection process. Direct observation and interviews are used to research the study object, while online news, manuals, and literature reviews are utilized for investigating other study objects. The building design drawings, the history of the disaster before it was constructed, the prefabrication variables namely, the environment the way the prefabricated project system is organized during construction, and the technology employed to adapt to the conditions of a natural disaster will be examined during analysis.

The study objects

The precedent object of figure 5 was studied by direct observation in Cianjur due to the impact of the Cianjur earthquake in 2022. Findings regarding the school design from Professor Yandi or the University of Indonesia have been implemented in several disaster-affected areas, including Palu, Sulawesi, and Lombok, in cooperation with other non-governmental organizations for fundraising purposes. The construction is done at no cost, and the school provides the location. Teachers who have been impacted by the disaster are interviewed to gain insight into the details of the school construction process from the time of the disaster until it can be used in the long run. The information gathered is derived not only from direct observation but also from the Internet and seminars based on Professor Yandi's statement regarding the origin of the school design.

Figure 5. UI disaster response school located in Cianjur

Review materials from books and the internet were utilized to generate study objects 2 and 3 in figures 6 and 7. Study object number two is a school in Thailand. After the earthquake in 2014 severely destroyed the school, the government worked with architects and contractors to create a plan to reconstruct schools that had been devastated by natural disasters. Because Study Object 3's building technique employs the RISHA prefabricated system for the school module, it was selected for analysis.

Figure 6. Bann Huay San Yaw School, Thailand's post-disaster school
Source: (Castro Fernanda 2015)

Figure 7. Cianjur area school was built with the RISHA method
Source: (Detiknews 2022)

Results and discussion

Environment prefabrication:

Figure 8. School location of study object 1
Source: (Google Earth, coordinate: -6.873484, 107.080528)

The school is located at Jl. National III, Bangbayang, Gekbrong Subdistrict, Cianjur Regency, West Java.

Figure 9. View of the school from the highway

The school was moved with the assistance of the neighborhood after the disaster, and it is now situated in a rice field area, using a vacant space donated by locals (see figure 8). The previous location of the school was far from the main road and in a steep area, making it less safe for buildings. The presence of automobile lanes makes the school environment easily accessible; nonetheless, there is only a footpath that leads from the highway to the school (figure 9), which considers accessibility during the planning process.

Figure 10. Materials used in study object 1

The materials utilized in schools are largely uniform in their usage. 11 such as PVC roof coverings, 8 mm GRC walls, concrete flooring, and a 5 x 10 cm hollow iron main framework. Prefabrication was employed in the iron structure's component pieces, which were cut off-site to meet development requirements and the building concept. It is still rather feasible to build a school in challenging circumstances even if the necessary materials are unavailable in the area. This is because the components can be substituted with alternative materials.

According to the results of the interviews, the workers who built this school worked in conjunction with the local community and skilled workers, such as those who specialize in welding hollow iron connections. The community also contributed significantly to the excavation of foundations and the creation of concrete floors, which made it possible for general workers to easily complete the school's design.

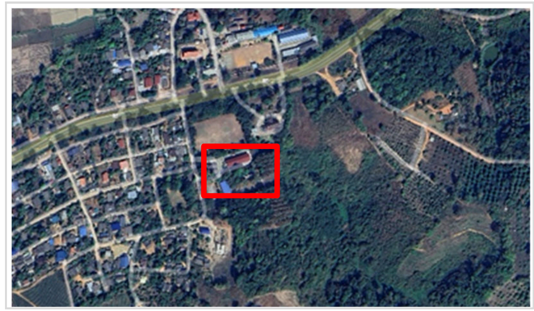

Figure 11. Location of the school of study object 2
Source: (Google Earth, coordinate: 19.743163, 99.649 181)

Figure 12. School entrance from the main road
Source: (Google Earth, Coordinate:19o44'34.76" N, 99o38'52.91" E)

The location of the school is far from the city center, which affects the mobility of school construction in the area. 12. A major issue during crises is the absence of suitable infrastructure for large-load vehicles, which increases the risk of road damage because the impacted locations are occasionally far away.

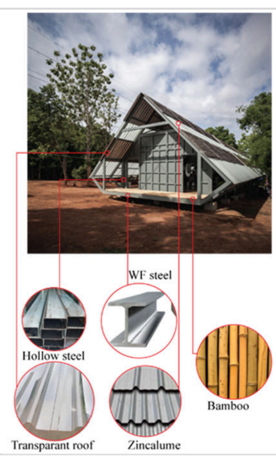

Figure 13. Materials used in the school design of study object 2

The construction of this school took about a year because of challenges with the delivery of large enough, difficult-to-send materials from cities, like WF steel, which is difficult to replace in the design. Additionally, the building design has its complexity, making it difficult for workers with low expertise to complete, as this building requires the services of expert contractors to connect iron that has been cut in the factory. One of the building's advantages is that it makes use of bamboo, which is inexpensive to procure and recycle, giving the materials used a contextual approach to their site.

Figure 14. Location of the school of study object 3
Source: (Google Earth, Coordinate: -6.845848, 107.179126)

Figure 15. The front gate of the school
Source: (Google Earth, Coordinate: -6.845943, 107. 178839)

The school is situated in a densely populated area with many plantations and towns; nonetheless, cars may still pass by the school entry area with the gate facing the main road. This school is in a more strategic position than other study objects because it is administered by the government and was renovated as part of the government's plan to upgrade underperforming school buildings with RISHA technology components. Because the building was renovated at the time of the disaster, it was confirmed that there was no significant damage and that it would therefore be sufficiently sturdy to withstand earthquake vibrations.

The materials are employed to construct basic school buildings in Indonesia; few modifications are possible, such as using lightweight steel roof trusses, brick and stone walls, sand metal for the roof, and prefabricated RISHA components, which are manufactured at the location demonstrated in figure 16.

Figure 16. Materials used in the school design of study object 3

Organization Prefabrication:

An organization or project implementation system's performance from planning to on-site construction can be used to determine how successful prefabricated development has been. Study object 1 performs prefabrication by segmenting the necessary parts, particularly the hollow iron structure outside the site, and cutting them to size so that the only thing left to do in the field is connect the iron with welding connections, which are performed by skilled welders' figure 17.

Figure 17. Prototype construction in Depok before construction at the affected site
Source: (HMA Adhisthana 2021)

Study object 1's design considers the circumstances of Indonesia's worker market so that, as demonstrated in Figure 18, even common people can contribute to growth by enhancing their skill levels.

Figure 18. Community collaboration to build the school
Source: (HMA Adhisthana 2021)

Study object 2 differs in that the construction process makes use of specialized construction tools and expert contractor skills in iron prefabrication (figure 19). Furthermore, the building's complexity necessitates the use of large enough materials in conjunction with specialized personnel during the construction process. The challenge in this development arose from the impact of damaged roads between cities, which made it difficult to ship goods. As a result, building components that had previously been modified to the design had to be cut smaller to be more easily distributed, naturally resulting in a longer assembly time on site.

In terms of architectural design and structural quality, study object 2 offers advantages that are better calculated and stronger. The building process is not a solution in disaster situations where speed is necessary.

Figure 19. Building a school with specialized skills from workers outside the disaster-affected area
Source: (Castro Fernanda 2015)

Figure 20. Location of the school of study object 2 Source: (Medcom.id 2022)

Study object 3 offers great guidelines for building that is quick, affordable, and earthquake-resistant. This work is made more accurate and precise by direct government supervision and capital funding. However, RISHA method development is lacking from the literature currently in circulation. This is because RISHA work is built directly after disasters, requiring a warrant before construction can begin, which can take several months. Another disadvantage is that, despite the method's advancement, there are still few kitchens and RISHA workers.

Technology prefabrication:

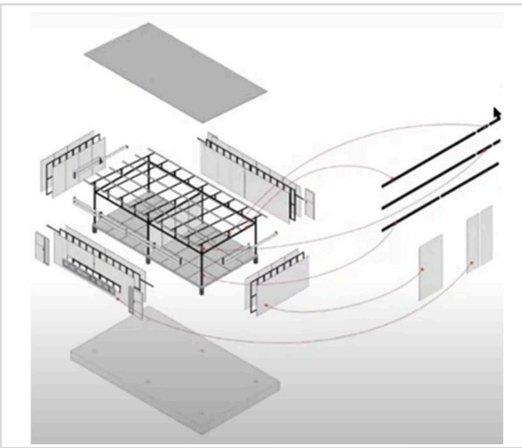

Figure 21. Detail of prefabricated components of study object 1
Source: (HMA Adhisthana 2021)

Prefabricated manufacture or off-site work is one of the key elements that will influence on-site delivery and installation. Study item 1 prepares the components in a form already adapted to the size to be created so that there is not too much finance instead of producing in a factory or assembling them off-site.

The idea behind the design may be implemented throughout Indonesia, a country that has seen many natural disasters. Its straightforward form and readily available materials lend support to the idea.

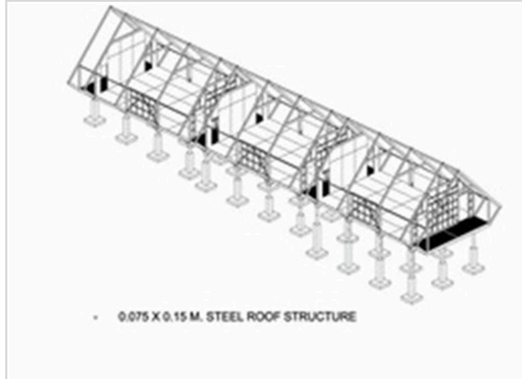

Figure 22. Building components of study object 2
Source: (Castro Fernanda 2015)

The design of this structure is appropriate for the area in which the school is situated; as the figure 22 structural module illustrates, the school is not intended for commercial use and can be erected in a variety of locations. There are still several buildings that are only used when there is not enough room for the underprivileged students in the neighborhood to have the classrooms that the affected schools require.

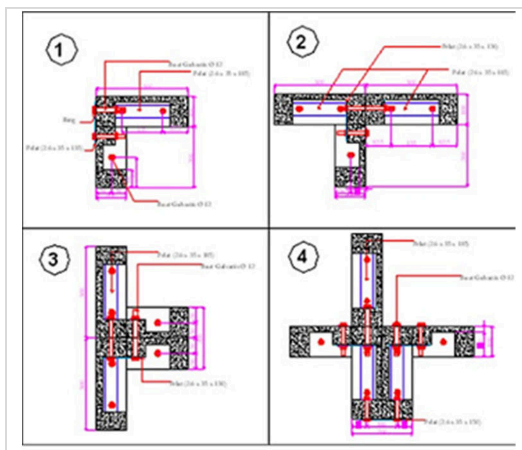

Figure 23. RISHA component connection details
Source: (aplikatorrisha 2018)

Requiring only three components to enable prefabrication and installation at the construction site, RISHA components can be produced off-site rapidly and affordably in around 14 days (figure 23). The building components that are lightweight and compact can be easily transported to their intended location, installed, and managed by hand without the need for heavy machinery. Modules consisting of three components can be formed and assembled in multiple sizes (see figure 24).

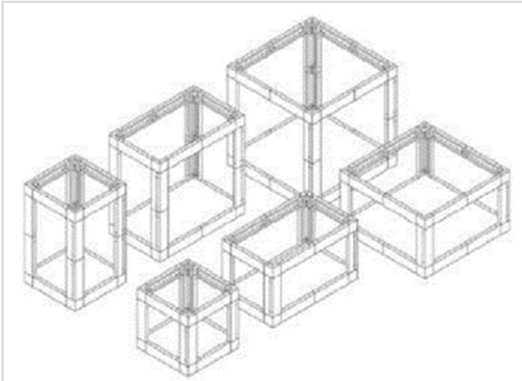

Figure 24. Space shaping module with RISHA components
Source: ResearchGate (Irham 2020)

School criteria (Ventilation)

Figure 25. The existing condition of upper ventilation and illustration of air openings

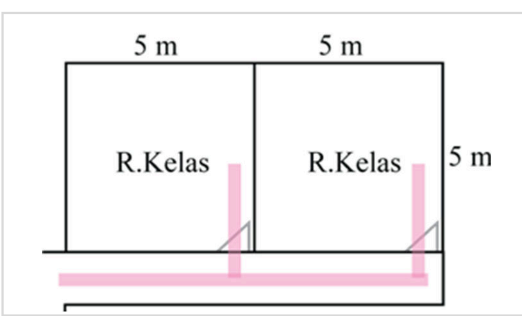

Figure 26. Class circulation at the front

This building has a great deal of ventilation, with openings at the bottom, middle, and top of figure 25. However, in extreme weather conditions, like heat or rain, it can be challenging to regulate the weather from outside the obstruction into the building parts. As a result, frequently, lessons are halted or interrupted.

Although the responses from the teachers who were interviewed are sufficiently comfortable to be used, this type of space design cannot optimize each side of the classroom as an air opening because one side of the room is congested with each other.

Study object 2 has a better variety of openings and considers the comfort level of the inner space from the climatic conditions outside the figure 27 classroom.

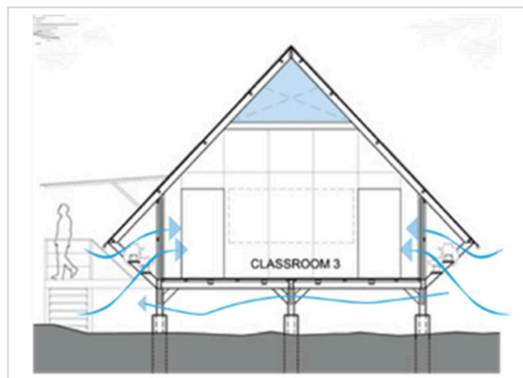

Figure 27. Illustration of building cutout

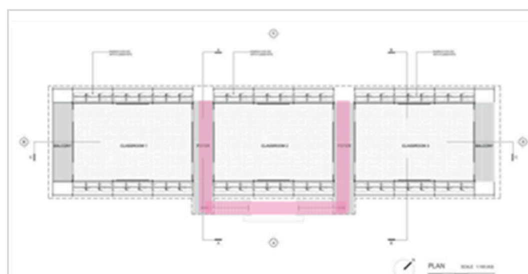

Figure 28. Circulation corridor between classrooms

The arrangement of space in figure 28, which features corridor circulation between classes, has the benefit of allowing enough space between them to maintain noise levels and enable air circulation. Though perhaps less efficient in terms of land use, this layout offers better-quality space.

Figure 29. Circulation plan of study object 3
Source: (Sahirwan 2020)

The pattern in the study object 3 school plan was not updated or changed in a significant way. The layout of the corridor space is similar to study object 1, with the corridors at the front and side of the class connected, and the space creating an L with field activities concentrated in the middle zone. This is typical of Indonesian schools.

With the use of recycled materials, the partially closed classroom's renewal included air ventilation holes created by perforating GRC boards and using bottle caps as a mold (figure 30).

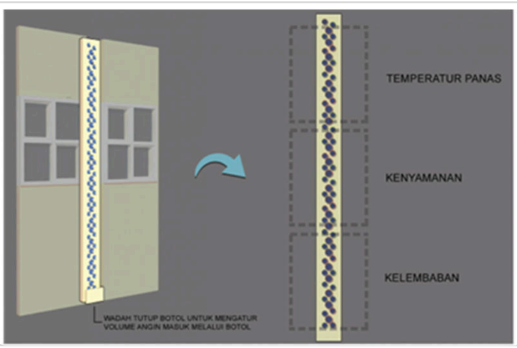

Figure 30. Air circulation innovation in the classroom
Source: (Sahirwan 2020)

School Criteria (lighting)

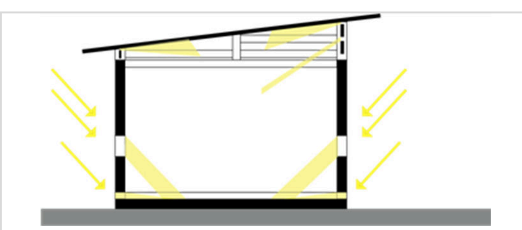

Figure 31. Illustration of the incoming light cutout on study object 1

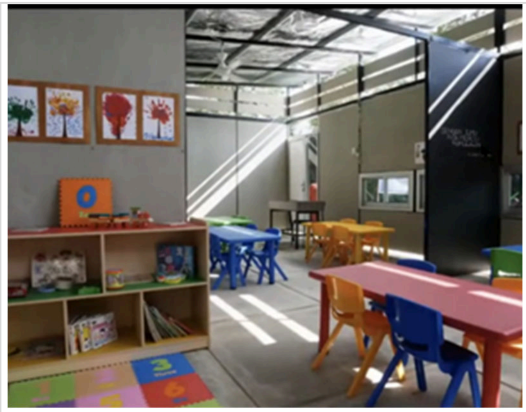

Figure 32. Inside the condition of the classroom
Source: (HMA Adhisthana 2021)

The building's natural lighting employs the openings at the top to distribute the greatest light (figure 32). On the one hand, this is necessary due to the heated classroom conditions provided by incoming sunshine. classrooms with the aid of fans to decrease thermal heating and accelerate air exchange figure 33.

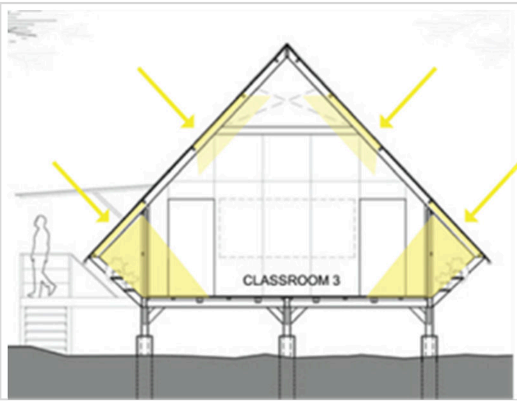

Figure 33. Illustration of the incoming light cutout on study object 2

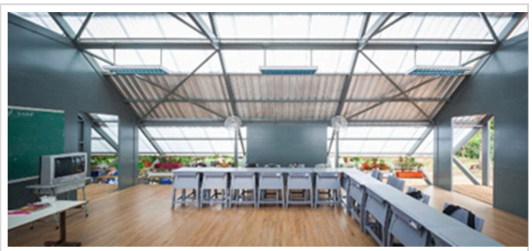

Figure 34. Classroom condition
Source: (Castro Fernanda 2015)

The classroom's lighting generates the use of natural light coming through the transparent roof and side openings of the building. However, there are numerous lamps for one figure 34 room, and the wall openings do not include windows or glass materials to prevent glass breakage in the event of a natural disaster.

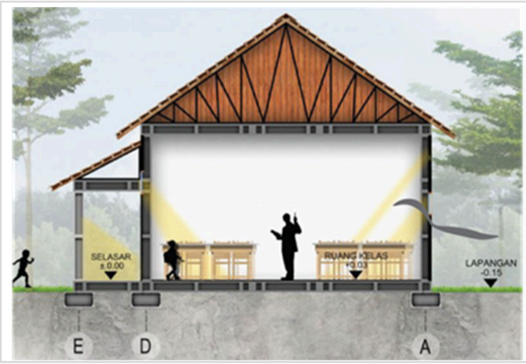

Figure 35. Circulation plan of study object 3
Source: (Sahirwan 2020)

The current school's design generally means that natural light is not used very differently in the classrooms, but it does have the benefit of providing warmth due to heat that rises from the roof into the figure 35 room. To make the structure more open and less massive particularly on the roof there needs to be creativity in the type of apertures since there must be fewer differences in the modules.

School criteria (contextual response)

Figure 36. Use of color in wall and floor elements to encourage children

The three constructed locations of Hammer, Lombok, and Cianjur demonstrate that the building's physical contextual approach to climate and landforms differs mainly in the arrangement of spaces to conform to the natural contours of the site.

Aside from accelerating building, the objective is to enhance the circumstances of the traumatized children. One of the primary elements in meeting children's requirements is having a play area; other significant aspects include using color on the walls and flooring with appropriate variances. Children need to be able to show off their work, so the walls are mostly left plain.

Figure 37. Vegetation elements on the space divider and utilization of the area under the building as open space
Source: (Castro Fernanda 2015)

Compared to the previous two study objects, study object 2 has a more contextual approach concept. In the boundary portion, a plant pot serves as a reminder to preserve nature, even though it is one of the factors contributing to school destruction. The most obvious design is the stage system employed on the foundation, which allows for different elevations of the land to be utilized for different purposes, such as children's play areas and site drainage. The roof design is sufficiently robust to be used in tropical climates or traditional homes.

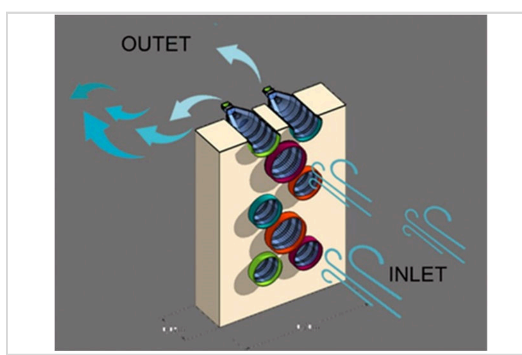

Figure 38. Detail of design adjustments to airing requirements during post-disaster conditions
Source: (Sahirwan 2020)

Study object 3 is more about the need to promote healthy airing in space than it pertains to employing a contextual approach to the location and conditions of natural disasters in design. Specifically, it is about inventing openings with recycled plastic bottle material to reduce waste and protect natural conditions from harm.

Conclusions

Prefabrication has the potential to help with construction needs after a disaster in terms of speed, economy, convenience, and strength.

The design criteria arranged are already in the standard requirements and some are the results of the design criteria.

Thus, the main focus of post-disaster school design is on speed, convenience, and strength; the comfort factor becomes the second part and is undoubtedly important as the success of the design visually raises the context of the issue in location and disaster conditions. The above analysis concludes that the three variables mentioned above are important and will affect each other, especially in the construction and organization criteria. On the other hand, the comfort criteria can be achieved in a separate way of thinking. It is intended that this document can help identify the needs for buildings that the general population, particularly the less fortunate, needs.

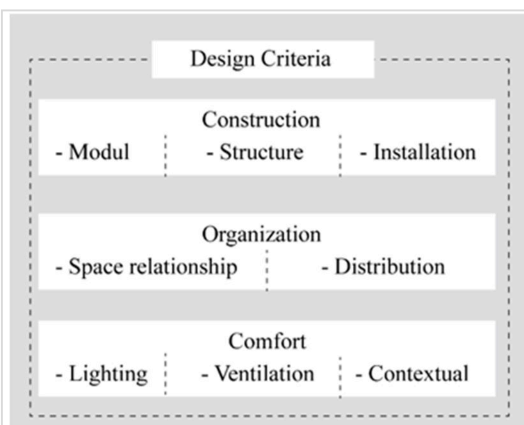

Figure 39. Post-disaster school design criteria

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Ziyad Fauzi Na'im contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Yohanes Basuki Dwisusanto contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.