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FERROCEMENT WOODEN HOUSE: LEARNING FROM POST-DISASTER RECONSTRUCTION IN INDONESIA

Andry Widyowijatnoko[1], Dibya Kusyala[2], Fajar Ikhwan Harnomo[3]

ABSTRACT: Earthquakes are the most common natural disasters in Indonesia, frequently causing not just deaths but also considerable damage to buildings and infrastructure. As a result, a quick and effective post-disaster reconstruction infrastructure is required to ensure that recovery operations can begin as soon as feasible. The need for temporary shelters that are adequate and ready to be upgraded to permanent housing in order to reduce the cost involved and reduce construction waste. In response to these constraints, this paper aims to offer an alternative viewpoint on developing a post-disaster architecture reconstruction system leveraging local wood as an affordable material resource that integrates Ferrocement as part of the architectural elements. In addition, the involvement of local workers addresses the shortage of skilled labour and creates employment opportunities for local communities. The paper provides a comprehensive review of the advantages and limitations of the technique and recommends future research and development.

KEYWORDS: Post Disaster, Rehabilitation, Reconstruction, Local Wood

1 INTRODUCTION

Due to its location on the "Pacific Ring of Fire," an active subduction zone area, Indonesia is a country with considerable earthquake activity. Most earthquake disasters in Indonesia have a significant influence on people's life, resulting in deaths, material losses, and severe psychological suffering. Many big earthquakes have occurred in Indonesia in the previous 20 years, according to documented data [1] including the 2004 Aceh earthquake, the 2006 Yogyakarta earthquake, the 2010 Mentawai earthquake, and the 2018 Lombok earthquake. The greatest earthquake to date was the Aceh Earthquake, which measured 9.1 on the Richter scale and produced a massive tsunami wave to impact the coast of Sumatra, including Aceh. Additionally, the most recent earthquake in Indonesia was the Cianjur Earthquake [2], which occurred in 2022 and had a magnitude of 5.6. According to data from the National Disaster Management Agency, 272 persons were killed, 2,046 were wounded, and 62,545 were displaced. There were 56,311 dwellings affected, with 22,267 badly damaged, 11,836 moderately damaged, and 22,208 lightly damaged.

The Indonesian government and elements of society continue to improve preparedness and handling in the face of earthquake disasters. The first step when an earthquake occurs in order of time is to collect information and distribute assistance to institutions and donors to distribute aid. Further steps rebuild damaged infrastructure, one of which is public buildings, and continue with efforts to rebuild housing for affected communities. The earliest emergency effort that needs to be done is the provision of health facilities by building posts and initial buildings so that people can continue their activities and slowly improve their quality of life.

On the other hand, mobility is usually a constraint in the post-disaster restoration procedure on the spot. According to Sinaga [2], the handling of the Mentawai Earthquake rebuilding and rehabilitation in 2010 was constrained by cross-sectoral coordination, which was still difficult to carry properly. Furthermore, the difficulty of post-disaster rebuilding is tied to a wide range of interests and a considerable expenditure. As a result, for two years following the Mentawai Earthquake, victims of the earthquake and tsunami were housed in insufficient temporary shelters.

2 RESIDENTIAL REHABILITATION OF THE COMMUNITY IMPACTED

In responding to the impact of the disaster, the Indonesian government and humanitarian agencies have so far worked together to provide shelter. The Indonesian government usually works with international organizations such as the United Nations (UN) and the International Committee of the Red Cross and Red Crescent (ICRC) to provide shelter assistance for earthquake victims. In addition, many non-governmental organizations are also involved in relief efforts for earthquake victims in Indonesia.
Here are some of the forms of housing reconstruction that are usually provided:

[1] Andry Widyowijatnoko, Institut Teknologi Bandung, Indonesia, andry@itb.ac.id
[2] Dibya Kusyala, Institut Teknologi Bandung, Indonesia, dibja@itb.ac.id
[3] Fajar Ikhwan Harnomo, Institut Teknologi Nasional Bandung (Itenas), Bandung, fajarharnomo@gmail.com

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1. Temporary shelter. Once earthquake victims lose their homes, the government and humanitarian organizations offer temporary shelters such as tents, posts, or emergency houses for victims to use while they recover.
2. Home rehabilitation. After the earthquake, the government and humanitarian organizations assist victims in rebuilding or renovating their earthquake-damaged houses. This aid might take the shape of building supplies, financial assistance, or skilled technical advice.
3. Housing programs: Long-term housing programs can be implemented to help earthquake victims obtain liveable homes. These programs can take the form of government assistance to build new houses or provide low-interest housing loans for earthquake victims.

Furthermore, the Institut Teknologi Bandung (ITB), with the assistance of Rumah Amal Salman and the Institute for Research and Community Service, took some action by creating drawings and specifications for refugee shelter. The design and structure were designed to be safe, earthquake resistant, quick to assemble and disassemble, and capable of comfortably accommodating numerous migrants. Moreover, the materials and resources required to construct the refugee barracks must be made accessible during implementation. This includes construction supplies, tools and equipment, and on-the-job labour. In actuality, inexperienced victims are frequently accessible. To guarantee that the refugee barracks are erected appropriately and safely, careful construction and oversight are required.

Standardized designs and standards are necessary, and all of the structure's components must be tested before usage. Additionally, measures to maintain and care for these shared facilities are required to keep refugees safe and comfortable. Other fundamental facility requirements, such as clean water, sanitation, and health care. The government, non-governmental organizations (NGOs), and communities must also collaborate to ensure that evacuees' needs are fulfilled and that they receive the appropriate help during the disaster recovery phase.

3 MATERIAL MATTERS

3.1 INDUSTRIAL MATERIALS vs BIO-BASED MATERIALS

For the speed of on-site construction, the solutions that are now widely used are industrial materials such as concrete and lightweight steel (Figure 1 and Figure 2). While buildings made from concrete and steel materials can provide the stability and strength needed to withstand earthquakes, some drawbacks need to be considered when using these types of buildings for post-earthquake relief, including:

1 Because of the expensive materials and intricate construction procedure, buildings composed of concrete and steel have high expenses.

2 The construction of concrete and steel buildings takes a long time and necessitates a large amount of work as well as specialized equipment. This has the potential to stymie the post-earthquake reconstruction effort.

3 Concrete and steel materials are not ecologically friendly since their production and transportation consume a lot of energy and emit a lot of carbon dioxide.

4 Because of the frequent vibrations induced by earthquakes, concrete and steel constructions are prone to material fatigue. This might result in serious damage to the structure, especially if it is built in an earthquake-prone location.

5 Concrete and steel structures are difficult to demolish and recycle. This might cause environmental and social issues, especially if the building needs to be demolished to return the area to its former state when the post-earthquake relief is finished.

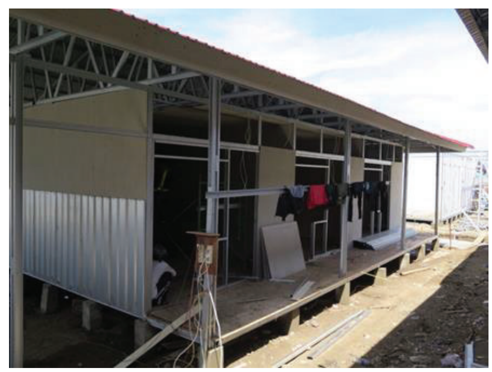

Figure 1: *Shelters built in Petobo, Palu, using light steel, spandex roofs and GRC walls.*

Figure 2: *Model house using risha concrete frame and GRC wall covering.*

On the other hand, bio-based materials are materials derived from natural sources, especially trees that are widely available in nature in Indonesia, and have several advantages as post-earthquake building materials, including:

1 Bio-based materials are manufactured from recyclable natural resources and have a lesser environmental effect than traditional materials like concrete and steel.

2 Certain bio-based materials, such as bamboo and laminated wood, have high strength and durability and may be utilized to construct sturdy and earthquake-resistant structures.

3 Bio-based materials such as bamboo and wood are widely available and reasonably priced in many regions of Indonesia.

4 Because some bio-based materials, such as coconut fibre and straw, disintegrate naturally, they do not cause environmental or social difficulties when the structure is demolished.

5 Since bio-based materials have natural colours and textures, they may improve the appearance of buildings while also enriching local cultural values and traditions.

6 Bio-based materials, such as bamboo, can absorb and minimize seismic vibrations, reducing building damage.

7 Certain bio-based materials offer high thermal qualities, such as heat and sound insulation, which can aid in the creation of comfortable and healthy

3.2 WOOD MATERIAL

Timber has long been utilized in Indonesian buildings and is one of the finest solutions for reducing earthquake damage. It is recommended to utilize high-quality lumber that meets international standards such as SNI or ISO for post-earthquake use. Low-grade timber can cause structural problems and make a building more prone to earthquakes. The following premise is to use the appropriate building system. The proper building system can assist minimize the danger of seismic damage. The wood frame system and the timber beam system resting on poles are two building techniques that are suited for timber materials. The correct construction system should take into account the building's strength, stiffness, and stability. For this reason, it is essential to think about the upkeep and durability features before to use by paying attention to the material's drying process, protection from insects and mildew, and systems that make it protected from weather attacks, particularly rain and high humidity.

There are various varieties of rapid wooden dwellings used for disaster relief in Indonesia. Some of them are:

1. Basic Wooden House (RKS) The RKS is the most often utilized form of a wooden house in Indonesia for disaster relief. The roof is made of zinc and the home is made of wood. RKSs are typically 4x6 meters in size and can accommodate 4-6 persons.
2. Earthquake Resistant House (RTG) An earthquake-resistant house (RTG) is a type of wooden building that is meant to be earthquake resistant and robust enough to withstand natural calamities such as earthquakes. Other constructions, such as steel and thin concrete walls, are generally installed in this dwelling. RTGs vary in size according to the application.
3. Health-House (Rukesa) Rukesa is a type of wooden hut used as a health station in rural or difficult-to-reach places. This residence has medical amenities such as examination rooms, waiting rooms, and sleeping rooms. Rukesa is also often provided with safe drinking water and sanitary services.
4. Ready-to-Use House (RSP) RSP is a sort of wooden home that is meant to be rapidly and readily erected. It generally has basic furniture and home necessities including mattresses, tables, and chairs. RSPs can be utilized as either temporary or permanent buildings.
5. Community House A communal home is a form of wooden structure designed to host numerous families or groups. This house has several bedrooms, living rooms, kitchens, and bathrooms that are shared by several families. Communal houses are usually built in areas affected by natural disasters such as floods or landslides.

4 CASE STUDY

4.1 CASE STUDY I: FERROCEMENT WOODEN CONSTRUCTION IN MAMUJU, SULAWESI

The Mamuju earthquake [3] with a magnitude of M 6.2 that occurred on January 15, 2021, was an aftershock of an earlier earthquake with a magnitude of M 5.9 that occurred on January 14, 2021, where this disaster event occurred when it coincided with a period of activity restrictions due to the Covid 19 Pandemic. Travel restrictions were still in effect in Indonesia at the time. Getting to the field was equally challenging for the ITB team. Disaster management in Mamuju is inextricably linked to the prior program in Palu. The Palu earthquake, which was followed by liquefaction and a tsunami, happened before the Mamuju earthquake. A group of volunteers was trained in timber building there to build communal shelters and a permanent mosque (Figure 3 and Figure 4).

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Figure 3: *Vault Structure-based Shelter*

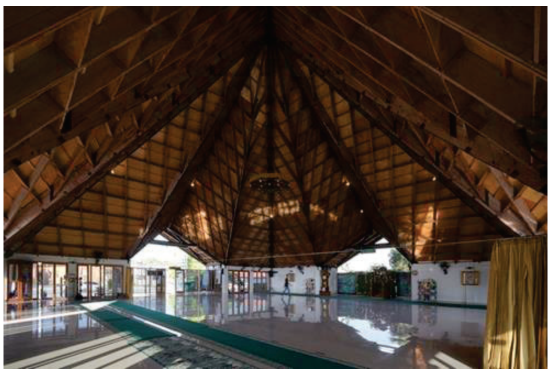


Figure 4: *Nurul Hasanah Wooden Mosque in Palu*

Having developed solid networks with volunteers who had worked together in the previous post-disaster response in Palu, the Mamuju post-disaster response was carried out by activating these volunteers to go to the field with materials and equipment from Palu, which is a 9-hour drive away. Travel restrictions due to the pandemic, especially air travel, made this the most appropriate option. A prefabrication system was employed to keep work on the ground in unfavourable conditions to a minimum. Four shelters similar to the wooden shelters in Figure 3 were built in Mamuju at several evacuation sites plus two wooden Ferrocement houses (see Figure 5).

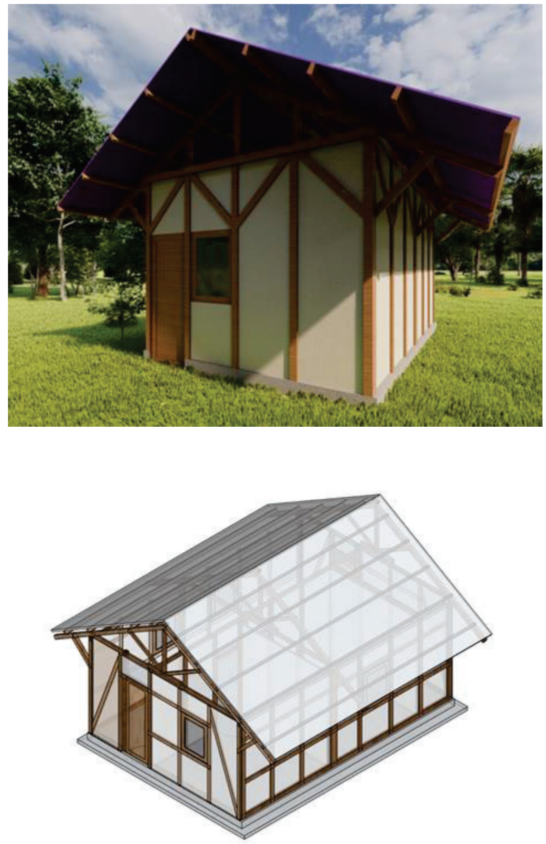


Figure 5: *Timber + Ferrocement House 24m^2 (above) and 35m^2 (below)*

Ferrocement timber homes are built using a semi-fabricated technology in which hardwood wall frames are combined with chicken wire mesh in a wood workshop in Palu. The manufacture of the wall frame (Figure 6 and Figure 7) took place in areas that were not impacted by the disaster and had accessibility to timber raw materials. This was also done to lower the expense of mobilizing field supervision staff. Another factor to consider was that Mamuju's situation at the time was still affected by the earthquake, thus the availability of labour, materials, and equipment, as well as electricity, was still uncertain. Because of the pandemic circumstances that prohibited travel by plane, supervisor monitoring was conducted by phone, video conference, and Zoom Meetings.

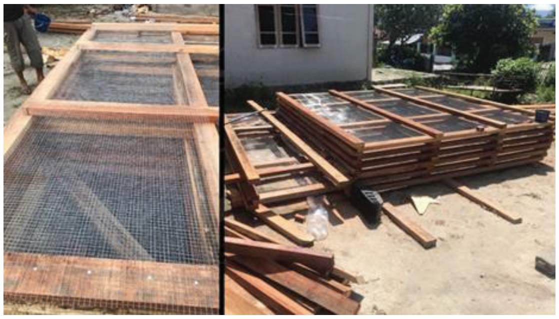
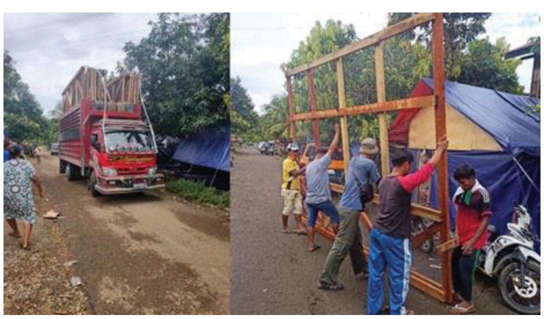


Figure 6: *Prefabrication of timber and chicken wire wall frame modules at the workshop in Palu.*

Figure 7: *Local foundation construction at a house site in Mamuju.*

The basic building method is used to build Ferrocement timber houses, which includes clamping chicken wire between vertical and horizontal logs. The size of the wall frame modules was defined by the measurements of the timber utilized, with as little material as possible left over. Bracing was added to the wall frame, both at the top and at the height of the wall plane on the side of the structure, to give stiffness against horizontal forces such as earthquakes and wind forces, as illustrated in Figure 5. Once the wall frames were finished, they were transported by truck to Palu (Figure 8 and Figure 9). Ferrocement wooden house modules for two dwelling units may be shipped in a single shipment.



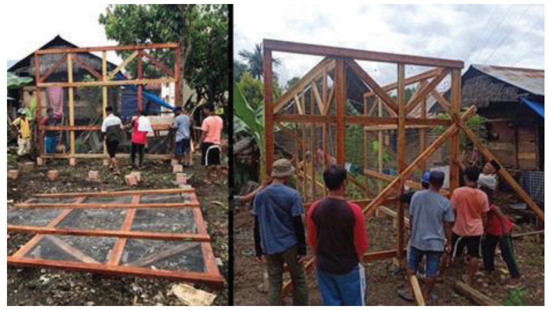


Figure 8: *Delivery of Rukaf (Ferrocement wooden house) modules from Palu to Mamuju (left-below) and house construction (right).*

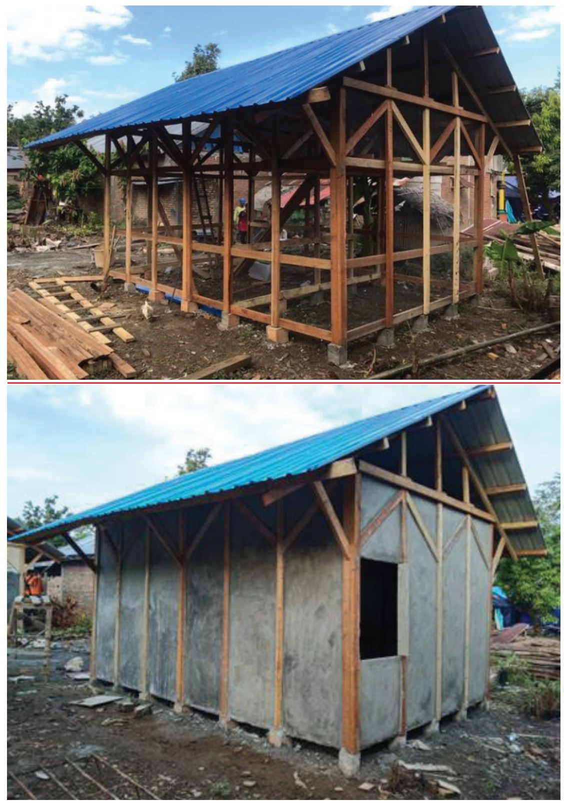


Figure 9: *Ferrocement wooden house before plastering and after plastering*

4.2 CASE STUDY II: FERROCEMENT TIMBER HOUSE CONSTRUCTION IN PASAMAN, WEST SUMATRA

The Ferrocement wood wall method was utilized as well during the construction of a musholla at Pasaman, West Sumatra, following the February 25, 2022 earthquake. The prefabrication system was carried out locally, with the production of the timber wall frame panels and chicken wire mesh taking place in the same area as the building phase. The benefit of this approach is that the

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frame panels are made on the ground and beneath the shade of a tarpaulin tent, making the labour considerably easier than standing work. Furthermore, because it does not require vehicle transportation from the workshop to the building site, the wall panel module may be larger.

The application of wood construction integrated with Ferrocement is also carried out as a partition and at the same time provides shear strength in the construction of the Al-Munawarrah Mamuju Musholla (Figure 10). The wood used as the structure of the Musholla is Coconut Wood. Ferrocement-based walls are used as dividers for the imam's room at the front of the Musholla and also on the sides of the Musholla.

Figure 30: *Musholla in Pasaman (left) and Al Munawarrah mosque in Mamuju (right) using ferrocement wood wall construction.*

5 CONCLUSIONS

Based on previous cases, post-disaster rehabilitation in Indonesia has depended more on large industrial materials supplied from outside the region. Steel, GRC, precast concrete, lightweight bricks, and other materials can enable to create of temporary or permanent housing in large quantities fast. Nevertheless, because these industrial inputs are imported from outside the disaster region, the majority of the economic turnover from the aforementioned technique occurs outside the disaster area.

Timber and Ferrocement wall technology are long-established but largely neglected technology. Timber is a renewable building material with huge potential in Indonesia, including coconut wood. Meanwhile, Ferrocement is an old technology that is very efficient to apply due to the relatively minimal use of materials. A wall thickness of 2-3 cm can be achieved with Ferrocement technology. Compared to plastered brick walls on both sides that are up to 15 cm thick, Ferrocement walls are much more cost-effective and much lighter. Combining Ferrocement walls with timber can improve construction performance because they can make up for the shortcomings of each material. Timber framing has the advantages of low carbon footprint, earthquake resistance and speed of construction. The weakness of fire can be covered by Ferrocement, in addition to being a barrier to the exposure of wood to the climate.

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