Ocho Balay: The Design and Developmental Construction of a Typhoon Shelter for the Rural Areas in the Philippines

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A Dissertation

Presented to the

Marcel Breuer Doctoral School

Pollack Mihály Faculty of Engineering and Information Technology

University of Pécs

Pécs,Vasvári Pál utca 4, Hungary

In Partial Fulfilment

of the Requirements for the Degree

DOCTOR OF PHILOSOPHY IN ARCHITECTURAL ENGINEERING

By

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ACKNOWLEDGEMENTS

I would first like to thank my two supervisors, Dr. István Kistelegdi and Dr. Gabriella Medvegy, for their continual teachings, support, guidance and acceptance throughout my time in the Marcel Breuer Doctoral School research program. My best regards also goes to Dr. Bálint Bachmann, the former Dean of the Pollack Mihály Faculty of Engineering and Information Technology**,** which made this dissertation possible. I would also like to thank the University of San Carlos (Cebu, Philippines) for generously funding my research, studies and trip. Much of my thanks also go to Professor Béla Lányi who assisted my journey here in Hungary. In addition I would like to thank each of the Doctoral students and professors that collaborated with me to further our research. Of course, to Architect Danilo V. Ravina, the brains behind several of the community shelter series from which I took inspiration from and his associates at the Institute of Planning and Design of the University of San Carlos School of Architecture, Fine Arts and Design (IPD-USC-SAFAD) that made this a successful research collaboration and therefore made my dissertation conceivable. Finally, my special thanks to my entire family and friends which have, as always, been the greatest support to my personal and career endeavours. I hope that I can always be there for you.

Many Thanks,

Rowell Ray L. Shih

PREFACE

The Philippines, a country that comprises of more than 7,107 islands, is one of the most disaster prone areas in the world. Typhoons, landslides, earthquakes, volcanic eruptions and storm surges affect this country almost regularly. Thus, in the effect of changing climates and weather mean gives architects an opportunity to our build more typhoon environments. In the face of catastrophic natural events, architecture is every so often the first line of defence. But then again architecture can also harness nature to empower inhabitants. With storms now becoming stronger and energy demands growing exponentially, the world needs architecture that addresses nature in all its forms. In this study, the author introduces the O*cho Balay*, which is based on the design of an "8" sided house that the shelter is known for. The shelter is a result of the lessons from the experience in previous transitional shelter programmes show that these shelters should always be developed in deep consultation with affected the communities, focused on the permanent reconstruction that comes after the transitional stage. This paper is therefore focused on the design and development of a typhoon permanent shelter, specifically for the rural areas of the Philippines. The resulting study will benefit in the formulation of guidelines for the design of a sustainable shelter that is both typhoon and affordable for the affected rural communities.

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ABSTRACT

The objective of this study is the design and development of a typhoon shelter for the rural communities of Cebu, Philippines. This study also aims to establish a continuation of the successful *I-Siguro Daan* Transitional Shelter which was successfully deployed in 2014 after the onslaught of Typhoon Yolanda. Moreover, this project is to further develop the framework of the *I-Siguro Daan* Transitional Shelter to design the next phase of typhoon shelters: the Permanent Shelter. In order to develop the methodological design of the Permanent Shelter, the author presented several factors into consideration: the understanding how the rural communities use the *present I-Siguro Daan Transitional Shelter*; to further develop and improve the interior space of the shelter; to propose a more roof design; and to design a sustainable toilet and kitchen area for the users. Aside from using surveys and interactions with the rural communities, one of the methodologies used in this design process involves the process of *Exploratory Design*, which focuses on gaining the understanding how the communities use the present *I-Siguro Daan Transitional Shelter*. Secondly, the study also uses the process of Design based Research that is the development and implementation of design through collaboration among researchers and practitioners in the real world built environment and consequently leads to contextually sensitive design solutions. By exploring related case studies and literatures, site surveys and consultations with different groups, the resulting Permanent Shelter will a promising solution for improving the lives of the communities while also providing groundwork for future shelter related studies. Finally, other potential areas of development and application of this concept will also being discussed.

Keywords: Permanent Shelters, Emergency Shelters, Post disaster housing, Typhoon Haiyan

Chapter 1. INTRODUCTION

The Philippines, sitting on the "Pacific Ring of Fire", is a country that frequently faces various natural disasters such as earthquakes, typhoons, and volcanic eruptions (Van Voorst, 2015), (Blaikie, 2004). In 2013, the Central Visayas region experienced the Bohol earthquake, which affected more than 670,000 families (Cross, 2014). A month later, typhoon Haiyan devastated the central Visayas, killing more than 7,000 people, mostly in the rural communities and shorelines. Studies and meteorological records have shown that the Philippine islands are one of the world's most typhoon impacted places (Holden, W. N., & Marshall, S. J.). These stronger typhoons carry more moisture, track differently, move faster and will be aggravated by sea level rise, one of the most certain consequences of climate change. However, while the islands of the Philippines are vulnerable to typhoons augmented by climate change, the local people has a disproportionately low responsibility for causing climate change (Holden, W. N., & Marshall, S. J.). More than 360,000 houses in Eastern Visayas were totally destroyed by Super Typhoon Yolanda, thus highlighting the importance of typhoon-resistant architecture. However, the existing literature tends to characterize post-disaster recovery projects and the attempts to understand the process of recovery following disasters are complex (Esteban, et al., 2016). This is because the complexity varies in degree depending on factors like the type of disaster (e.g., typhoon, flood, or earthquake) and its magnitude. Furthermore, there are complications with the sources required for recovery, such as land, construction materials, financial resources, and labour. In addition, the number of stakeholders involved as well as the recovery is onsite or offsite must be taken into consideration. Many studies on resettlement projects in the Philippines show that beneficiaries' greater involvement in the construction of their houses shows advantages that are not normally associated with agency-driven. Further studies have also shown that successful community based disaster governance show broader partnerships with other stakeholders, especially with the local government agencies and units (Esteban, et al., 2016). The Philippines is a rapidly developing country which experiences the problem of rapid family formation, poor housing and an increased scarcity of land. Housing shortage is particularly serious in the urban areas, combined with the rising cost of construction (Diacon, 1992). The local housing construction is largely a private sector activity although the government is now beginning to take a more active role, especially with the onslaught of super typhoon Haiyan. Traditional housing made from locally available materials is the only form of housing available to the poorest families and lacks any typhoon resistant features. These traditional houses can be found in the coastal and rural areas of the country and since they are weak, many of them are destroyed annually. Although efforts to rebuild these houses are growing, the assistance provided by the government and international organizations is very limited. Lastly, with a changing climate, severe natural disasters can only be expected to occur more frequently compared to the majority of the 20th century. The importance of and need for disaster shelters are increasing globally, as no nation is immune from the effects of natural disasters. An important step governments should take around the world would be to prepare for disasters in terms of adaptation and infrastructure resilience. Waiting to plan and act until a disaster strikes is therefore not a viable option. This is the main intent of this study.

1.1 Background of the Study

On Nov 8, 2013, the Philippines experienced its most devastating catastrophe in 20 years—Super Typhoon Haiyan. The typhoon, with sustained wind speeds of around 150 Kilometres per hour (170 knots), was cataclysmic and resulted in the deaths of more than 7,000 people and the displacement of 4 million Filipinos, mostly centred in the rural areas of the country. After the typhoon the lives of some 14 million Filipinos were affected by the destruction.

This typhoon was equivalent to a category 5 on the Saffir-Simpson hurricane scale, which means it has the capacity to cause catastrophic damage and a high percentage of destruction to houses that could last for weeks or months (Weather, 2005). Despite the initial international attention the country is still presently struggling with pressing housing needs for the affected communities.

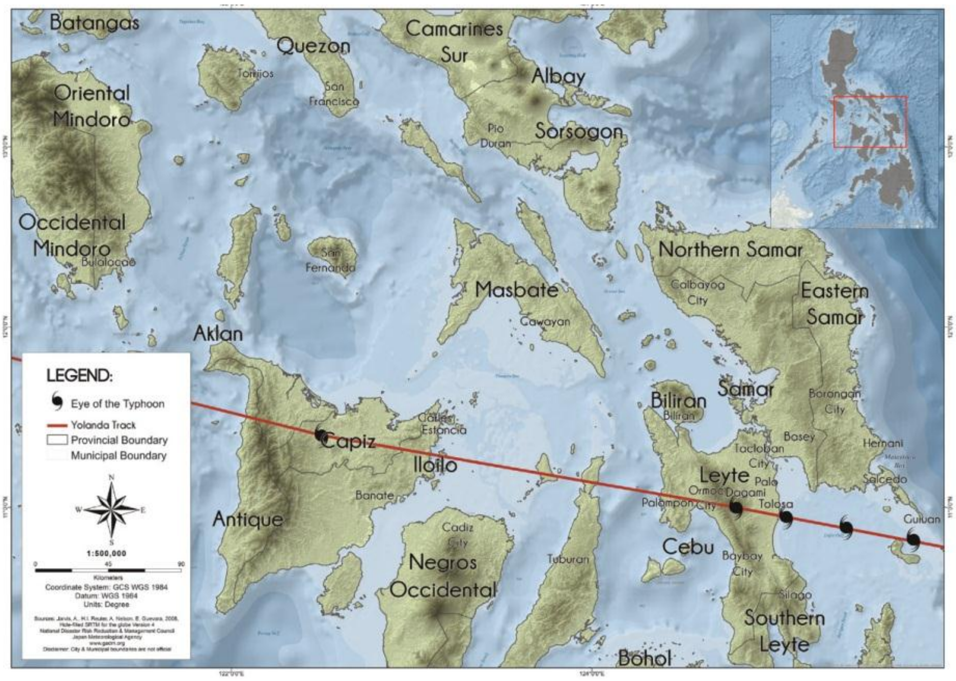


Figure 1. The path of Super Typhoon Haiyan.

Figure 2. Aftermath of Super Typhoon Haiyan in Leyte, Philippines

According to recent studies, as much as twenty typhoons enter the Philippines area of responsibility every year (Yamada, 2014). The storms are created above the warmer waters of the Pacific Ocean near the equator, and the Philippines' islands are often the first major landmass they hit as they move northwest. Out of these, between five and nine typhoons makes landfall and causing widespread damage and destruction. The resulting typhoons can cause widespread flooding and mudslides that can hit many rural towns and villages. These locations are rendered inaccessible sometimes for days or weeks. There have been studies that state this is due to climate change and is increasing the strength of the typhoons. The following are the deadliest typhoons on record in the Philippines:

Table 1. List of the deadliest typhoons recorded in the Philippines

Number	Name	Period	Number of Deaths
1	Angela	1867	1800
2	Haiphong	1881	20,000
3	Amy	Dec. 6-19, 1951	991

4	Trix	Oct. 16-23, 1952	995
5	Ining (Louise)	Nov. 15-20,1964	400
6	Sening	Oct. 11-15, 1970	768
7	Titang	Oct. 16-23, 1970	631
8	Yoling	Nov. 17-20, 1970	611
9	Didang	May 12-17, 1976	374
10	Kading	Oct. 25-27, 1978	444
11	Anding	Nov. 21-27, 1981	409
12	Weling	Oct. 11-15, 1982	309
13	Nitang	Aug. 31–Sept. 4, 1984	3000+
14	Undang	Nov. 3-6, 1984	895
15	Sisang	Nov. 23-27, 1987	979
16	Ruping	Nov. 10-14, 1990	748
17	Uring	Nov. 2-7, 1991	8000+
18	Kadiang	Sept. 30 – Oct. 7, 1993	576
19	Monang	Dec. 2-7, 1993	363
20	Rosing	Oct. 30 – Nov. 4, 1995	936
21	Winnie	Nov. 28–30, 2004	407
22	Reming	Nov. 26–Dec. 1, 2006	1,200+
23	Frank	June 18-23, 2008	557
24	Ondoy	Sept. 24-28, 2009	464
25	Pepeng	Sept. 30-Oct. 10, 2009	465
26	Sendong	Dec. 13 - 19 2011	1,268
27	Pablo	Nov.25 – Dec. 9 2012	1,901
28	Yolanda	Nov. 3 – 11 2013	7000+

1.1.1 Typhoon disaster relief shelters after a disaster

The provision of adequate shelter for the affected communities has a significant impact on human survival in the initial stages of a disaster (Bashwari, 2014). Thus, a shelter requires more than just a roof for a space to be habitable; it must have enough clothing, blankets, mattresses, stoves, fuel, and access to services such as water and sanitation (Ashmore, 2004). These typhoon disaster relief shelters are commonly roofed, secure, hygienic, and liveable locations for people to utilize during periods of disaster until they are able to move back to their permanent dwellings. Furthermore, many of these types of shelters are intended so that they can be erected, dismantled, and stored for future use (Arslan, 2007) and these varieties of shelters are lightweight structures that can be used for a several purposes (Institution of Structural Engineers, 2007). These disaster relief shelters include plastic sheets, tents, prefabricated housing, and public community buildings such as, in the case of the Philippines, public schools and gymnasiums. The author would also add that these tents, which are usually made of synthetic plastics, are impractical where there is not sufficient ground anchorage or when the terrain is not flat. Of course, site constraints such as elevated floor are required for safety and comfort for the affected families. These tent materials are often not fire-resistant and are weather-resistant only for a limited time. Besides, the indoor temperature of tents cannot be controlled and this can create further discomfort in traumatized victims, during periods of extreme weather. Putting up heavy-duty tents may not be a straight-forward process for unskilled workers. To conclude this chapter, the author wishes to add that a safe and dignified shelter is a basic human right, and in a post-disaster scenario provision is more than just putting a new roof over people's heads and providing emergency shelter (Murray, 2015). It is important that the design of these shelters also address the local culture, environment and economy of the community. The best housing will improve on what went before and incorporate future risk mitigation in the design (Murray, 2015).

1.1.2 Features of a typhoon resistant house

According to the *Sheltering from a Gathering Storm* project, characteristics of shelters include: (1) The ability to absorb shocks, (2) Reinforced spaces that can protect inhabitants even if other parts of the house are destroyed or flooded, (3) Escape gateways, (4) The employment of water-resistant materials in sections that are likely to be hit by floods, (5) Redundancy and modularity that allow the interaction of different components of the building; solid structures, (6) The use of simple forms that can easily be built locally with local materials, and (7) Flexibility that allows expansion and adaptation when needed in the future. A few days after the Super Typhoon affected the country, prominent Filipino architects surveyed and studied the affected areas and came up with appropriate designs for new homes. They also discussed features of a typhoon-ready house. According to the United Architects of the Philippines (UAP), these are the five features that a typhoon house that must be implemented in the country: (1) Highly replicable; (2) Uses durable materials, (3) The use of four (4) sided roofs or the *Quatro Aguas* in Spanish terms, and (5) Shorter eaves.

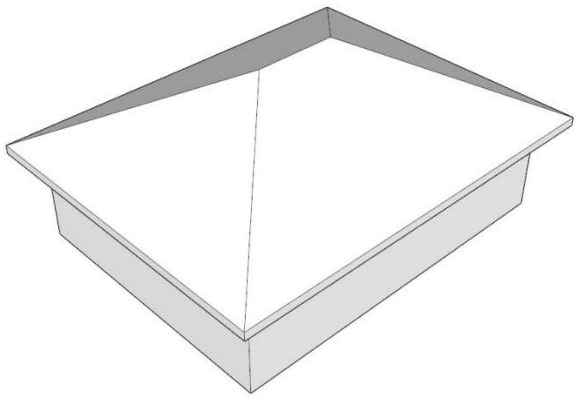


Figure 3. The "Quatro aguas" roof type for typhoon shelters

In effect, the 4-sided roof is more typhoon-resistant because it gives wind less traction to pry the roof away, a horrific phenomenon witnessed by people living in houses with two-sided roofs during the storm. A 4-sided roof is more streamlined and sealed against buffeting winds. Eaves should no longer be a feature of typhoon-resistant homes. Eaves, which are the edges of a roof which jut out beyond the walls of the house, only give the wind more surfaces with which it can lift the entire roof. The use of stilts is highly effective in storm surges. Similar houses can be observed by the local riverside-dwelling Badjaos built their houses on stilts because of the possibility of flooding. The firm Royal Pineda of Budji+Royal architecture firm have stated that these stilts can serve as a basis for flood-resistant and storm surge-resistant homes. During a storm the flying jagged metal pieces can no doubt cause serious injury. Tempered glass will not have the same fatal effect because it falls in tiny pieces and therefore can cause less injury. However, tempered glass is very expensive and for the average family and the author of this study prefers to use the storm shutters over windows and doors, thus effectively sealing the house from winds and rain.

Of course, even a well-designed housing unit could not stand a massive storm, thus location is very important in typhoon-ready architecture. Coastal communities should be moved further away from the shoreline to lessen the risk of storm surges. The vacated shoreline can then be converted into a public park, a place of leisure that won't be a big loss in case of a storm surge. Finally, the UAP recommends updating the Philippine National Building Code to keep up with the storms that have been getting stronger. The Code requires that walls of buildings should withstand at least 250 Kilometres per hour winds. But, because Yolanda's winds went over 300 Kilometres per hour, these part of the building code must be re-examined further.

1.1.3 Access to Housing as a basic human right

The access to adequate housing is defined by the Universal Declaration of Human Rights in Article 25, and states that "*Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family*..." (The United Nations Declaration of

Human Rights, 2006). As described by the UN charter, people have the right to housing that guarantees physical safety, adequate space, protection against the cold, damp, heat, rain, wind, and other threats to health and structural hazards (Leckie, 1992). However, despite these classifications, housing is still one of the most challenging aspects of the recovery during natural disasters due to its convolution and because it is a long-term activity not suitable for short-term elucidations (Sanderson, 2013). Additionally, UN-Habitat designates that adequate housing must deliver more than four walls and a roof and should meet the following criteria: security of tenure, convenience of services, affordability, ease of access, location, cultural competence, and habitability (Leckie, 1992). Likewise, there are budgeting restrictions and elevated costs, especially when no emergency shelter and housing preparedness has been planned. Housing is more than shelter that protects us from the surroundings. It is the dwelling that represents our local Philippine culture, values, and needs. Nevertheless, in time of crises, culture seems to be a luxury (Duyne, 2011), and short-term efficiency is the main focus, in general. Unfortunately, ignoring people' housing culture and livelihoods in post-disaster reconstruction has created failed projects with new ecological damage, health problems and dangerous buildings (Duyne, 2011). Finally, it is important to note that every disaster creates unique circumstances that require relief responses tailored to the specific situation and especially the need of adequate shelters.

1.1.4 Categories of housing and shelters

The Philippine shelter problem is no longer quantitative, but qualitative. The families tend to constantly improve and adapt their shelters in order to better accommodate their changing needs. Therefore, housing is a process and not and end. During a calamity, the affected families usually move between different shelter setups before they either return to their previous permanent residencies or build their new houses. In this study, the author, therefore, presents studies by researchers in the different categories of shelters. These shelters, which serve as a guide and inspiration for this study, can be divided into four categories: emergency shelters, temporary shelters, temporary housing, and permanent housing (Quarantelli, 1991, Wu and Lindell, 2004, Johnson et al., 2006, Johnson, 2007a, Johnson, 2007b, Félix et al., 2013a). Still, the International Federation of the Red Cross and Red Crescent Societies (2013) have added additional categories to these, such as transitional shelters, progressive shelters, and core shelters or the one room type of shelters:

1. *Emergency Shelters* are used for brief periods of time to deliver life-saving support and is the most basic kind of shelter support according to the IFRC/RCS of 2013. Apart from staying in another permanent structure for one night to a few days during an emergency (Quarantelli, 1991, Wu and Lindell, 2004, Johnson et al., 2006, Johnson, 2007a, Johnson, 2007b, Félix et al., 2013a). However, it must be noted that this kind of shelter does not allow for the extensive provision of food or extended medical services.
2. *Temporary Shelters* are meant only for short-term use. A basic tent used for a few weeks following a disaster constitutes a temporary shelter (Quarantelli, 1991, Wu and Lindell, 2004, Johnson et al., 2006, Johnson, 2007a, Johnson, 2007b, Félix et al., 2013a). According to the IFRC/RCS (2013), the length of stay in such shelters may be restricted. The most significant priority in this situation is speed and limiting the cost of the shelter.
3. *Temporary Housing* is regularly distributed for long-term periods from six (6) months to three (3) years. Temporary housing such as rental houses and prefabricated unit allow the families people affected by the disaster to return to their normal activities (Quarantelli, 1991, Wu and Lindell, 2004, Johnson et al., 2006,

Johnson, 2007a, Johnson, 2007b, Félix et al., 2013a). In many cases, temporary houses are installed on temporary or donated land.

4. *Transitional Shelters* are frequently developed by affected families supporting themselves following a disaster and such resourcefulness and self-management should be supported (IFRC/RCS, 2013). By definition, transitional shelters are usually relocated from a transitory site to a permanent location, upgraded into part of a permanent house, resold to generate income to aid with recovery, recycled for reconstruction, and reused for other purposes (International Organization for Migration, 2012). Yoshimitsu added that these transitional shelters are expected to aid for many months or even years (Yoshimitsu et al., 2013). The conception of "transition" is used as the period that goes immediately after a disaster and that finishes when durable housing is achieved. The term applies to different and overlapping processes of transformation in order to produce immediate results for vulnerable communities and to promote longer-term recovery (Wagemann, 2018).
5. *Progressive Shelters* were designed and built to be more permanent and upgradeable in the future through alterable structural components (IFRC/RCS, 2013).
6. *Core Shelters* or the *One-Room Shelters* are designed with the intent of being permanent housing in the future, including a foundation and all or some of the key services, such as plumbing and various utilities (International Organization for Migration, 2012). The aim of these types of shelters is to build at least one or two rooms to meet permanent housing standards and facilitate improvement. Nonetheless, these shelters are not planned to be full permanent houses (IFRC/RCS, 2013).
7. *Permanent Shelters* are usually progressed from transitional shelters and from a core shelter (Quarantelli, 1991, Wu and Lindell, 2004, Johnson et al., 2006, Johnson,

2007a, Johnson, 2007b, Félix et al., 2013a). Such shelters should be to the impending disasters.

The author would like to further add that these types of shelter must be studied by the local government units to which type of shelter is most appropriate for a group of survivors' needs and conditions. For instance, in certain disaster cases, it is recommended to use emergency shelters if damages can be repaired quickly (within weeks) before returning back to one's home, or if one cannot return to his or her own home due to it being too damaged. However, in such a case it would be better to build transitional shelters on one's own land if possible. The earlier the reconstruction process begins, the lower the social and economic costs of a disaster. It is also thought that phases of sheltering and houses are unlikely to work in a neat linear fashion (Quarantelli, 1991, Nigg et al., 2006).

1.1.5 Incremental housing as a sustainable housing solution

The indication of incremental development is typically associated with developing countries, where access to institutional housing finance is limited or unavailable, particularly for low-income households. However, the concept of incremental housing is being explored by the author of this study. The concept of Incremental Housing is based on the capacity to adapt the house model to the development of the family. Nevertheless it is important to assure that it is available to adapt this evolution of the housing to the site and urban context (Neves, 2013). Coelho and Cabrita discusses that the process of incremental housing is directly connected to the family evolution: "…*embracing forms of gradual improvement and adaptability to the changes, more or less successive, of their inhabitants lifestyles, may so, ensuring the progressive realization of the "housing desires", as they are being made and discussed by locals and chosen as real objectives to be attained at a certain time in these homes*."1 (Coelho & Cabrita, 2009: p.11). One of the famous uses of the incremental housing design concept is the design firm, *Elemental* headed by Alejandro Aravena. According to the Pritzker Prize winner, the projects are based on performances over bounded communities, through the establishment of housing projects that intend to an appreciation over time taking into account housing not only as a habitat but as a mechanism for the family investment. First, the family begins with the base and finally wins motivation for their continuity through creative solutions for the community housing needs, according to a sustainable base and local economy. The architect defends that communities themselves promote their constructions and economy who have impact in the social improved stability and in the vision of a city equal for everyone. It was concluded that give the residents the possibility to adapt their "homes" to their true needs and lifestyle, allows safeguard the housing and adapt their functioning to the actual needs and at the same time allow them to create a strong sense of belonging and identity (Aravena, 2013). Additionally, according to Portas and Silva Dias in the study "Incremental Housing", the main quality of incremental housing is the capacity to build a system based on simple rules of design and execution, able to define the first phase of installation, promoting qualitative evolution of the home environment and others areas, essential to next inhabitant's sociocultural evolution (Portas & Dias, 1972: pp.100-121). This concept ensures that the improvements of housing are according to the capacities and investment funds of each family. Coelho and Cabrita also state that some operating characteristics of the standard make it impossible the continuous evolution and improvement of housing: *"...spaces designed with only one function; inadequate fixed equipment; windows designed for rooms with specific function; proportions of compartments related to certain functions; narrow access and circulation; and the existence of only one access to the outside* (Coelho & Cabrita, 2009: p.12). Therefore, to circumvent such difficulties it appears necessary the establishment of a minimum set of initial requirements, from which it will be possible to develop housing in a sustainable routine.

1.1.6 Transitional Shelters as a viable solution in post-disaster recovery

By definition, the concept of "Transitional Shelter" describes an adequate shelter that serves during the process that begins within the time frame of emergency intervention and finishes with the permanent reconstruction, leading to sustainable development (Morris, 2018), (Garay, 2014). The concept of "transition" is used here as the period that goes directly after a disaster and ends when housing is achieved. The term applies to different and overlapping processes of transformation in order to produce speedy results for susceptible communities and to encourage longer-term recovery (Twigg, 2009). Correspondingly, the term 'transitional' emphasizes that 'shelter' and 'settlement' are processes (Leon, 2009). However, studies have shown that there are concerns about the absence of consideration to the transition towards reconstruction and the uncertainty about the end of the transition (Collins, 2010). Now, the question has been "transition to what?" (Collins, 2010). This question has been responded as "transition to a less susceptible state than before" (Kennedy, 2008). Furthermore, Transitional shelters also may be loosely connected to as "Transitional Habitability", which is understood as the habitability demands of the affected from the moment they are out of danger. For instance, when arriving at safety zones in case of typhoons or storm surges, the affected communities are primarily assisted by organizations in charge of the immediate response and then are transferred to shelters. From that moment, a process begins where the affected have health, protection and privacy requirements that are not adequately regulated and that should be part of risk management (Duyne, 2011). Transitional Habitability was linked to the concept of "Build Back Safer", based on the phrase "Build Back Better" introduced in 2006, after a report on the 2004 Indian Ocean tsunami (Leon, 2009). Lessons from experience in transitional shelter programs show that the transition should always be developed in consultation with affected communities, focused on the permanent reconstruction that comes after the transitional stage (Leon, 2009). Additionally, the word “habitability” is a concept that is referred to a dwelling that is appropriate for humans to live in and which depends on the characteristics of the shelter as well as the circumstances of the surrounding environment, the access to amenities and access to resources. The standards of these characteristics change from country and because they are associated to housing adequacy which depends on housing preferences and socio-economic characteristics (Ibem, 2015).

1.2 Statement of the Problem

Post disaster shelters made from materials that can be upgraded or re-used in more permanent structures is vital to any community that is affected by natural calamities (Griekspoor, & Collins, 2001). These transitional shelters can be relocated from temporary sites to permanent locations and are designed to facilitate the transition by affected populations to more durable shelters. Transitional shelters respond to the fact that post disaster shelter is often undertaken by the affected population themselves and that this resourcefulness and self-management should be supported. However, since the onslaught of Typhoon Haiyan in 2013, the Philippine Government fell short of providing Permanent Shelters to some of the most affected communities. The purchase of available land, high cost of materials and labor have likewise contributed to the delay of these shelters. There is an urgent need of Permanent, Sustainable and affordable Shelters for the victims of these typhoons and other calamities.

1.3 Research Questions

The research questions provide the main theme and direction of this study. An exploration of the experiences of typhoon shelters applied in the local communities highlights the differences between general and local experiences and therefore, answers the questions raised in this research. Nevertheless, in this paper, the author wishes to identify the following questions: First, what are the challenges in the design and development of a typhoon shelter for the Philippines? Ever since the first prototype of the *I-Siguro Daan* transitional shelter was contributed to the affected communities, the designers and architects have been planning and developing a permanent shelter for the families. Secondly, the author would therefore want to identify the constraints and limitations in designing a Typhoon permanent shelter using the same design parameters of *I-Siguro Daan* Transitional Shelter. For example, the use of locally sourced materials and use of simple tools and locally sourced manpower can further be explored in the proposed shelter. Third, the author would also like to know the possibilities in reducing the initial cost without sacrificing the structural characteristics of the shelter. Fourth, the author would recommend the directions and study of the proposed typhoon shelter in the Philippines and how it can help designers in their quest for sustainable housing design in the future.

1.4 Research Objectives

The objective of this research is to design and develop a Typhoon permanent shelter as a continuance of the previous original work of the *I-Siguro Daan* Transitional Shelter. The proposed typhoon shelter must require the same or close to the minimum on-site construction activities, workers and equipment while using the available local resources. The aim of the study is not to improve the *I-Siguro Daan* Transitional but to provide a transition to the permanent shelter design. Specifically, the aim of this research is to be able to conceptualize, design and develop a permanent typhoon shelter for a single family based upon the original groundwork of the *I-Siguro Daan* Transitional Shelter. The aim is to also the use of locally sourced materials and labour while using locally sourced human labour. The shelter must likewise be affordable without sacrificing the structural integrity of the project and must be culturally sensitive to the Filipino community. Finally, the author of this study would recommend future directions and study of the design of typhoon shelters in the Philippines.

1.5 Significance of the Study

There is an enormous need for resilient shelters in the Philippines because it is one of the countries that have the greatest number of natural disasters and incidence of flooding in the world. In the Philippines, the continued use of schools and gymnasiums as evacuation centres may cause further disruption to the normal livelihoods and activities of people, especially those who have not been directly affected by a disaster. Currently, emergency temporary shelters in the Philippines are mostly prefabricated, thus the time required to construct permanent shelters are imperative. Most of the donated permanent shelters are either fully assembled in the plant before delivery at the site, or partially assembled in the plant and completed at the site. In most cases, heavy equipment is needed to transport or position prefabricated shelter components at the site, and power tools are needed to fix and fasten them (Karim, 2012). Furthermore, the absence of cultural sensitivity in the design of these shelters can result in the rejection of these shelters in the future (Ravina, 2017). The knowledge gathered in this paper will be useful for architects and designers to improve the design and use of emergency and permanent shelters. The author hopes that this research will inspire and motivate researchers to further investigate new sustainable solutions into typhoon resistant shelters.

1.6 Scope and Limitations of the Study

The limitations of this research apply to only the design, development and construction of a typhoon resistant shelter. Actual structural loads and computational simulations are therefore not part of the study. However, the potential of the prosed shelter for further structural analysis studies and investigation is very promising.

Chapter 2. REVIEW OF RELATED LITERATURE

2.1 Introduction

The literature review in the following chapters aims to be broad but not exhaustive. In Chapter 2.1, the author introduces the concept of vernacular architecture in the Philippines. This serves as my background study which uses the knowledge of the past in presenting the final design of my typhoon shelter. In Chapter 2.2, the author presents case studies and design concepts of disaster relief architecture, not only in Asia but in other climatic regions as well. Knowledge of these disaster shelters can assist me in the further development of the typhoon shelter. In Chapter 2.3, the author shows literature on various student designs which was held as a design competition for climate-adaptive houses and school buildings in the Philippines after typhoon Haiyan. In Chapter 2.4, the author shows literature of various climate-adaptive houses and school buildings in other Asian Regions. In Chapter 2.5, the author shoes the review on the *I-Siguro Da-an*' transitional shelter, which, as stated earlier, serves as the starting point of this study. Finally the author discusses the various design concepts and literary studies of the transition to permanent shelter in Chapter 2.6.

2.1 Vernacular Architecture in the Philippines

Studies have shown that the individual dwelling is the most common building type of vernacular architecture in the Philippines. The proposed shelter was inspired by the pre-

Spanish Filipino House, called the Bahay Kubo. Studies by prominent scholars have shown that the Philippine domestic architecture started with the Bahay Kubo (Figure 4), a nipa hut (Klassen, 1986).

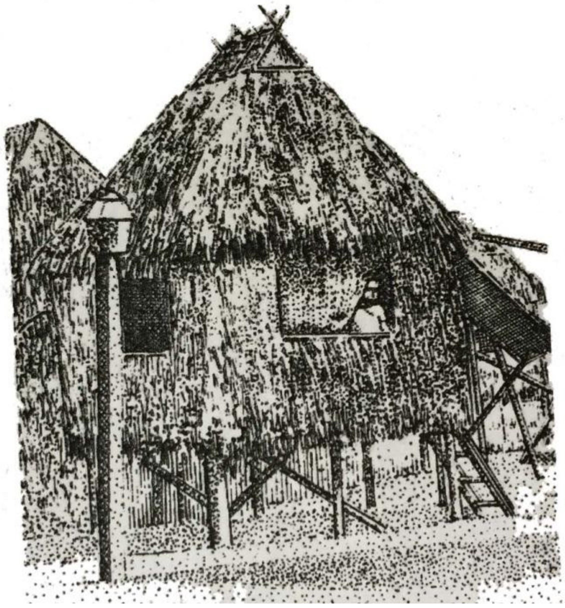


Figure 4. The Bahay Kubo

In spite of the regional difference in construction and appearance, there is one unifying element in these houses: It is basically a house of a “floating Volume” raised on stilts (Figure 5).

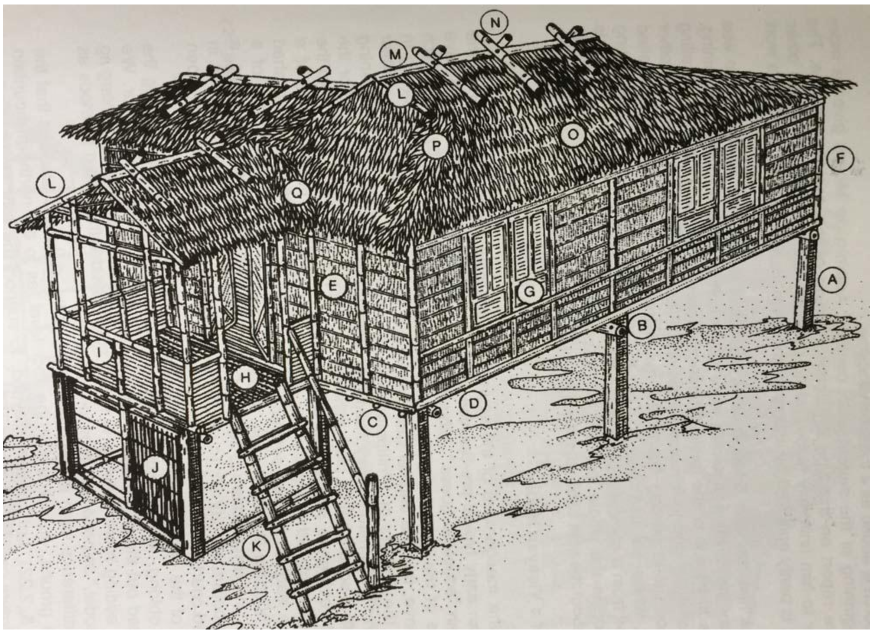


Figure 5. The Filipino House as a "Floating Volume"

It could not be determined whether this type of design was influenced from the Philippines or from its outside neighbours, it is certain that these types of houses is common in Asia (Klassen, 1986). Countries like Indonesia, Malaysia have similar building types. The construction and form of the vernacular Filipino house was being studied by the author in order to construct a shelter that is prominently Filipino in order to respect the cultural characteristics of the local communities. From Figure 6, it shows the traditional Ifugao House, which was also very common in the Philippines before the arrival of the Spaniards. The wide overhanging roof resulted in a minimum wall surface area which is further exposed to the natural elements. The edges of the pyramidal roof are tempered by the organic roofing material which is usually made up of coconut leaves.

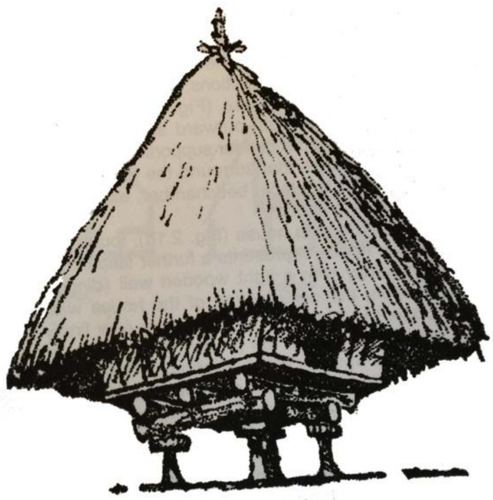


Figure 6. Traditional Ifugao House

The house is lifted around 1.50 meters from the ground using local hard wood, such as the Narra (Figure 7). These posts are sunk into the ground around .50 meters deep and stones are placed around them to keep them vertical and to prevent them from sinking into the ground even further. Filipino houses are usually lifted because of the frequent flooding and to prevent animals such as rodents entering the house.

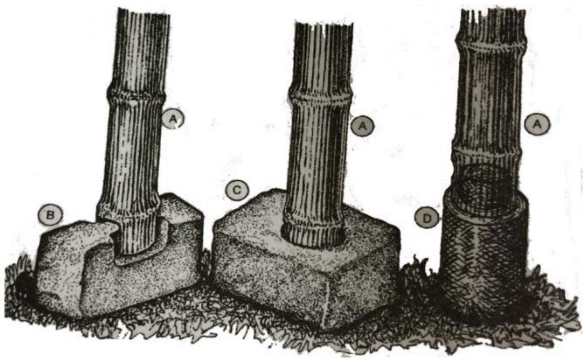


Figure 7. Filipino Houses are usually lifted from the ground to avoid flooding and from animals.

The Bontoc House (Figure 8) features a roof that is exiting both outward and downward. Post in the ground are therefore not required for supporting the roof but, rather serves as nailing strips for the wooden planks that surround the wooden floor which is now the living and working areas. The open space that is above the attic can be served as additional space for granary.

Figure 8. The Bontoc House

The Sagada House (Figure 9) encloses the ground floor with a wooden wall. By using this procedure the house construction was simplified. This resulted in a flaring of the rafters firmly supported by the beams with additional post into the ground. This results in a "house within a house" concept. As with other houses in the Philippines, there are different variations of this due to different climates in the region.

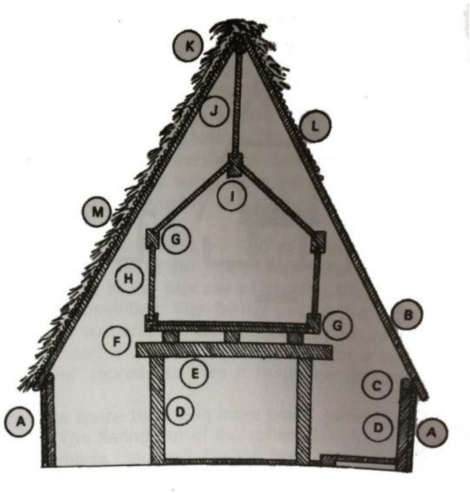


Figure 9. The Sagada House

The Bokod House has an enlarged space due to the addition of pore post, joints and girders. The flaring of the rafters is now significantly enlarged and thus requires separate structural elements. In the Figure 10, the ends of the rafters are not supported from the ground as they are in the Sagada House and the Bontoc House.

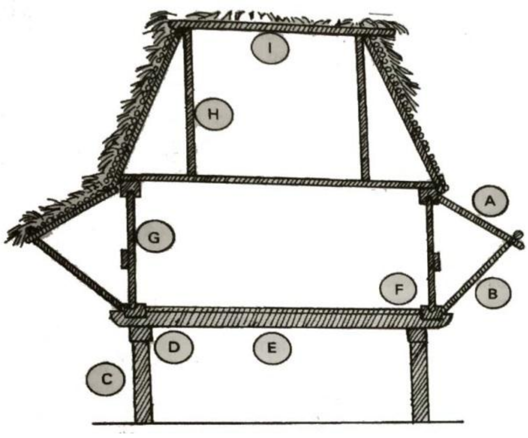


Figure 10. The Bokod House

2.2 Disaster relief architecture designs

Designer Michael McDaniel was inspired to create EXO after Hurricane Katrina devastated parts of the US continent. The shelter is a portable and low cost disaster relief solution for those affected by the calamity. The EXO's has the advantage of being easy and can be set up in a few minutes. It is completely transportable due to its stackable design.

Figure 11. EXO by Michael McDaniel.

Carter Williamson Architects designed The Grid. It is an archetype of a lightweight sustainable housing that can be easily transported to the affected areas. The initial structure acts as a base that can be built out using found diverse materials such as debris. The shelter can easily house around eight (8) individuals.

Figure 12. The GRID by Carter Williamson.

Shigeru Ban designed and built temporary structures out of paper and shipping containers after a horrible earthquake hit Japan in 2011. The shelters are passively cooled and therefore were instrumental in revitalizing the community and help lift the morale of those affected by the earthquake.

Figure 13. Shigeru Ban Shelters made of paper and shipping containers.

Another inspiring disaster relief project from Shigeru Ban is a disaster relief shelter built from bricked earth and uses locally sourced rubber tree wood. More than one hundred (100) of these shelters were built after a tsunami hit Sri Lanka in 2004.

Figure 14. Shigeru Ban is a disaster relief shelter.

Design and architecture firm MAT-TER designed this bamboo structure schools to an earthquake hit area in the Philippines. These structures are also typhoon resistant. Furthermore, the firm proposed to plant a small bamboo forest around the school to be used as a wind screen (against typhoons) and act as a local resource to make maintenances for the schools.

Figure 15. Bamboo as a building materials conceptualized by MAT-TER

The design firm Architects for Society uses the shape of the hexagon as an inspiration for shelters that can fit together to form community areas and other larger structures. These structures are predestined to be used for short-term relief, but can also transition into long-term housing or up to 10-20 years.

Figure 16. Hexagon shaped structures by Architects for Society

Students from the University of South Florida, Jason Ross and Sean Verdecia, designed the Able Nook. This shelter is an excellent example of modular disaster relief architecture. The structure can be used for different purposes, such as housing, school classrooms or storage. Finally, the light framework allows for mass production and can be transported easily to any location.

Figure 17. Able Nook as a modular disaster shelter.

A Post-Earthquake Reconstruction Project in Guangming Village by the Chinese University of Hong Kong & Kunming University of Science and Technology (2016): During the aftermath of the Ludian earthquake in 2014, most of the local buildings in the Chinese village of Guangming were destroyed. The displaced residents chose to build brick–concrete houses during the reconstruction period. Conversely, the price of building materials rapidly increased and became unaffordable for most local villagers (Figure 18). The principal architects, Edward Ng, Li Wan, Xinan Chi and Wenfeng Bai conceptualized a project that involves the traditional rammed-earth building technology. It is a harmless, cost-effective, comfortable, and sustainable reconstruction strategy that the families can eventually afford. A prototype house, with a total area of 148.32 square meters, has been built for an aged couple to validate the technology and building performance of the innovative rammed-earth building system. Within a limited land, the design is integrated with the living and semi-outdoor spaces to provide a comfortable and artistic living environment for the aged couple. Double-glazed windows and insulated roof are used to improve the thermal performance of the building. Finally, to improve the seismic performance, the components of the wall are well adjusted using clay, sand, grass, etc. Steel bars and concrete belts are added to the wall to improve structural integrity and to avoid vertical cracking. The concrete belts are hidden in the wall so that the earth facade could be integrated. The quality of the building materials, rammed tools and formwork are increased. The result of a shaking table test shows that the seismic performance of the rammed-earth building is significantly improved and can meet the local seismic codes.

Figure 18. Guangming Village for a Post-Earthquake Reconstruction Project.

Chacras Project by Natura Futura Arquitectura + Colectivo Cronopios (2016): Chacras is a small town located in the province of El Oro, Ecuador. A family lost their home in a 2016 earthquake and found sanctuary in a shelter of an area of 12 x 10 meters (Figure 19). The project was built in May 2016 during a period of 10 days. Natura Futura Arquitectura along with Cronopios-El Oro carried out the project. Donated materials and tools are collected, and volunteers gather for the construction. These people were also trained to perform the various daily tasks that will achieve the construction of the shelter. As described by the designers: *"The shelter was expressed as modules on pallets, built with pine wood, usually used to load goods in large warehouses. Sticks and strips are used as structural support. The windows were built with semi-hard wood and recycled waste strips. In the end, zinc plates are used to make the roof. The design concept was based on transparency, light and wind. The house was based on three volumes, two used for sleeping and one for kitchen and living room, with an optional progressive growth towards the platform. The distance from the elevated house to the ground protects the structures from moisture while allowing a constant flow of air under the floor. The height of the roof and open spaces plus the transparency of the windows allow for cross ventilation at all times.*

The form of the roof and its eaves are like a large hat that protects the house providing shade and protecting it from the rain. The reliability of pallet modules is mixed with spaces for windows whose spaces between strips allow for light to come inside. The low floor level windows function as escape doors for the children and other recreational possibilities are embraced in a space that encourages fluidity." Finally, the wide front door articulates the basic kitchen, with its shelves made of recycled baskets with the platform expanding the space. The garden made of tires filled with sown ground renews hope in children who embrace it as their own project.

Figure 19. The Characas Project.

2.3 Student design competition for climate-adaptive houses and school buildings in the Philippines

A few months after the onslaught of Typhoon Yolanda, the Philippines Department of Science and Technology (DOST) together with the Habitat for Humanity Philippines, challenged architecture students from different parts of the Philippines Universities to design a typhoon shelter. In this chapter, the author presents the different finalist of the proposals submitted by the students. Furthermore, three major factors were considered:

strength, feasibility, and innovation. Of course, the use of locally sourced and readily available materials was also encouraged in the output. The images and descriptions presented in this chapter are from the Build-It-Forward website (www.buildforward.com.ph). Architecture students from the University of the Philippines proposed “Haligi” which is the fusion between a traditional and modern Filipino house. The design proposes wood and bamboo as primary materials with a concrete core to serve as storage of food and emergency kits.

Figure 20. The Haligi Concept.

The students from the University of Santo Tomas proposed the “Bambox Hut”, which is an amphibious housing unit for the affected communities of Tacloban, Leyte. According to the designers, the housing unit boasts of its ability to “stand rigid through strong winds and earthquakes and to float in the gush of floods”.

Figure 21. The Bambox Hut

Students from the Mapúa University proposed the “Bahay Panalag Laban sa Kalamidad”. These multiple hexagonal units make the over-all structures more resistant to strong earthquakes and floods.

Figure 22. The “Bahay Panalag Laban sa Kalamidad”

Students and professors from the University of San Carlos proposed using an Earth Technology called ICEB. This Interlocking Compressed Earth Block (ICEB) is a cement-stabilized and Earth-based construction material that has a relatively high compressive strength, which could be used as a load-bearing wall or shear wall for a two or three-story building.

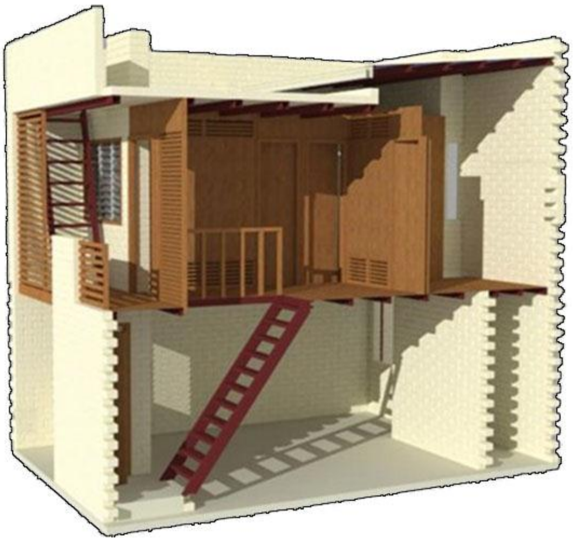


Figure 23. Using Interlocking Compressed Earth Blocks for a housing unit.

Designers and students from the Technological Institute of the Philippines proposed the "Neobalay", which got its inspiration from the Filipino vernacular house, the Bahay Kubo. The housing unit could withstand intensity 8 earthquakes and a typhoon with a wind gust of 250 Kph.

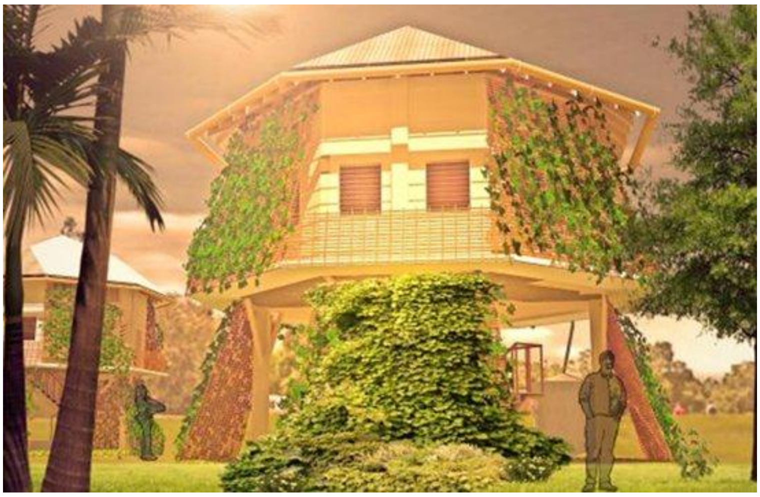


Figure 24. The "Neobalay" got its inspiration from the traditional bahay kubo Filipino vernacular housing.

Another project from the University of the Philippines Diliman Campus, is the "Taklob", which is a low-cost and disaster school and evacuation centre. The conceptual design structure can easily be adapted during summer and typhoon seasons because of its openness for wind circulation as well as the instalment of storm shutters.

Figure 25. "Taklob" has an open plan and circulation with the addition of storm shutters that can be easily adapted during summer and typhoon season.

Students from the University of Northern Philippines proposed a housing and school unit that focus on elevation which can easily adapt in times of typhoons and rising floods. Stilts have been adopted by Filipino vernacular architecture long before the arrival of the Spaniards in the Philippines.

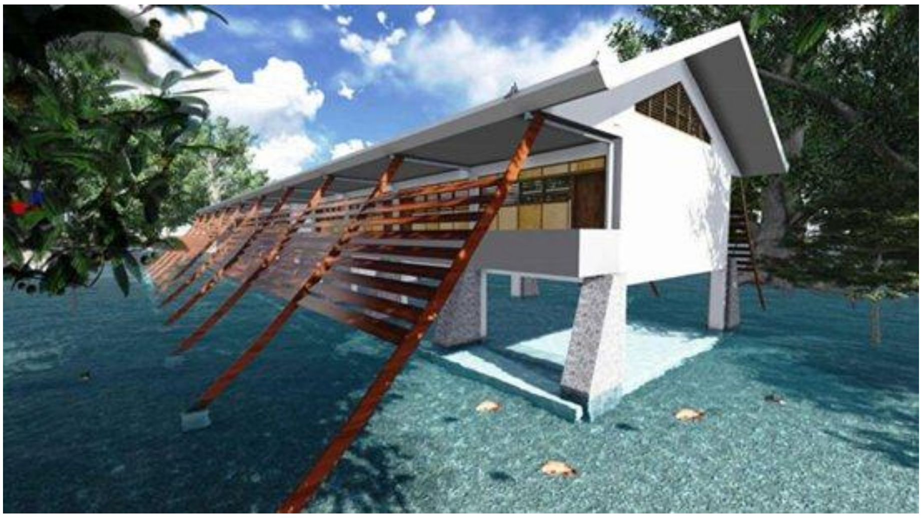


Figure 26. Stilts are the main conceptual design of this housing and school unit.

Students from the University of the Philippines Diliman Campus proposed the “Incubator”, which is basically a school-disaster relief structure. The design concept features a floor plan featuring louvered vents which is ideal for tropical climates, low eaves and a wide corridor. These areas can serve as an activity area or extension space during times of calamity.

Figure 27. The “Incubator” school disaster relief structure.

2.4 Climate-adaptive houses and school buildings in other Asian Regions

The group Architecture Sans Frontières Indonesia (ASF-ID) designed a kindergarten school made mostly of bamboo. The structure is situated on a rice field in the hinterland of

Western Java**.** Architects have used the traditional material for *nur hikmah*'s main structure for economic and environmental reasons. Bamboo, due to its flexible nature allowed the entire structure to sway and bend gently, creating more and earthquake-friendly conditions.

Figure 28. Bamboo Kindergarten House.

A summary of the journals and other related papers of different and disaster relief architecture mentioned in this paper are listed in table 2. These are the various academic articles and journals which have been located using electronic databases (e.g., Science Direct, Web of Science, etc.) and Google Scholar. The author paid special attention to architecture that was specializing in design.

Table 2. Summary of related literature of and disaster relief architecture

Name	**Designer(s)**	**Building type**	**Design considerations**
EXO	Michael McDaniel	Residential Shelter	Transportable, low cost, lightweight and stackable design
GRID	Carter Williamson	Residential Shelter	Lightweight and base materials can easily be found

Shigeru Ban	Shigeru Ban	Residential Shelter	Use of paper and shipping containers, passively cooled
Shigeru Ban	Shigeru Ban	Residential Shelter	Use of earth bricks and locally sourced rubber tree wood
Bamboo School	MAT-TER	School	Use of bamboo as the base material
Hesagonal House	Architects for Society	Residential Shelters	Hexagonal shaped for strength
AbleNook	University of South Florida	Residential Shelters	Modular architecture, light framework
Haligi	University of the Philippines	Residential Shelters	Bamboo and concrete as primary materials
Bamboo Hut	University of Santo Tomas	Residential Shelters	Amphibious Housing
Bahay Panalag	Mapúa University	Residential Shelters	Hexagonal design and elevated structures
ICEB	University of San Carlos	Residential Shelters	Use of earth based construction material
NeoBalay	Technological Institute of the Philippines	Residential Shelters	Filipino vernacular passive cooling and typhoon methods
Taklob	University of the Philippines Diliman	School and evacuation center	Storm shutters and wind circulation
Stilts House	University of Northern Philippines	School	House on Stilts
Incubator	University of the Philippines Diliman	School	Louvered vents, wide corridors and spaces

2.6 The *I-Siguro Da-an*' Transitional shelter

One of the main objectives of this study to further develop the *I-Siguro Da-an*' transitional shelter, which was proposed and built with the cooperation of the Institute of Planning and Design of the University of San Carlos School of Architecture and Fine Arts, with the cooperation of different Non-Government Agencies (NGO's). The shelter was affordable, easy to construct using basic tools and that can provide maximum space for a family of five (5) while being able to withstand an onslaught on another incoming typhoon. Furthermore, the design concept incorporated the Bent Method of construction while only using locally sourced coco lumber and actual validation on a full scale prototype. In order to successfully design the shelter, first a site analysis as well as consultations and interviews with the victims were being done and the results evaluated. Second, the conceptual designs as well as the method are presented to the local government and the beneficiaries of the shelter to obtain feedback. Third, the construction of a prototype was then employed to evaluate the construction conditions as well as the spatial considerations for the users. As discussed earlier, the proposed shelter used only locally sourced materials and simple tools for a family of five (5) members. Finally, a post evaluation analysis was conducted in order to obtain feedback on the performance of the shelter and provide future knowledge in improving the design and its use. The design of the shelter shows how due to the design of the shelter, the families were able to develop their own spaces as well as make subtle design alterations according to their expanding needs. Results from the studies reveal that by understanding the needs of the users, the design and methodology of the '*I-Siguro Da-an*' transitional shelter was effective and practical in providing temporary housing for the victims of the typhoon (Ravina and Shih, 2017). The shelter design must be flexible enough on the use of construction materials and allow replacement with alternatives. A large scale transitional shelter construction project requires large volumes of materials that may negatively impact on the local environment. Large timber requirement may adversely affect the forest environment and the total components should be limited to allow for easy transportation. Alternate steel material may offset this imbalance. It is therefore suggested that the shelters be made of materials that can easily be reused and upgraded instead of being easily disposed. In the Visayas region coco lumber is readily available and is the staple construction material being used by the local community because it is abundant and cheap to acquire. However, 4”x4” for the post is difficult to come by, so the basic dimension to be used shall be 2”x4” and 2”x6” with lengths at 8’ and 10’. These types of wooden houses must be rapidly available and must draw on local resources and industries. This lesson was learned after the Kalamata earthquake in Greece in which the prefabricated temporary houses for the affected families were donated by the international community. However, delays in the delivery meant that temporary housing was not readily available. From this experience, it is therefore imperative that speed in construction can be achieved in the construction of these shelters.

2.1.4.1 Technical description of the *I-Siguro Da-an* Transitional shelter

The amount of covered living space that a transitional shelter must provide is a critical determinant of the design, logistic requirements and cost. A minimum of 12 square meters of covered living space is assumed based on a family of 5 with 2.40 square meters per person occupant density. This can be expanded into 18 square meters by an addition of a 6 square meter module. Figure 29 illustrates the geometry and construction process of the shelter. This configuration has a rectangular floor plan of 4.7 m x 2.4 m with a total height of 3.5 meters, measured up to the apex of the roof.

Figure 29. The construction process of the shelter.

The design of the shelter is based on the Bent Method of construction which essentially consists of a series of structural frames called 'bents' to which the flooring system, roofing system as well as the interior and exterior walls are fastened and tied down (Figure 30). Furthermore, the walls or skins are non-structural and act mainly as a means of giving rigidity to the bents and enclosing the house. The bents can be pre-fabricated or constructed in situ. Additional diagonal braces are added on all sides for protection whiles its slanted walls, it maximizes space inside for sleeping and household chores for the family. The roof of the shelter is not extended to prevent the roof from tearing during strong winds. The simplicity of the design allows for the reduction of training period of the construction workers and resources which can lead to delays (Figure 30. Detail of the Bent Structure). The shelter is made up of bamboo and coconut lumber, materials which are readily available in case of modifications by the family. There are currently two (2) types of shelters: The Lipak version, of which consists of bamboo slits (Figure 31. The Lipak version of the shelter.) and the Amakan version, of which consists of the native material called Amakan (Figure 32).

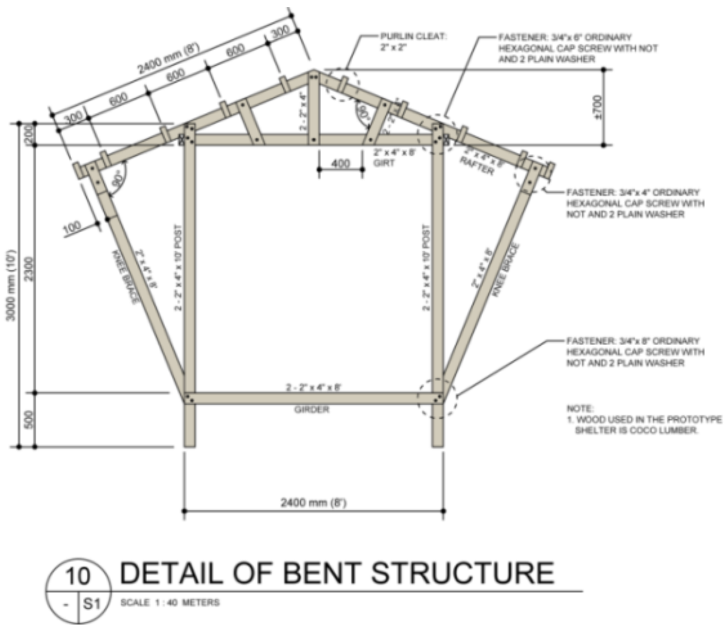


Figure 30. Detail of the Bent Structure

Figure 31. The Lipak version of the shelter.

Figure 32. The Amakan version of the shelter

The form and plan of the shelter evokes a seemingly modern *Nipa Hut*, the traditional residential shelter in the Philippines that blends well with cultural appropriateness. The simple roof plan has a 30° inclination to allow for rainwater to slide off and harvested while reducing the impact of strong winds. The design encourages passive cooling and allow for maximum ventilation for the users. Shelters which accentuate natural ventilation which is essential for hot-humid climates like the Philippines. Prominent feature of the form are the slanted walls in the longer sides of the house. These canted walls offer four advantages, which are: (1) They lessen wind resistance and deflect airflow, although this is still subject for wind analysis in further studies; (2) The slanted design of the walls allows it to shade itself from the sun during the overheating period from 900 in the morning to 1500 in the afternoon. It also eliminated overhangs and thus prevents the 'Monroe' effect caused by wind updraft; (3) creates a sense of wider interior spaces; (4) Finally, in the event of a further disaster, the wall will simply fall outward and thus minimize serious injury to the occupants. The crawl space serves a multipurpose function for domesticated animals, storage space and as play space for the children. In the interiors, the volumetric space becomes bigger as the walls lean outward. This generates a practical and usable anthropometrics because movement and perception of a person becomes wider from the hips to the extended arms and the eyes (for visual expanse). The leaning walls also offer opportunity to attach shelves that do not encroach into the established floor footprint in the Living Module (Figure 34*)*. At the Sleeping Module (Figure 35*)*, bunk beds can be made at the sides allowing two persons to sleep above floor level and make 3 to 4 persons to sleep comfortably on the floor. Ventilation flow through is achieve via awning windows at the front, rear and side walls. Table 3 shows a summary of the design features and the participative process of the proposed shelter.

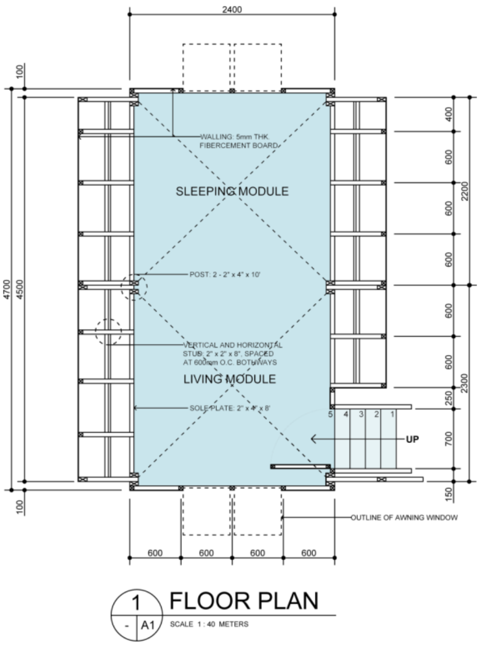


Figure 33. Floor plan

Figure 34. The Living Module

Figure 35. The Sleeping Module

Table 3. The design of the *I-Siguro Da-an Shelter*.

Design Features	
Foundations	Reinforced concrete on all foundations
Reinforcements	Tied down from bottom-up. Additional wooden diagonal braces on all sides
Roof type	Simple Hip roof (30° inclination) for easy rain flow
Shape	Simple rectangular shape for easy construction
Flood preventive measures	On stilts to avoid flooding and protection from other elements
Materials	Locally available, re-usable materials
Portability	Can be relocated and easily upgraded
No. of occupants	For a family of five (5), which is the average family size of the affected community
Ventilation	Cross ventilation from all sides (side, bottom, top)
Community participation	Affected communities and local government units are involved with the design process
Evaluation	Post occupancy evaluation and surveys with the beneficiaries for future design improvement
Total Area	**12 square meters**

With the help of different Non-Government Organizations (NGO's) like Dr. Fritz Strolz and his wife Pearle Strolz of the Swiss Rotary of Switzerland (Figure 36), Movement for a Livable Cebu (MLC), JPIC-IDC, OM Philippines and the Ramon Aboitiz Foundation (RAFI) close to 500 units have already been successfully constructed.

Figure 36. The first beneficiaries of the transitional shelter through the efforts of
Dr. Frtiz Strolz Rotary of Switzerland

These shelters are mostly in the northern parts of Cebu where much of the damage has been done by the typhoon, however there are also shelters being built on the neighbouring Bohol Island. In a few months after the families received their new homes, the research team went back to assess the performance of the shelters. The main objective of this evaluation was to identify and evaluate critical aspects of the performance of the shelter. This will allow the research team to identify problem areas of the structure and thus to be able to build better design guidelines in the future. Studies were also being made on how the families utilize the space and a survey was done on the various performance of the shelter. It was observed that the families are finding various ways to expand the shelter. The sloping roof allowed for extended extensions and thus families can get more space (Figure 37).

Figure 37. The inclined roof allowed for an extended overhang

Most of the families have also used the abundant space under the shelter for various farm animals (*Fig. 8b*). In the consultation with the families, there was increased user satisfaction mainly due to the involvement that the community had in the final design of the shelter. This meant that the beneficiaries were not just passive victims receiving humanitarian aid but responsible for their own shelter project. Presently, the shelter units were still in used and lasted much longer than they were needed as a mere 'transitional' shelter. The length of time this transitional shelter is needed will highly depend upon the ability of the local government in trying to construct the permanent housing program for the affected families. Further experimental testing was still being done in the field to determine the effectiveness and durability of the proposed transitional shelter.

2.6 From Transitional to Permanent Shelter

There are numerous examples from around the world where what started as emergency shelters for a short period of time end up being used for years after the disaster. In academic and non-academic literature we can find are some innovative approaches and designs for sustainable temporary housing both. One of the prominent concepts was proposed by a non-profit organization called the Humanitarian House International (HHI). In Haiti, there were still an estimated 172,000 people living in temporary housing four years after the earthquake devastated the area in 2010 (Félix, 2013). HHI created temporary housing that can be assembled quickly while making it affordable. The model consisted of two possibilities, the Emergency Shelter (ES) and a Long Term Dwelling (LTD) that lasts up to 10 years. Both of these models consisted of prefabricated wall panels, PVC tubes, and metal fasteners. There is also the possibility to upgrade an ES to a LTD unit if the need arises. There is also the possibility of installing a kitchen and bathroom that can be added during in the future. Finally, the proposed shelter also included rainwater collection systems, waste management systems and solar power systems (Ohlson, & Melich, 2014). Another proposed design, named as “Blog House”, allows a 17 square meters2 house for about $2,500. The design does not require craftsmanship skills but involves employing the structure via metal bolts, making the construction of the shelter simple. Furthermore, the proposed shelter allows the potential occupants to assemble the entire structure themselves. Prefabricated light-weight cardboard tubes were used for walls and ceiling. The foundation was made up of sandbag crates and a tented fabric served as a roof. Finally, the roof hatch allowed airflow during hot seasons (Abulnour, 2014).

Chapter 3. CONCEPTUAL FRAMEWORK

In this study, the author adheres to some principles in the design of a permanent shelter for the affected Filipino families. There is a need to better understand how shelter recovery processes employed by stakeholders lead to eventual infrastructure system outcomes. Thus, this chapter outlines the conceptual framework of the *Ocho Balay* typhoon shelter. The author cannot stress enough how significant a sustainable shelter that is used and maintained by communities over time is very much needed in developing countries like the Philippines (Figure 38). Finally, the “3L”, *Local Technology*, *Local Materials* and *Local Labour* strategy has been used in the design framework of the study. These are summarized into the following sub-chapters of the study.

Figure 38. A typical shelter from the rural parts of the Philippines.

3.1 Features of the Proposed Typhoon Shelter

As stated earlier in chapter 1.1.4, the author designed the proposed shelter according to the guidelines of the *Sheltering from a Gathering Storm* project and from the United Architects of the Philippines. From these studies, the following are the features of the proposed typhoon shelter: (1) Modularity, (2) Allow for incremental growth, (3) The use of locally sourced materials and use of simple tools, (4) Adaptability, (5) Minimalist design and (6)

Cultural sensitivity. These design characteristics are explained further in the following sub-chapters.

3.1.1 Modularity and Redundancy

Allowing for easy fabrication is also one of the main objectives of the design of the shelter. The interacting components are composed of similar parts that can be easily replaced if one or many fail. Redundancy is supported by the presence of buffer stocks within the bent structure system that can compensate if functions in one area of the system are disrupted. The main structure of the housing is designed stronger than traditional housing as all parts are securely connected. Finally, the shelter can easily be constructed and, if further required, be easily transported to another location. Furthermore, the shelter, because of its unique roof design, can easily be expanded. These spaces allow for rapid expansion when the families upgrade their financial status.

3.1.2 Allow for Incremental Growth

Flexibility for expansion of the shelter means that the interior is more free and flexible. Both the interior and exterior can be changed and adapted to new needs and are allowed to be developed by division (transformation into two independent modules). Furthermore, the proposed shelter has key assets and functions physically distributed so that they are not all affected by a given event at one time (spatial diversity) and have various ways of meeting a given need (functional diversity/multiplicity of function). The function of the interior can be flexible. For example, the rooms can be used as storage during typhoon season to reduce the property damage.

3.1.3 Easily Accessible and Locally Sourced Materials

Studies have shown that easily accessible and economic materials are an important factor when constructing permanent structures (Ohlson and Melich, 2014). It is therefore important to analyse the context of the location of the shelters. With this knowledge, the designer can implement materials local in the area and define appropriate construction techniques for the design. The shelter design must be flexible enough on the use of construction materials and allow replacement with alternatives. The basic materials used in the shelter are: (1) Coco Lumber; (2) Amakan and (3) Bamboo Splits. Thus, the Bent Structure used by the author in this study uses Coco Lumber. Coco Lumber is a hardwood substitute from the coconut palm trees found in the Philippines. It is referred to as Coconut Lumber, or Coco Lumber. It is a new timber resource that comes from plantation crops and offers an alternative to rainforest timber. Here in the Visayas, readily available material is coco lumber and this shall be the staple construction material to be used. However, 4” x 4” for post may be difficult to come by, so the basic dimension to be used shall be 2”x4” and 2”x6” with lengths at 8’ and 10’. As for the walls, Amakan offers a cheap yet durable alternative. The use of concrete board (Hardiflex) and plywood can also be used in the future when the families are able to upgrade their economic status.

3.1.4 Maximize Comfort with Low Energy Consumption

The application of bio-climatic and sustainable strategies will help improve conditions of habitability within the space of these shelters. Additionally, the orientation and location of the shelter should take advantage of natural ventilation to improve the conditioning within the space. Finally, the implementation of inclined roofs can help collect rainwater to be used for other needs.

3.1.5 Simplicity

In this paper, the author presents the importance and benefits to designing and maintaining a simple typhoon shelter. First, simple shelters for the commons are much easier to communicate. Communication includes both documentation and comprehension. By naming the shelter in common native language, the commons can actually relate it to their own culture. Furthermore, a simple shelter or structure can easily be documented with a smaller model and fewer drawings/annotations which would lead to improved comprehension by stakeholders. Comprehension is critical for shared understanding, which some define as the architecture (from Martin's Fowler's influential *Who Needs an Architect?*). A shared understanding is critical to maintaining alignment across stakeholders and the design team members, and ensuring an efficient implementation. Second, simple structures are every so often easier to implement. These shelters have fewer moving parts, fewer interactions, and fewer opportunities for failure. However, this isn't always the case as occasionally it may take more time to implement a simple design given the number of iterations that go into the process of identifying a final design concept. Third, simple shelters are easier to operate and deploy. The lesser the moving parts are, the more straightforward is the deployment. Then once in production, the shelters are more easily scaled and monitored. Finally, simple structures are easier to modify. It allows the designer to be more productive since there is less complexity to track and fewer points of impact when making changes.

3.1.6 Cultural Sensitivity

Strengthening individual identity and sense of community is one of the main objectives of the proposed shelter. The way individuals react following a disaster is in part shaped by their culture, history, and other sociocultural factors. Thus, a strong awareness of local cultural principles is the first step to a culturally sensitive shelter in disaster affected areas. Furthermore, the shelter design adapts to the local tropical climate conditions. It employs passive cooling principles and has ample natural light during the day.

Chapter 4. RESEARCH METHODOLOGY

4.1 Introduction

The methodology approach for this study was divided into three main stages: literature review, general study of typhoon shelters in the Philippines and case studies of the *I-Siguro Daan Shelter* as a preliminary point of the study. Furthermore, in order to meet the objectives of this study, the author of this study adopted a research strategy of a mix of qualitative and Design Based research. Design Based Research is further explained in the following chapters.

4.1.1 Defining Design

Scholars have identified that Design is described as explorative and innovative, exceeding the limits of the body of knowledge both in a methodological and a theoretical way (Rosemann, 2006), it is exploring several truths, and hence it is "non-cumulative". Bordens further states that design is a conversation that is typically held via a medium such as paper and pencil together with another as the casual partner (Bordens, 2002). Therefore, Design is both an object of study and a means of carrying out this study of the permanent typhoon shelters.

4.1.2 Defining Design Based Research Methodology

The process of Exploratory or *Design Based Research*, according to Mills, focuses more on gaining insights and familiarity when research problems are in a preliminary state of investigation (Mills et al., 2009). This study also uses the process of Design Based Research as proposed by Wang and Hannafin (2005) captures its critical characteristics:

…"a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among

researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories."

Edleson (2000) defined Design Based Research as experimental approaches in order to apply the principles of theory and associated experimental results support (Edelson, 2002). In design-based research, however, the goal is not testing whether or not the theory works (Van den Akker, 1999). Both design and theory are equally established throughout the research process methodology. Therefore, researchers use design to frequently enact and refine theories (Edelson, 2002) so that the theories "do real work" in practice (Cobb, Confrey, diSessa, Lehrer, and Shauble, 2003) and eventually lead to substantial change in educational practice (Van den Akker, 1999). Additionally, Design Based Research involves an examination of stratagems, processes, methods, and modes through which people work creatively. Since Design involves the analysis of ideas, materials and technologies, it also includes state-of-the-art conceptual development, product evolution and market adjustments. Additionally, it also involves research into cultural, social, economic, aesthetic and ethical issues (Armstrong, 1999). In literature, Design Based Research is both the study of design and the process of knowledge production that occurs through the act of design (Fallman, 2007), (Koskinen, 2011). Furthermore, Wakkary argues for designing as "a dynamic process that is improvisational and responsive to the changing design situation" (Wakkary, 2005).

4.1.3 The Participatory Design Method: Involving the Affected Community

The process of community participation was also used in the final design of the proposed permanent shelter. This is significant because the re-housing process involves major change and requires a profound restructuring of daily life of the community (Portas, 1995). Christopher Alexander states that "*the only way to build forms that are loved by its* *inhabitants is through their participation in the process. The mere fact of an individual participating in the planning or construction of his home or neighbourhood establishes a connection between him and the realized object… most people don't have the least concern for formal design virtues, they just want something that they can truly consider theirs*." (AAVV, 2006:p.28). During the rehousing process, the housing living space appropriation are important aspect because the affected families face a process that can break with previous modes of life, and required and rethinking of the space appropriation form and the established identity relations. Herman Hertzberger defends the need for the participation of the affected communities as a condition for a perfect future space appropriation. The author of this paper proposes reciprocity between the shape and the use and the experience for different people and different times. This involvement and participation should follow the whole process of evaluation from the planning to the implementation (Hertzberger, 1999).

4.1.4 Surveys and Interviews

Field research, interviews and surveys were being used as one of the basis for the final of the shelter. In this methodology, the author gathered data analysis from the beneficiaries of the I-Siguro Daan Shelters, particularly from the Northern part of Cebu (one of the worst affected areas and badly hit by the typhoon) after Typhoon Yolanda. Furthermore, field research and surveys were being done by the author from the beneficiaries of the permanent socialized housing units donated by various non-government groups and organizations headed by the Philippine Action for Community led Shelter Initiatives (PACSI), the Slum Dwellers International (SDW), the Asian Coalition for Housing Rights (ACHR) and the Real Equity For All (REAL, formerly British Homeless International). These various organizations donated socialized housing for the homeless and families distraught by natural and man-made disasters. The locations of the shelters are located in various parts of

Mandaue city, which includes Barangay Tipolo, Sitio Mahayag, Sitio Lower Malibu of Barangay Subangdaku. In the field research, together with professors from Cardiff University was held last November 12 to 17, 2018. The author conducted a survey for a total of 50 family housing beneficiaries (Figure 39). The shelters have a size of 28 square meters (4 x 7 meters) with drainage, lighting and other fixtures. The main objective of the surveys and interviews was the user satisfaction rate and use of the shelters by the beneficiaries. The families of the beneficiaries of the housing projects were generally cooperative the study and the final data analysis were done on the sixth day. The survey also included community group discussions as well as focus-group discussions with NGO (non-government units) aid local Filipino construction workers and local officials (Figure 40).

Figure 39. The author with the beneficiaries of the Socialized Housing in Mandaue City

Figure 40. Conducting interviews with various leaders of the community

4.2 Findings and results of the survey and interviews

The results of the surveys and interviews resulted in the importance of better shelters for the Filipino. Furthermore, data showed that the average number of families that occupy these units number to five (5) which includes the children and in some cases, the extended family members. These family members are contented with the 28 square meters provided by each housing unit, although most of the users would want to socialize with their friends and neighbours outside their home. The need to socialize and interact with different friends and family members is a trait that most of the Filipino family adheres to. There is a need to also have a large open space for other extra-curricular activities that may involve other members of the family, such as a birthday party or a singing contest. Some of the beneficiaries find the houses a little bit too inconvenient to live in, especially during the hot summer months. Proper ventilation and use of passive cooling is an important factor in the design of these new shelters. The family members also find the need to make their own small business such as a small *sari-sari* (mixed) store. Majority of the beneficiaries also raised some sort of poultry and livestock such as chickens and small pigs. Although these animals are being regulated by the members of the community, they are very useful especially when families have a hard time buying their own food. The findings of the survey resulted in the following concerns by the beneficiaries: (i). Need for more open spaces, (ii) Flood prevention system, (iii) Spaces for poultry and plants, (iv) Affordable housing, (v) Improved indoor ventilation, (vi) Expandable indoor space and (vii) Capacity to develop the shelter when their financial status improves over time. The results of these surveys will therefore be one of the design considerations of the proposed typhoon shelter that is presented in this study. Finally, the author will also add additional design features (as indicated in the related literature) that can improve the functional features of the shelter.

Chapter 5. DESIGN OF THE OCHO BALAY SHELTER

The proposed shelter is based on the traditional Filipino House, the Bahay Kubo. The design solution explores a solution against typhoons and the design can also be adapted to any climate where timber is available and considering the local building techniques. The spaces of the interior of the shelter can be divided into two parts: (1) *Living Module* and the (2) *Sleeping Module*. These spaces also encourage communal activity, which allows social gatherings and activities and is an important cultural trait of the Filipino family. Walls are constructed of breathable materials for better thermal comfort and allow views from the inside to the outside while allowing natural cross ventilation. The following are the main key characteristics of the proposed shelter such as the use of the *Bent Structure*. By definition, a *Bent Structure* is a transverse rigid frame similar to that of the three-hinged arches (Benson, T.). The term is also used for the cross-ways support structures in a trestle. In British English this structural assemblage is sometimes also called a "cross frame". The term *bent* is an ancient past tense of the verb *to bind*, denoting to the way the timbers of a bent are fused together. Bents are the building blocks that describe the overall shape and character of a structure. They do not have any sort of pre-defined configuration in the way that a Pratt truss does. Rather, bents are simply cross-sectional templates of structural members that repeat on parallel planes along the length of the structure. The term bent is not restricted to any particular material and, therefore may be formed of wooden piles, timber framing, (Bosher, L., & Dainty) steel framing, or even concrete (Faherty, K.F., & Williamson, T. G.). In this study, the *Bent Structure* structural system, made of coco lumber, was used as shown in Figure 42. The resulting design will result in slanted walls on the exterior Figure 41.

Figure 41. Slanted Exterior Walls of the Shelter and corner wall (exposed)

The slanted walls will make the interior appear larger while providing more storage. The sides can also be safely extendable in all directions when the families improve their financial status in the future. This can also be seen as a strategy for continuous growth and improvement. Work or improvements done on one side can be easily upgraded on the other side in a more permanent way with a more resistant material.

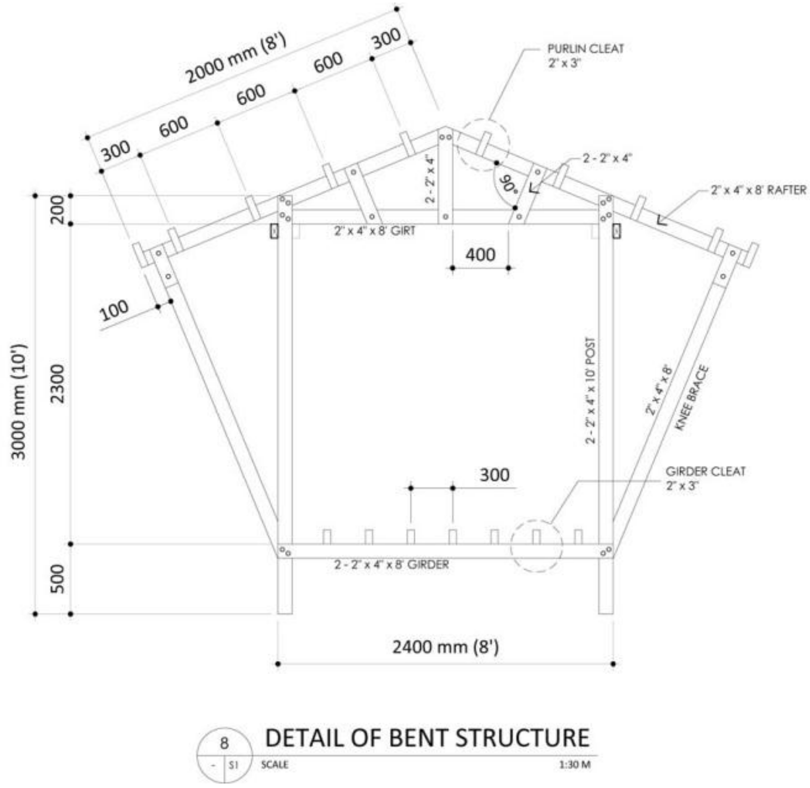


Figure 42. Detail of the Coco Lumber Bent Structure of the proposed shelter

The author also paid homage to Local Philippine Architecture. The proposed unit was designed after an extensive analysis of local architecture while respecting the local traditions and culture so as to enhance the feasibility of replication and maintenance of the shelters by the beneficiaries. Furthermore, this will reduce their vulnerability to future hazards. In terms of cost, the estimated budget for each unit is Ninety Nine Thousand Seven Hundred Seventy Seven and Thirty Centavos (**₱99,775.30**) or the amount of **US$ 1, 904.66** as of January 8, 2019 with a floor area of 19 square meters for a family of five (5). Making each unit affordable will obviously allow for more housing unit to be built and therefore will result in more beneficiaries having a shelter of their own. As compared to the permanent shelters constructed by the Philippine Action for Community Led Shelter Initiatives (PACSII) and the Homeless People's Federation of the Philippines (HPFPI), each housing unit cost around **₱196,000.00** for a 28 square meter floor area. Most of the houses were built along the Mandaue area using ICEB blocks on a concept of Row Houses (These are the same concept as the British Terraced houses or the American Townhouses. These are the same concept as the British Terraced houses or the American Townhouses). The author also aims to reach more people with less, instead of reaching less people with overly expensive shelters. The shelter also offers a flexible solution which at the same time is moderate in cost. The use of the Hip Roof (*Quatro Aguas*) Design was also chosen in this study Figure 43. The proposed unit has a simple rectangular building form with hip roof at 30% to enable easy construction by the local workers.

Figure 43. The Hip Roof "Quatro Aguas" Design was used in this shelter

The short overhang design can effectively reduce the impacts of wind force that is the main cause of damage to the roof structure during a typhoon. The author likewise recognizes the importance of the Slanted Wall Design, as applied to *the I-Siguro Daan Shelter* series. As stated earlier, the slanted walls will make the interior appear larger while providing more storage. The unusable space where the walls meet the floor can be turned into storage spaces. The house can also be expanded horizontally to have more spaces if the need arise. In terms of added function as compared to the *I-Siguro Daan*

Shelter, the author added an outdoor toilet and kitchen. The outdoor toilet and kitchen are designed with a reinforced concrete frame combined with reinforced concrete slab, forming a safe box for occupants to shelter in case of extreme typhoon. The slanted roof encourages rainwater harvesting for the families. Rainwater can be collected for toilet use and/or for urban gardening systems. Building the toilet and kitchen with hollow blocks and reinforced concrete will also provide opportunity to incorporate training program for masons and thus improve the construction quality in the foreseeable future. The u*se* of local and readily available materials was also highlighted in this study. The main structural material used in the shelter is Coco Lumber Figure 44, which is very abundant in the Philippines, especially in the rural areas where the proposed shelter will be donated.

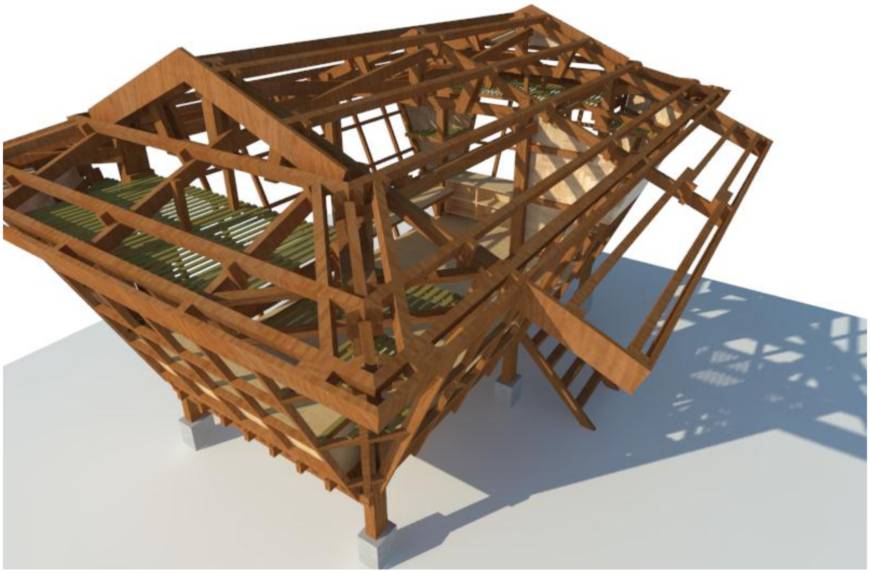


Figure 44. The use of Coco Lumber Framing as the main structural material for the Shelter.

Coco lumber is readily available especially during typhoons where most of the trees that fell are coconut trees. Additionally, coco lumber can be harvested using local manpower, thus aiding in self-recovery efforts of the affected population during typhoon. This will enhance local skills and capacities for carpentry. Finally, the shelter has high adaptability. The shelter can easily be relocated when necessary from unsafe to safe sites or if a more secured land is finally purchased. Thus, the shelter is adaptable to the different realities on the ground in the potential project areas like urban/rural locations, material availability or natural hazards.

5.1 The Main Shelter

The main shelter was designed as a safe typhoon shelter. It was designed with materials to protect the inhabitants and their property during a typhoon. The main shelter can have a lifespan of at least 8 to 10 years and offers a structure for future expansions. The main shelter is divided into two (2) parts, the *Living Module* and the *Sleeping Module*. The spaces on the walls serve as sleeping areas and or storage spaces. The main shelter can safely house a family of five (5) members, which is more than enough of the average size of a typical Filipino family (Steinberg, 2018), (Philippine Statistics Authority-2015 Census Population).

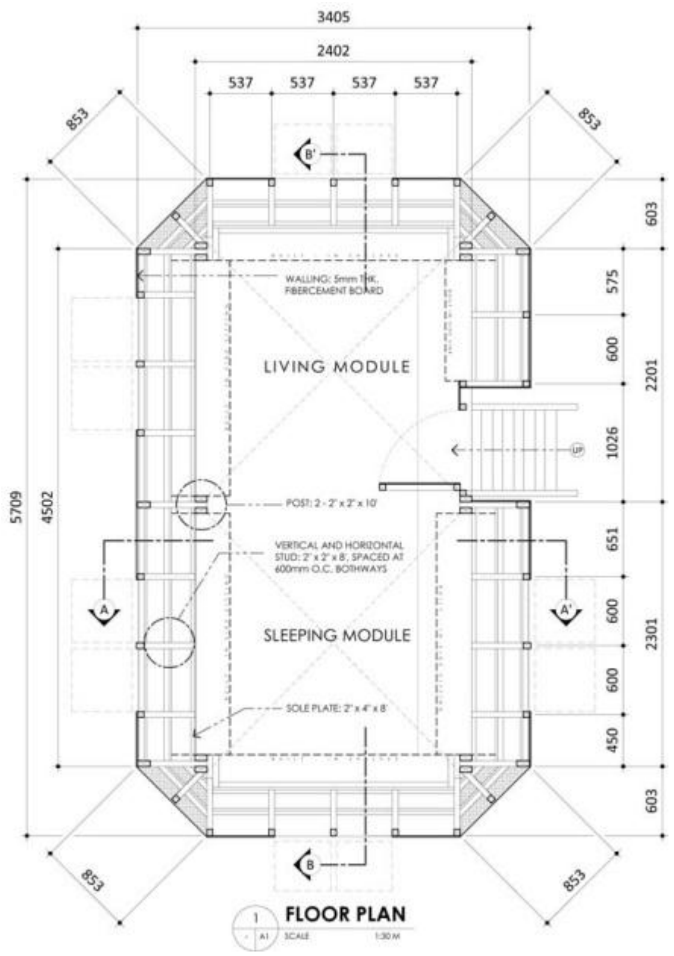


Figure 45. Floor Plan of the main Shelter Unit.

5.1.1 Materials

The wooden main structure of the shelter is composed of coco lumber. The substructure of the walls are made up of coco lumber, which is a locally known material and easy (and cheap) to purchase. The walls are made up of cement boards, *Amakan* or bamboo stripes to allow cross ventilation and thermal comfort during the day. The elevated floor is made up of fiber cement boards or bamboo stripes. Lockable windows made of wooden shutters enhance the cross ventilation and thermal comfort while fascia boards and short overhangs of the roof minimize the negative forces on the roof during a typhoon. The roof is made up of GI Corrugated sheets on coco purlins and reinforced with the traditional umbrella nails, which can help in securing the roof during a strong typhoon. The design of the shelter allows the construction to be entirely built in wood. However, as elevated wood constructions are very often not considered as “permanent” this might offer a solution where the land ownership is not yet final. The height of the floor level is 900mm but nevertheless can be adjusted according to the site location (Figure 47 and Figure 47). Depending on the site location and potential hazards of the area, the height of the post can be adjusted, especially in flood prone areas.

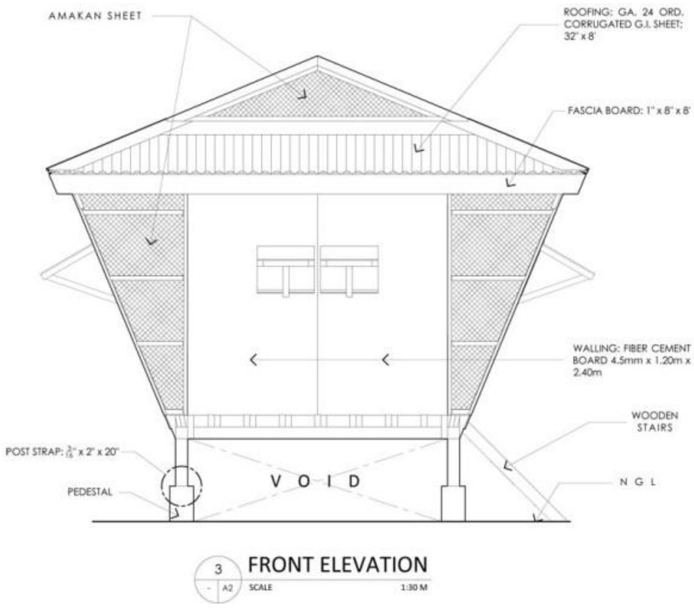


Figure 46. Front Elevation. Shown here with the elevated stilts and Amakan Sheet for added ventilation.

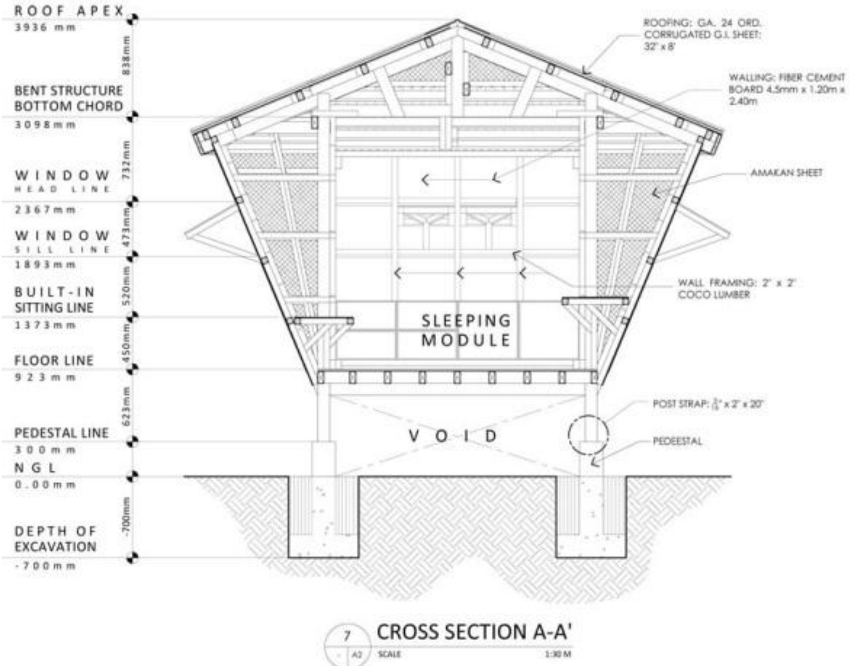


Figure 47. Cross Section of the Proposed Shelter.

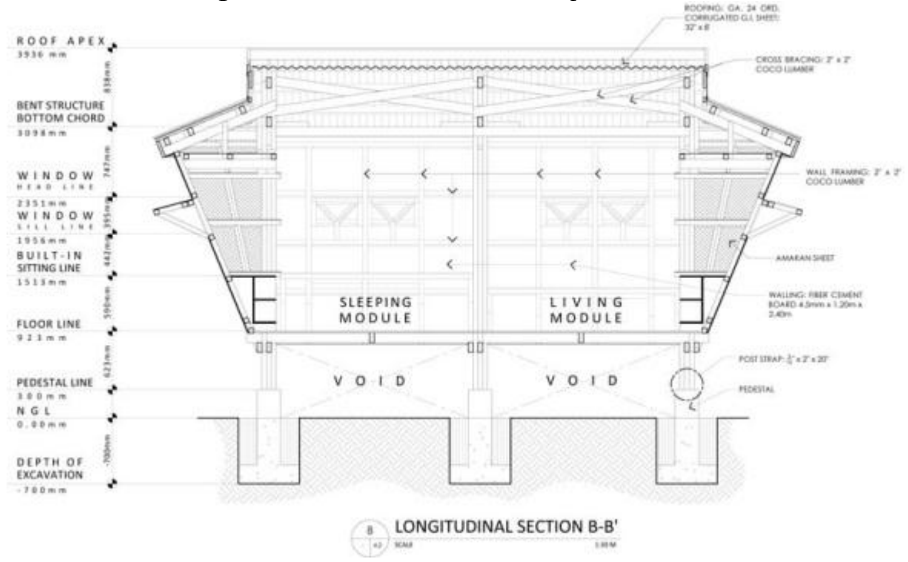


Figure 48. Longitudinal Cross Section of the Proposed Shelter.

Figure 49. Exterior Perspective of the Main Shelter

5.2 Kitchen and Toilet

The open Kitchen and Toilet is a separate unit which can be built in the backyard or placed within the boundaries of the shelter and can be accessible from the outside. These two functional units are positioned together to save on plumbing cost and share the same water system. Although it is a separate unit, the Kitchen and Toilet can be placed anywhere near the main shelter where privacy and or accessibility is important. From the elevation (Figure 51, Figure 52, Figure 53, Figure 54) the main material used in the toilet is concrete hollow blocks or CHB in the local dialect. These materials are easily available and are a popular choice of wall material in the Philippines due to their thermal properties and longevity. The roof is made of Galvanized Iron Sheets and painted white to reduce interior heating. The toilet is connected to a portable septic tank composed of two chambers. Detailed structural plans can be found in Chapter 8 of the References Section. Figure 55 shows the exterior perspective of the proposed Toilet and Kitchen.

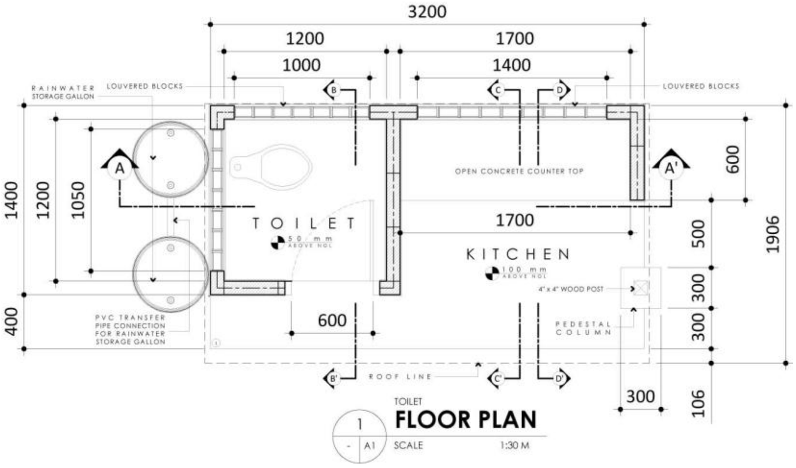


Figure 50. Toilet Floor Plan.

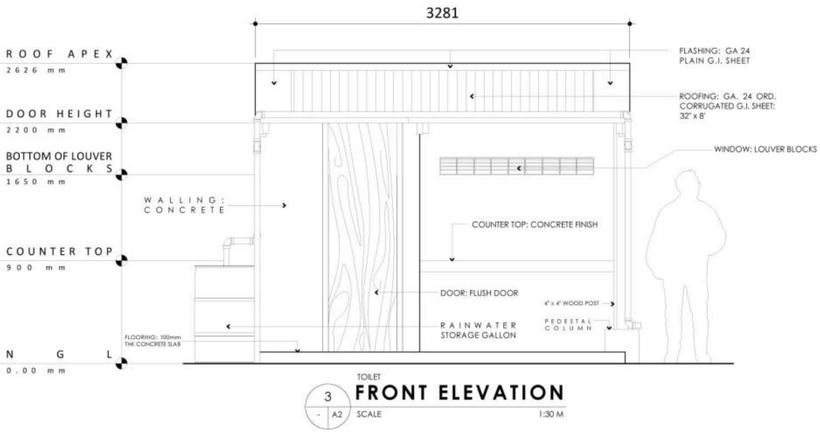


Figure 51. Toilet Front Elevation.

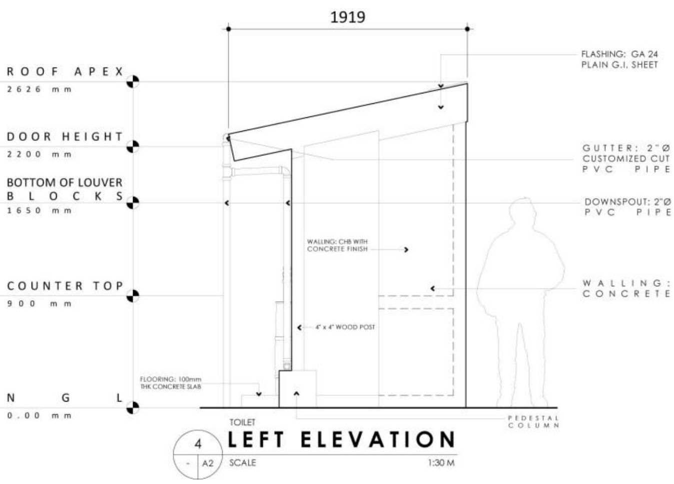


Figure 52. Toilet Left Elevation

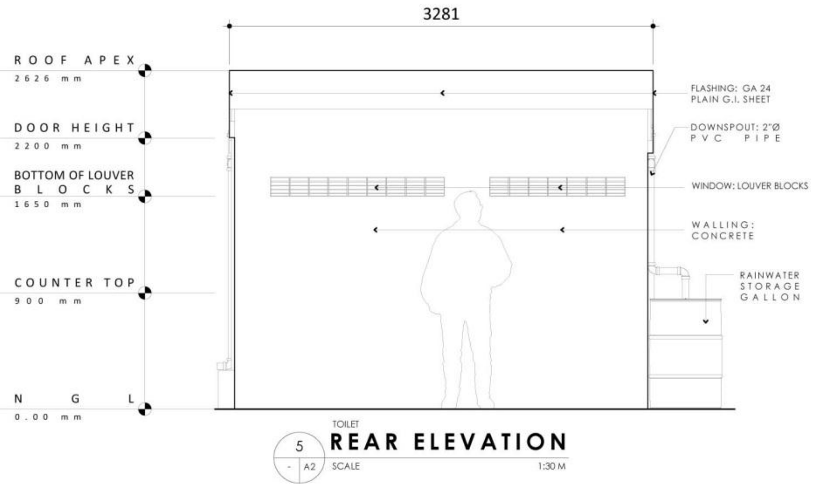


Figure 53. Toilet Rear Elevation.

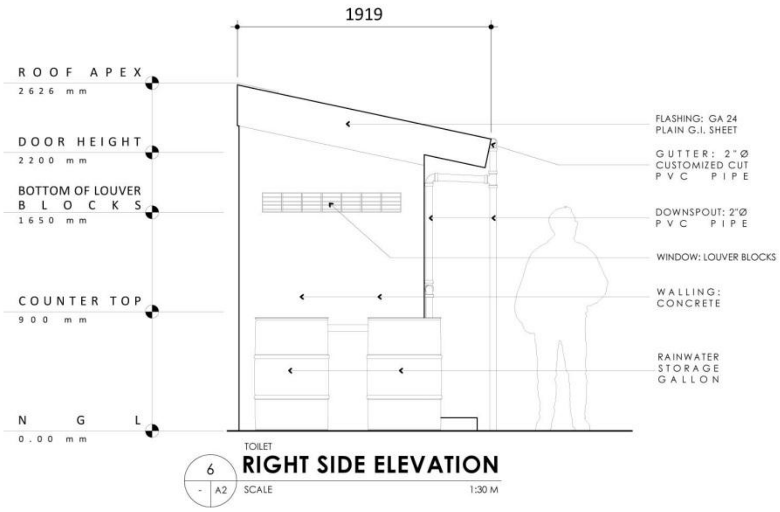


Figure 54. Toilet Right Side Elevation.

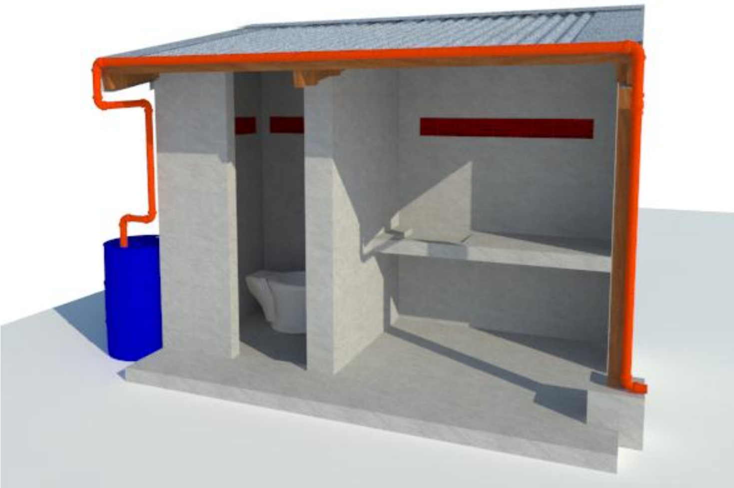


Figure 55. Exterior Perspective View of the Toilet and Kitchen area.

5.3 Rainwater Harvesting

Rooftop rainwater harvesting is the most common technique of rainwater harvesting for domestic consumption. In rural areas, this is most often done at small-scale. Rainwater harvesting can supplement water sources when they become scarce or are of low quality like brackish groundwater or polluted surface water in the rainy season. This is simple, low-cost technique that requires minimum specific expertise or knowledge and offers many benefits. Rainwater is collected on the roof and transported with gutters to a storage reservoir, where it provides water at the point of consumption for the families. In this design, the author proposed a rainwater harvesting system with the use of a simple PVC container which is popular in the Philippines Figure 56. Rainwater are collected in the gutter of the roof and then channelled down via pipes to a plastic water container tank near the comfort room.

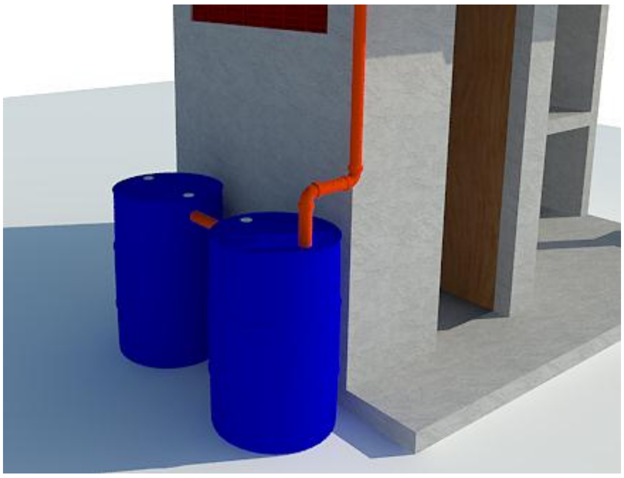


Figure 56. A simple rainwater harvesting system.

5.4 Cost Estimates

Estimated cost of the shelter is further discusses in this chapter. The cost of the shelter must be affordable to every Filipino household and is one of the main objectives of this study. As stated earlier, the main material used in the shelter is Coconut timber, which is a hardwood substitute from the coconut palm trees found in the Philippines. Locally it is called as Coconut Lumber and come sin different lengths and sizes. After every major typhoon, these palm trees are very abundant and can be found almost everywhere. It can be used to either improve of repair the shelter. The shelter is divided into two main components: (1) The main shelter, where the living and sleeping spaces are located and (2) the basic outdoor kitchen and Toilet, which is separate from the main shelter. The total costs of the Ocho Balay Typhoon Shelter are quantified as follows:

B1: Bill of materials and Estimate Cost (As of January 8, 2019) of the Main Shelter in Philippine currency:

Table 4. Foundations

Foundation:				
DESCRIPTION OF ITEM	**NUMBERS**	**UNIT**	**UNIT COST**	**TOTAL COST**
Pozzolanic Cement	6	bags	₱ 191.00	₱ 1,146.00
River Sand	0.5	m³	₱ 750.00	₱ 375.00
Gravel, 3/4" diameter	1	m³	₱ 750.00	₱ 750.00
10mm dia. X 6m x grade 33 deformed bar	8	length	₱ 140.00	₱ 1,120.00
8mm dia. X 6m x grade 33 deformed bar	4	length	₱ 91.00	₱ 364.00
GI tie wire #16	3	kg	₱ 56.70	₱ 170.10
Form Plywood: 1/4" x 4' x 8' ordinary	3	sheets	₱ 426.70	₱ 1,280.10
Form Lumber: 2" x 2" x 8' coco lumber (48 bf)	18	pcs	₱ 64.00	₱ 1,152.00
			Total Cost for Foundation:	₱ 6,357.20

Table 5. Bent Structure

Bent Structure (3 set):				
DESCRIPTION OF ITEM	**NUMBERS**	**UNIT**	**UNIT COST**	**TOTAL COST**
Post: 2" x 4" x 10' coco lumber (80 bf)	12	pcs	₱ 153.30	₱ 1,839.60
Truss/Girt: 2" x 4" x 8' coco lumber (96 bf)	18	pcs	₱ 122.70	₱ 2,208.60
Knee Brace: 2" x 4" x 8' coco lumber (32 bf)	6	pcs	₱ 122.70	₱ 736.20
Purlin Cleat: 2" x 2" x 10' coco lumber (13.33 bf)	4	pcs	₱ 76.70	₱ 306.80
			Total Cost for Bent Structure (3 set):	₱ 5,091.20

Table 6. Framings for the two modules @2.4m x 2.4

Framings (2 modules @2.4m x 2.4m each):				
DESCRIPTION OF ITEM	**NUMBERS**	**UNIT**	**UNIT COST**	**TOTAL COST**
End Girder: 2" x 4" x 8' coco lumber (21.33 bf)	4	pcs	₱ 122.70	₱ 490.80
End Girt: 2" x 4" x 8' coco lumber (21.33 bf)	4	pcs	₱ 122.70	₱ 490.80
Floor Joist: 2" x 4" x 8' coco lumber (96 bf)	18	pcs	₱ 122.70	₱ 2,208.60
Joist Cleat: 2" x 2" x 10' coco lumber (13.33 bf)	4	pcs	₱ 76.70	₱ 306.80
Bridging: 2" x 4" x 8' coco lumber (10.67 bf)	2	pcs	₱ 122.70	₱ 245.40
Purlin: 2" x 3" x 8' coco lumber (96 bf)	24	pcs	₱ 92.00	₱ 2,208.00
Fascia Board: 1" x 8" x 8' coco lumber (32 bf)	8	pcs	₱ 149.30	₱ 1,194.40
Fascia Trim: 1" x 2" x 8' coco lumber (5.33 bf)	4	pcs	₱ 30.70	₱ 122.80
Drip Cap: 1" x 6" x 8' coco lumber (64 bf)	2	pcs	₱ 112.00	₱ 224.00
Nailer: 1" x 3" x 8' coco lumber (8 bf)	4	pcs	₱ 46.00	₱ 184.00
Cross Bracing: 2" x 4" x 10' coco lumber (26.67 bf)	4	pcs	₱ 153.30	₱ 613.20
Stair: 2" x 4" x 8' coco lumber (16 bf)	3	pcs	₱ 122.70	₱ 368.10
			Total Cost for Framings (2 modules @2.4m x 2.4m each):	₱ 8,656.90

Table 7. Hardware

Hardware:				
DESCRIPTION OF ITEM	**NUMBERS**	**UNIT**	**UNIT COST**	**TOTAL COST**
*Hexagonal cap screw w/ nut & washer: 3/8" x 8"	12	pcs	₱ 40.25	₱ 483.00
*Hexagonal cap screw w/ nut & washer: 3/8" x 6"	51	pcs	₱ 8.25	₱ 420.75
*Hexagonal cap screw w/ nut & washer: 3/8" x 4"	18	pcs	₱ 6.25	₱ 112.50
*Machine bolt with nut & washer: 1/2" x 5"	6	pcs	₱ 27.00	₱ 162.00
*Machine bolt with nut & washer: 1/2" x 7"	6	pcs	₱ 32.00	₱ 192.00
**Post strap: 3/16" x 2" x 20"	6	pair	₱ 145.00	₱ 870.00
Common wire nail: 2 1/2"	6	kg	₱ 48.20	₱ 289.20
Common wire nail: 3"	6	kg	₱ 45.50	₱ 273.00
Concrete Nails 4"	6	kg	₱ 79.80	₱ 478.80
			Total Cost for Hardware:	₱ 3,281.25

Table 8. Roofing Enclosure

Roofing Enclosure:				
DESCRIPTION OF ITEM	NUMBERS	UNIT	UNIT COST	TOTAL COST
Corrugated GI Roofing: 32" x 8' x gauge 24	16	sheets	₱ 566.00	₱ 9,056.00
Umbrella nail (twisted)	4	kg	₱ 60.00	₱ 240.00
Plain GI Sheet: 4' x 10' x gauge 24 (for Ridgeroll)	2	sheets	₱ 865.00	₱ 1,730.00
Plain GI Sheet: 4' x 8' x gauge 24 (for Roof End Flashing)	2	sheets	₱ 865.00	₱ 1,730.00
			Total Cost for Roofing Enclosure:	₱ 12,756.00

Table 9. Flooring Enclosure

Flooring Enclosure:				
DESCRIPTION OF ITEM	NUMBERS	UNIT	UNIT COST	TOTAL COST
Bamboo strips: 8' (front and rear wing wall is included)	16	Bundles	₱ 100.00	₱ 1,600.00
Finishing Nails: 1-1/2"	6	kg	₱ 70.00	₱ 420.00
			Total Cost for Flooring Enclosure:	₱ 2,020.00

Table 10. Wall Framing and Enclosure

Wall Framing and Wall Enclosure:				
DESCRIPTION OF ITEM	NUMBERS	UNIT	UNIT COST	TOTAL COST
Studs: 2" x 2' x 8' coco lumber (120 bf)	60	pcs	₱ 64.00	₱ 3,840.00
Bamboo Woven Sheets (Amakan)	7	sheets	₱ 200.00	₱ 1,400.00
Hardiflex Fiber cement Board: 4.5mm x 1.20m x 2.40m	9	sheets	₱ 440.00	₱ 3,960.00
Common wire nail: 2 1/2"	6	kg	₱ 48.20	₱ 289.20
Common wire nail: 4"	6	kg	₱ 44.20	₱ 265.20
hardiflex Nail	2.5	kg	₱ 80.00	₱ 200.00
Metal Wall angle 10' (to be used as diagonal bracings)	10	length	₱ 100.00	₱ 1,000.00
			Total Cost for Wall Framing and Wall Enclosure:	₱ 10,954.40

Table 11. Door Frames

Door Frame:				
DESCRIPTION OF ITEM	NUMBERS	UNIT	UNIT COST	TOTAL COST
Loose Pin Butt Hinge 2" x 4" (for Door)	2	pair	₱ 70.00	₱ 140.00
Loose Pin Butt Hinge 1" x 3" (for 10 Awning windows)	10	pair	₱ 80.00	₱ 800.00
Door Handle	2	pc	₱ 500.00	₱ 1,000.00
Barrel Bolt 4"	1	pc	₱ 500.00	₱ 500.00
			Total Cost for Door Frame:	₱ 2,440.00

Table 12. Other materials

Others:				
DESCRIPTION OF ITEM	NUMBERS	UNIT	UNIT COST	TOTAL COST
G.I. Sink, small	1	pc	₱ 376.00	₱ 376.00
Washing machine Hose (to be used as drain pipe for sink)	1	length	₱ 240.00	₱ 240.00
			Total Cost for Others:	₱ 616.00
			Total Cost of Materials:	₱ 52,172.95

For the main shelter, the total cost was estimated to be around Fifty-Two Thousand One Hundred Seventy Two and Ninety Five Centavos (P52, 172.95).

B2: Bill of materials and Estimate Cost of the additional Inclined Wall Feature of the End Walls:

Table 13. Kings Rafter

Kings Rafter:				
DESCRIPTION OF ITEM	NUMBERS	UNIT	UNIT COST	TOTAL COST
Bottom Chord: 2"x 4" x 8' coco lumber	3	pcs	₱ 122.70	₱ 368.10
Top Chord: 2"x 4" x 8' coco lumber	2	pcs	₱ 122.70	₱ 245.40
Supporting Anchor: 2"x 4" x 8' coco lumber	2	pcs	₱ 122.70	₱ 245.40
Rafter Cleats: 2"x 2" x 8' coco lumber	2	pcs	₱ 64.00	₱ 128.00
			Total Cost for Kings Rafter:	₱ 986.90

Table 14. Wall Framing and Enclosure

Wall Framing and Wall Enclosure:				
DESCRIPTION OF ITEM	NUMBERS	UNIT	UNIT COST	TOTAL COST
Studs: 2"x 2" x 8' coco lumber	17	pcs	₱ 64.00	₱ 1,088.00
Floor Joist Extension: 2"x 4" x 8' coco lumber	2	pcs	₱ 122.70	₱ 245.40
Wall Framing Anchor: 2"x 4" x 8' coco lumber	4	pcs	₱ 122.70	₱ 490.80
Hardiflex Fiber Cement Board: 4.5mm x 1.20m x 2.40m	4	sheets	₱ 440.00	₱ 1,760.00
Common wire nail: 2 1/2"	2	kg	₱ 48.20	₱ 96.40
Common wire nail: 4"	2	kg	₱ 44.20	₱ 88.40
hardiflex Nail	1.5	kg	₱ 80.00	₱ 120.00
			Total Cost for Wall Framing and Wall Enclosure:	₱ 3,889.00

Table 15. Roof Framing and Enclosure

Roof Framing and Roof Enclosure:				
DESCRIPTION OF ITEM	NUMBERS	UNIT	UNIT COST	TOTAL COST
Top Chords: 2"x 4" x 8' coco lumber	4	pcs	₱ 122.70	₱ 490.80
Purlins: 2"x 3" x 8' coco lumber	9	pcs	₱ 92.00	₱ 828.00
Fascia Board: 1" x 8" x 8' coco lumber	4	pcs	₱ 149.30	₱ 597.20
Cleats: 2" x 2" x 8' coco lumber	2	pcs	₱ 64.00	₱ 128.00
Corrugated GI Roofing: 32" x 8' x gauge 24	6	sheets	₱ 566.00	₱ 3,396.00
Umbrella Nail (twisted)	2	kg	₱ 60.00	₱ 120.00
Plain GI Sheet: 4' x 10' x gauge 24 (for Ridgeroll)	2	sheets	₱ 865.00	₱ 1,730.00
Plain GI Sheet: 4' x 8' x gauge 24 (for Roof End Flashing)	2	sheets	₱ 865.00	₱ 1,730.00
			Total Cost for Roof Framing and Roof Enclosure:	₱ 9,020.00

Table 16. Chamfered Wall

Chamfered Wall:				
DESCRIPTION OF ITEM	NUMBERS	UNIT	UNIT COST	TOTAL COST
Studs: 2"x 2" x 8' coco lumber	11	pcs	₱ 64.00	₱ 704.00
Bamboo Woven Sheets (Amakan)	5	pcs	₱ 200.00	₱ 1,000.00
			Total Cost for Chamfered Wall:	₱ 1,704.00
			Total Cost of Additional Inclination of End Walls:	₱ 15,599.90
			Grand Total Cost of Octa - Transitional Shelter:	**₱ 67,772.85**

Table 17. Extended Roof

Additional Features for Sheme 4 Transitional Shelter - EXTENDED ROOF AT ONE SIDE				
Extended Roof:				
DESCRIPTION OF ITEM	***NUMBERS***	***UNIT***	***UNIT COST***	***TOTAL COST***
Top Chords: 2"x 4" x 8' coco lumber	2	pcs	₱ 122.70	₱ 245.40
Purlins: 2"x 3" x 8' coco lumber	4	pcs	₱ 92.00	₱ 368.00
Fascia Board: 1" x 8" x 8' coco lumber	3	pcs	₱ 149.30	₱ 447.90
Cleats: 2" x 2" x 8' coco lumber	4	pcs	₱ 64.00	₱ 256.00
Corrugated GI Roofing: 32" x 8' x gauge 24	8	sheets	₱ 566.00	₱ 4,528.00
Umbrella Nail (twisted)	1	kg	₱ 60.00	₱ 60.00
Roof Painting - White (Total area Including Toilet)	3	gallon	₱ 1,000.00	₱ 3,000.00
	Total Cost for Extended Roof at One Side:			₱ 8,905.30
	Grand Total Cost of Octa - Transitional Shelter Including Extended Roof at One Side:			**₱ 76,678.15**

The grand total cost for the main shelter (with the chamfered wall) and Extended Wall is estimated to be around Seventy Six Thousand Six Hundred Seventy Eight and Fifteen Centavos (P76, 678.15) or US$ 1,463.75 as of January 8, 2019.

B3: Bill of materials and Estimate Cost of the additional Toilet and Kitchen with Rain Water Harvesting Feature.

Table 18. Concrete Wall

Concrete Wall:				
DESCRIPTION OF ITEM	***NUMBERS***	***UNIT***	***UNIT COST***	***TOTAL COST***
Concrete Hollow Block (CHB) - 4"	268	pcs	₱ 15.00	₱ 4,020.00
10mm dia. X 6m x grade 33 deformed bar for Horizontal run spaced at 600mm	5	length	₱ 140.00	₱ 700.00
10mm dia. X 6m x grade 33 deformed bar for Vertical rise spaced at 600mm	8	length	₱ 140.00	₱ 1,120.00
Pozzolanic Cement	10	bags	₱ 191.00	₱ 1,910.00
River Sand	8	m^3	₱ 750.00	₱ 6,000.00
GI tie wire #16	1	kg	₱ 56.70	₱ 56.70
	Total Cost for Toilet Concrete Wall:			₱ 13,806.70

Table 19. Concrete Pedestal

Concrete Pedestal:				
DESCRIPTION OF ITEM	***NUMBERS***	***UNIT***	***UNIT COST***	***TOTAL COST***
Pozzolanic Cement	2	bags	₱ 191.00	₱ 382.00
River Sand	0.09	m^3	₱ 750.00	₱ 67.50
Gravel, 3/4" diameter	0.171	m^3	₱ 750.00	₱ 128.25
10mm dia. X 6m x grade 33 deformed bar	2	length	₱ 140.00	₱ 280.00
8mm dia. X 6m x grade 33 deformed bar	1	length		₱ -
Wooden Post: 4" x 4" x 8'	1	pcs		₱ -
	Total Cost for Toilet Concete Pedestal:			₱ 857.75

Table 20. Hardware Materials

Hardware:				
DESCRIPTION OF ITEM	*NUMBERS*	*UNIT*	*UNIT COST*	*TOTAL COST*
Post strap: 3/16" x 2" x 20"	1	pair	₱ 145.00	₱ 145.00
Machine bolt with nut & washer: 1/2" x 5"	2	pcs	₱ 27.00	₱ 54.00
Hexagonal cap screw w/ nut & washer: 3/8" x 8"	2	pcs	₱ 40.25	₱ 80.50
Concrete Nails 4"	2	kg	₱ 79.80	₱ 159.60
		Total Cost for Toilet Hardwares:		₱ 439.10

Table 21. Roof Framing and Roofing Enclosure

Roof Framing and Roofing Enclosure:				
DESCRIPTION OF ITEM	*NUMBERS*	*UNIT*	*UNIT COST*	*TOTAL COST*
Rafter: 2" x 4" x 10' (13.33bf)	2	pcs	₱ 153.30	₱ 306.60
Purlins: 2" x 3" x 8' (24bf)	6	pcs	₱ 92.00	₱ 552.00
Cleats: 2" x 2" x 8' (2.67bf)	1	pcs	₱ 64.00	₱ 64.00
Corrugated GI Roofing: 32" x 8' x gauge 24	6	sheets	₱ 566.00	₱ 3,396.00
Umbrella nail (twisted)	2	kg	₱ 60.00	₱ 120.00
Plain GI Sheet: 4' x 8' x gauge 24 (for Roof End Flashing)	2	sheets	₱ 865.00	₱ 1,730.00
		Total Cost for Toilet Roof Framing and Roofing Enclosure:		₱ 6,168.60

Table 22. Other Materials

Others:				
DESCRIPTION OF ITEM	*NUMBERS*	*UNIT*	*UNIT COST*	*TOTAL COST*
Gutter: 2" dia. PVC Pipe	3	length	₱ 150.00	₱ 450.00
90° - 2" dia. PVC Elbow Plumbing fitting	8	pcs	₱ 25.00	₱ 200.00
2" dia. PVC Tee Plumbing Fitting	1	pcs	₱ 25.00	₱ 25.00
Louver Blocks	23	pcs	₱ 50.00	₱ 1,150.00
		Total Cost for Toilet - Others:		₱ 1,825.00
		Total Cost for Toilet:		₱ 23,097.15
		Grand Total Cost Including Extended Roof at One Side and toilet:		**₱ 99,775.30**

Therefore, the grand total cost of the proposed *Ocho Balay* Typhoon Shelter is estimated to be around Ninety Nine Thousand Seven Hundred Seventy Seven and Thirty Centavos (P99, 775.30) or **US$ 1, 904.66** as of January 8, 2019.

5.5 Local Materials, Labour and Technology

The “3L” (Local Materials, Local Labour, and Local Technology) approach has been used in the design of the Ocho Balay shelter. Additionally, the design is being sensitive to the following three (3) aspects, the Environmental Dimension, Economic Dimension and the Social Dimension. In environmental dimension, the environmental impacts of the houses are minimized. Good thermal and day lighting performance guaranteed low operating energy consumption, thus reducing energy cost as possible. In economic dimension, the construction and operating costs have been minimized to be affordable to families. The community can construct, upgrade or modify the shelters mainly with local manpower and simple tools that are easily available. They could easily improve and maintain the Ocho Balay shelters in the future and exploit this technology as a means of earning their livelihood. In social dimension, local residents are fully engaged in the entire process of reconstruction. Local government and resources are used to support rural reconstruction during a disaster.

5.6 Design Summary

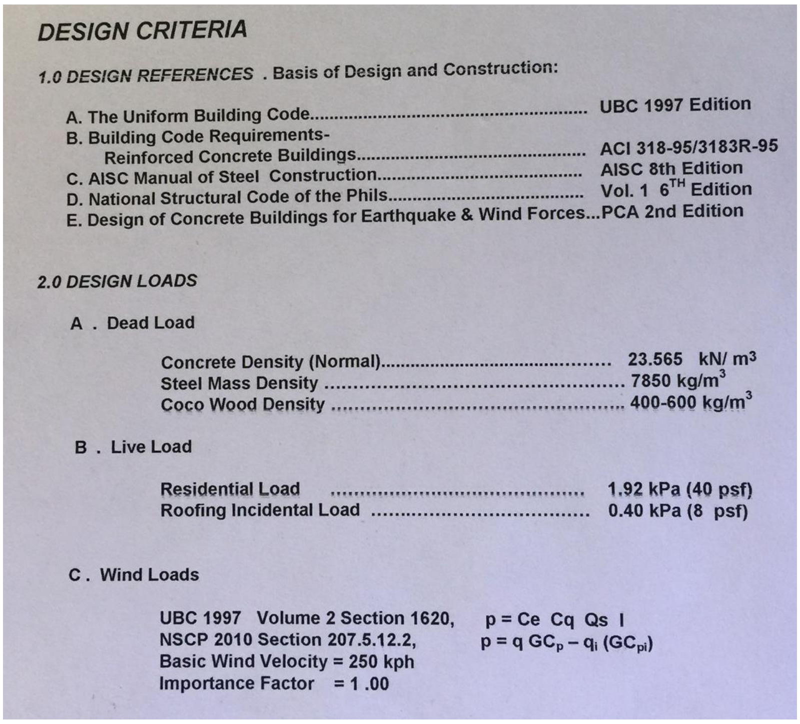
Presented in this chapter are the design summary and the breakdown of cost for the Main Shelter and Toilet/Kitchen:

Table 23. Design Summary and Estimated Cost

<table>
<tr><th>Structure</th><th>Total Area (sq.m.)</th><th>Basic Materials Used</th><th>Height (meters)</th><th>Cost (₱)</th></tr>
<tr><td>Main Shelter</td><td>19</td><td>Coco Lumber, Amakan, Corrugated GI Roof, Metal Sole Plates, Fiber Cement Boards, Metal Post Straps</td><td>2.2</td><td>76,675.15 (US$ 1,456.94)</td></tr>
<tr><td>Toilet</td><td>6</td><td rowspan="2">Concrete CHB, Corrugated GI Roof, 200L Plastic Water Tanks, PVC Pipes, Louvered Concrete Blocks</td><td>2.2</td><td rowspan="2">23,097.15 (US$ 438.88)</td></tr>
<tr><td>Kitchen</td><td>2.1</td><td>2.2</td></tr>
</table>

5.7 Structural Wind Load Analysis

The proposed Bent Structure, which is the main structural reinforcement of the shelter, was subjected to structural and wind load analysis using STAAD pro Version 2007 (build 04). STAAD Pro was used because it is the standard program used in the country for research engineers and structural analysis. The author has requested Engineer Wallace Lestane, a well-known structural engineer in the country, to find the maximum wind velocity that the Bent Structure can withstand. Using the National Structural Building Code of the Philippines as reference, the following data are the results of the analysis:



DESIGN CRITERIA

1.0 DESIGN REFERENCES . Basis of Design and Construction:

A. The Uniform Building Code.. UBC 1997 Edition
B. Building Code Requirements-
Reinforced Concrete Buildings... ACI 318-95/3183R-95
C. AISC Manual of Steel Construction... AISC 8th Edition
D. National Structural Code of the Phils....................................... Vol. 1 6TH Edition
E. Design of Concrete Buildings for Earthquake & Wind Forces...PCA 2nd Edition

2.0 DESIGN LOADS

A . Dead Load

Concrete Density (Normal).. 23.565 kN/ m^3
Steel Mass Density .... 7850 kg/m^3
Coco Wood Density .... 400-600 kg/m^3

B . Live Load

Residential Load .... 1.92 kPa (40 psf)
Roofing Incidental Load .... 0.40 kPa (8 psf)

C . Wind Loads

UBC 1997 Volume 2 Section 1620, $p = Ce\ Cq\ Qs\ I$
NSCP 2010 Section 207.5.12.2, $p = q\ GC_p - q_i\ (GC_{pi})$
Basic Wind Velocity = 250 kph
Importance Factor = 1 .00

Figure 57. Wind Velocity and Load Analysis Page 1

3.0 MATERIALS

A. Concrete . Minimum 28 days Ultimate Compressive Strength

Footings .... 3,000 psi (20.7 MPa)
Column .... 3,000 psi (20.7 MPa)

B . Reinforcing Steels.

ASTM A615
Grade 60, Fy= 414 Mpa, deformed bars for 25 mm0 above
Grade 40, Fy = 275 MPa, deformed bars for 20mm0 below
Stirrups @ Tie Bars shall have a minimum
Fy = 227 MPa , deformed bars

C. Coco Wood

Medium Grade Coco Wood
Stress Grade 80%

Modulus of Rupture in bending	= 63 MPa
Modulus of Elasticity	= 7,116 MPa
Compression parallel to grain	= 38 MPa
Compression perpendicular to grain	= 3.4 MPa
Shear parallel to grain	= 0.67 MPa

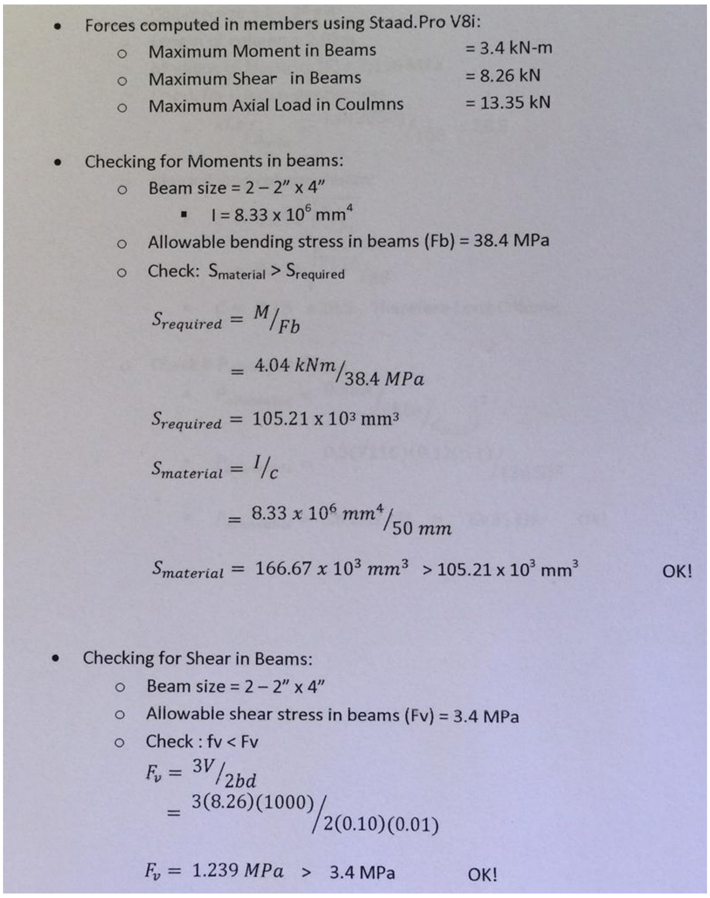
4.0 FOUNDATION

Assumed Allowable Soil Bearing Capacity = 3000 psf (144 kPa)
Assumed Soil unit Weight = 105 PCF
Internal Friction Angle = 30 deg. (Fill Materials)
= 0 deg. (Original soil)

Approved By:

Wallace D . Lestano, M.ASEP
Structural Design Engineer
Reg . No . : 65786
PTR N0. : 406129
Place ; Cebu City
Date : 1-07-2014
R . C. No. : 10316083
Tin : 135-439-219

Figure 58. Wind Velocity and Load Analysis Page 2



- Forces computed in members using Staad.Pro V8i:
  - Maximum Moment in Beams = 3.4 kN-m
  - Maximum Shear in Beams = 8.26 kN
  - Maximum Axial Load in Coulmns = 13.35 kN
- Checking for Moments in beams:
  - Beam size = 2 – 2" x 4"
    - $I = 8.33 \times 10^6 \ mm^4$
  - Allowable bending stress in beams (Fb) = 38.4 MPa
  - Check: $S_{material} > S_{required}$

$$S_{required} = M/_{Fb}$$

$$= 4.04 \ kNm/_{38.4 \ MPa}$$

$$S_{required} = 105.21 \times 10^3 \ mm^3$$

$$S_{material} = I/_{c}$$

$$= 8.33 \times 10^6 \ mm^4/_{50 \ mm}$$

$$S_{material} = 166.67 \times 10^3 \ mm^3 > 105.21 \times 10^3 \ mm^3 \quad \text{OK!}$$

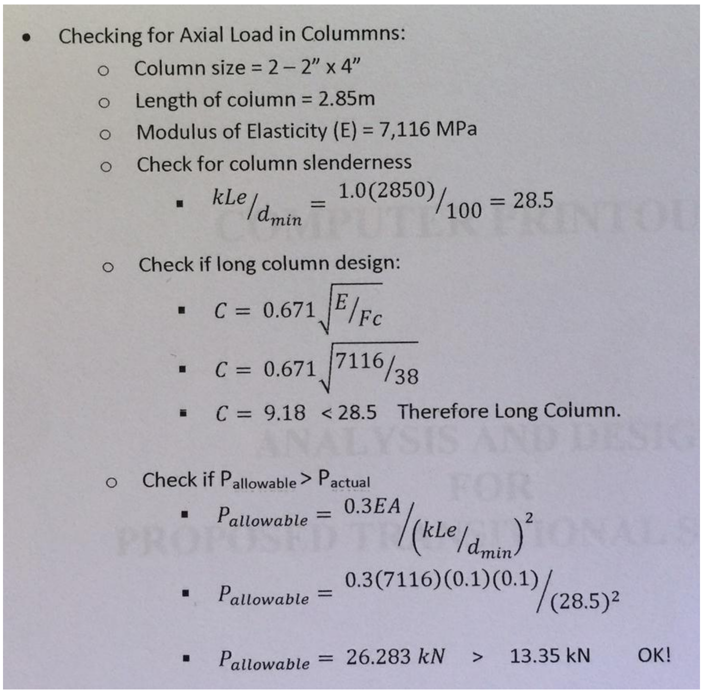
- Checking for Shear in Beams:
  - Beam size = 2 – 2" x 4"
  - Allowable shear stress in beams (Fv) = 3.4 MPa
  - Check : fv < Fv

$$F_v = 3V/_{2bd}$$

$$= 3(8.26)(1000)/_{2(0.10)(0.01)}$$

$$F_v = 1.239 \ MPa > 3.4 \ MPa \quad \text{OK!}$$

Figure 59. Wind Velocity and Load Analysis Page 3



- Checking for Axial Load in Colummns:
  - Column size = 2 – 2" x 4"
  - Length of column = 2.85m
  - Modulus of Elasticity (E) = 7,116 MPa
  - Check for column slenderness
    - $kLe/_{d_{min}} = 1.0(2850)/_{100} = 28.5$
  - Check if long column design:
    - $C = 0.671\sqrt{E/_{Fc}}$
    - $C = 0.671\sqrt{7116/_{38}}$
    - $C = 9.18 < 28.5$ Therefore Long Column.
  - Check if $P_{allowable} > P_{actual}$
    - $P_{allowable} = 0.3EA/_{\left(kLe/_{d_{min}}\right)^2}$
    - $P_{allowable} = 0.3(7116)(0.1)(0.1)/_{(28.5)^2}$
    - $P_{allowable} = 26.283 \ kN > 13.35 \ kN$ OK!

Figure 60. Wind Velocity and Load Analysis Page 4

In Figure 57, the maximum wind velocity that the Bent Structures can withstand is 250 kph. According to the latest documents from Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), the highest category for a Super Typhoon is more than 220 kph (kilometres-per-hour). The analysis proves that the proposed shelter is safe, especially during the onslaught of a super typhoon. However, this does not mean that other parts of the shelter are immune to the onslaught of a super typhoon. The structure needs to be further analysed in a wind tunnel scenario and computer simulations can also help in the analysis. These tools are, however, not available in our country and can be used for further studies in the future.

5.8 Design assessment: *I-Siguro Transitional* and the Ocho Balay Permanent Shelter

In this sub-chapter, the author presents the design assessment between the *I-Siguro Daan* Transitional Shelter and the proposed Ocho Balay Permanent Shelter:

Table 24. Design Assessment of the I-Siguro Daan and Ocho Balay

Structure	**Total Area (sq.m.)**	**Basic Materials Used**	**Kitchen/Toilet**	**Ventillation**	**Window Type**	**Roof Type**	**Wall Type**	**Initial Cost**
I-Siguro Daan Shelter	12	Coco lumber, Amakan, Corrugated GI, Post Strap, Bamboo Slits for slab	none	4 sides, bottom and top	Shutter	Hip Roof	4 sided slanted	US$ 1, 000.00 (As of 2013)
Ocho Balay Shelter	19	Coco lumber, Amakan, Corrugated GI, Post Strap, Concrete for slab, PVC	available	8 sides, bottom and top	Shutter	Gable Roof (recommended by studies)	8 sided slanted	US$ 1, 904.66 (As of 2019)

		tubes, PVC water collection units						

Aside from the obvious design difference, the Ocho Balay also has provisions for a rain water collection unit, flexibility in the location of the kitchen and toilet and an increased number of storage areas due to the eight (8) sided walls.

Chapter 6. CONCLUSIONS AND THESIS STATEMENTS

6.1 Conclusions

An increase in the severity of natural disasters combined with an increase in human populations and high density urban populations specifically, results in large numbers of displaced peoples following a natural disaster that strikes an urban region. Natural disasters continue to leave thousands of Filipino people homeless every year, forcing them to seek refuge without any other alternatives. On many occasions, the local government cannot cope with the affected families and therefore limiting their resources. In addition to this, the difficulties to sustain these families in a dignified way, becomes increasingly complex, leading to the collapse of traditional solutions and strategies. As architects and designers, is at this moment when innovation and creativity play an important role in construction practices, ultimately creating a quicker and more efficient construction model that can be replicated after natural disasters. In this study, the author proposed the *Ocho Balay*, a typhoon shelter that is within reach of more people, both socio-economically and geographically. This shelter will hopefully be a stepping stone on the journey towards a brighter future for the beneficiaries in the Filipino's pursuit of a better quality of life, especially after the traumatizing effects of a natural disaster.

6.2 Thesis Statements

1. The *Bent Structure* main structural system, made of coco lumber, was used in the proposed typhoon shelter. The resulting design will result in slanted walls on the exterior. The slanted walls will make the interior appear larger while providing more storage. The resulting design made the interior more flexible which can be adapted

to new needs and allowing these spaces to be developed by division. Therefore the families control the expansion of their housing based on their needs and resources.

2. The use of Local Materials, Local Labour, and Local Technology has been used in the design of the shelter. Furthermore, the design is being sensitive to the Environmental Dimension, Economic Dimension and the Social Dimension aspects of the community and users. This was designed after an extensive analysis of local architecture while respecting the local traditions and culture.
3. The use of onsite materials is an affordable and environmentally sustainable solution; reducing transport, fuel and construction costs while providing work opportunities for the families, thus improving the local economy.
4. The shelter also encourages the architects and beneficiaries to develop a flexible design process which enabled occupants to play an active part in the design of their own homes.
5. In social dimension, local residents are fully engaged in the entire process of reconstruction. The design allows empowerment to the community as the families can construct, upgrade or modify the shelters mainly with local manpower and simple tools that are easily available. They could easily improve and maintain the Ocho Balay shelters in the future and exploit this technology as a means of earning their livelihood.
6. Involving the population in the house construction and change of the neighborhood morphology enables the adaptation to the population real needs and develops the strong sense of belonging and affection which is fundamental to the well-being of the residents.
7. Rainwater harvesting was added as a design feature in the Ocho Balay Shelter. This can supplement water sources when they become scarce or are of low quality like

brackish groundwater or polluted surface water in the rainy season. This is a simple, low-cost technique that requires minimum specific expertise or knowledge and offers many benefits.

8. The estimated cost for each unit is **₱99,775.30** (**US$ 1,904.66** as of January 8, 2019) with a floor area of 19 square meters for a family of five (5). Making each unit affordable will obviously allow for more housing unit to be built and therefore will result in more beneficiaries having a shelter of their own.
9. The resulting permanent shelter is therefore the most affordable while providing sufficient protection from incoming typhoons. The proposed shelter can significantly improve the economic and social status for a family of five (5) while providing opportunities for further improvement.
10. Wind velocity analysis has shown that the Bent Structure, the basic structural unit of the shelter, can withstand a typhoon of 250 kph (kilometres-per-hour). The analysis was done using a simulation program and the National Structural Building Code of the Philippines as reference.
11. According to the latest documents from Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), the highest category for a Super Typhoon is more than 220 kph (kilometres-per-hour).
12. In contrast to the I-Siguro-Daan Transitional Shelter, the proposed Ocho Balay further added various design features that increases both the functionality and aesthetics. The final design was the result of painstaking studies and surveys of the previous users and beneficiaries. The resulting design was a careful analysis of the end users, which is one of the unique features of the shelter.

Chapter 7. RECOMMENDATIONS FOR FUTURE STUDIES

Housing is perhaps the biggest problem of actual societies since it is a basic human need. This is especially relevant during the advent of natural disasters, such as the once-in-a-lifetime-anomaly-of-nature, typhoon Haiyan. Because of this, the importance of this study cannot be undervalued and thus, the design of the proposed Ocho Balay must be in continual improvement in order to provide quality and durable shelters for the rural areas of the Philippines. The author recommends further study through the use of several scientific analyses. For example, the resiliency can be quantified through actual experiments of the structural analysis of different types of materials, in this case, the use of coco lumber. There is a need for further validation on the load bearing structure (civil engineering analysis) which can result in a huge potential that can save materials and provide high resiliency against typhoons. There is also a need to develop a climate responsive shelter and energy calculations and simulations can be quite useful. Other ccomputer simulations can also be used in this analysis and must be further verified through actual real world model. Thus, the design and effectiveness of the shelter has an inherent capacity for further development.

Chapter 8. REFERENCES

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Murray, L. (2015). Sheltering from disaster. Engineering & Technology, 10(1), 58-61.
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APPENDICES

A. Detailed Plans of the proposed Typhoon Shelter

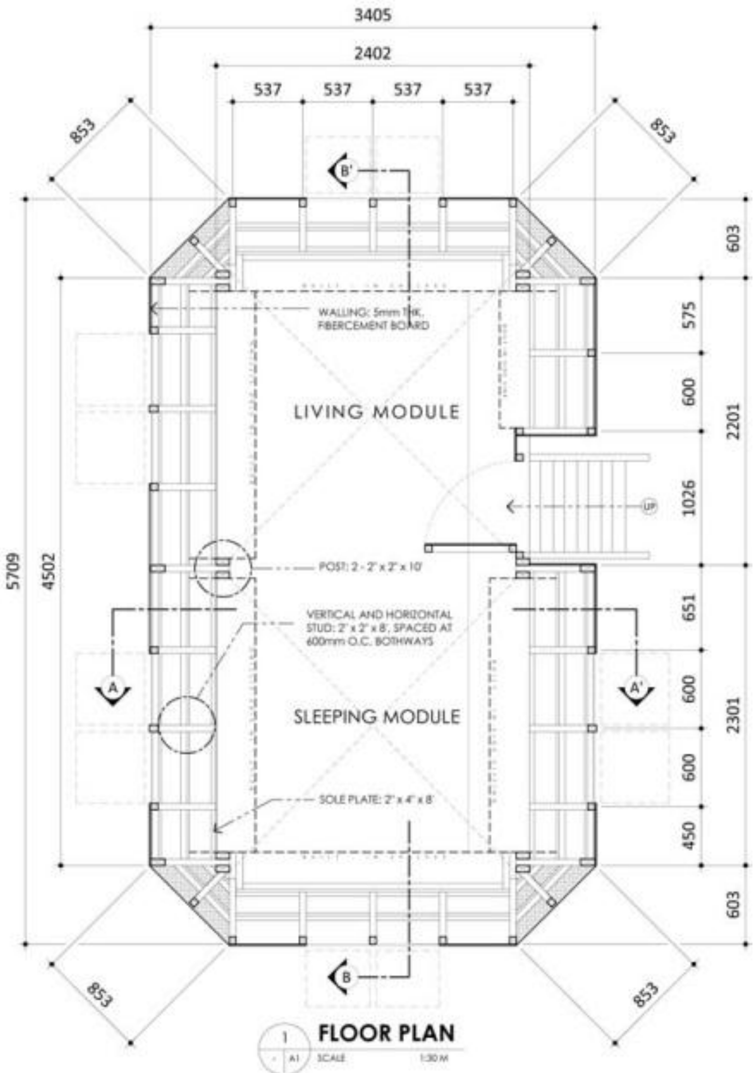

Image 1. Floor Plan.

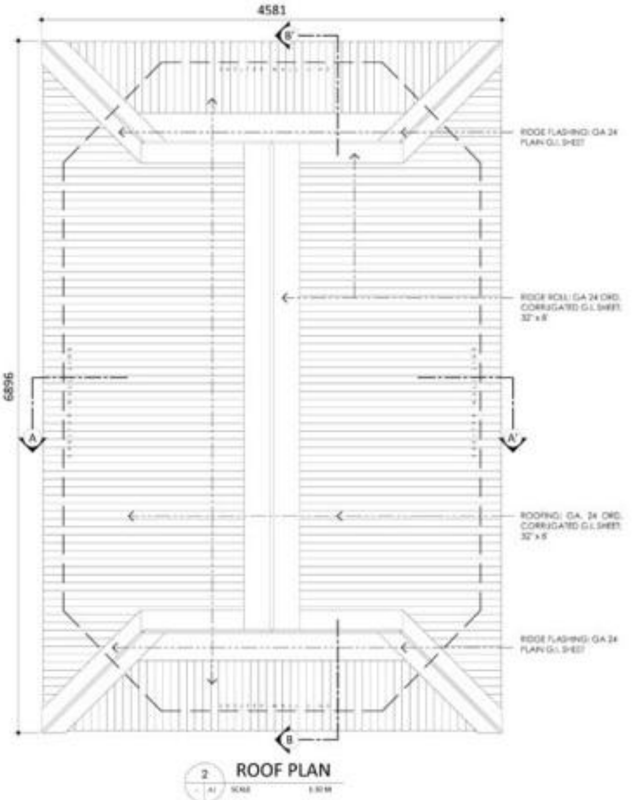

Image 2. Roof Plan.

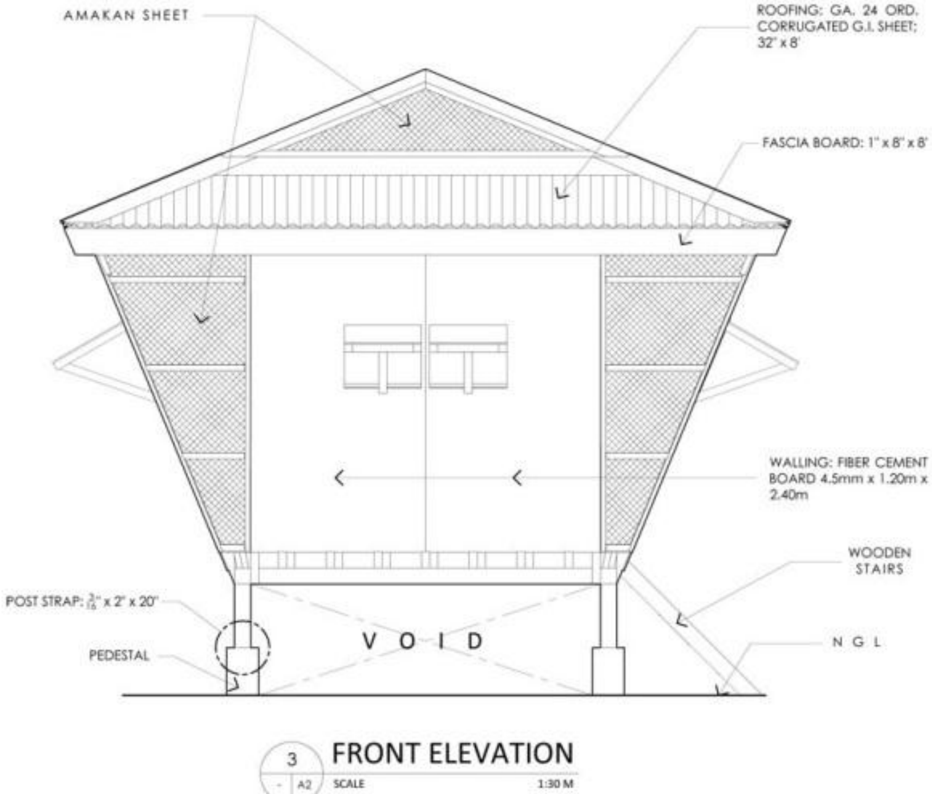

Figure 61. Front Elevation.

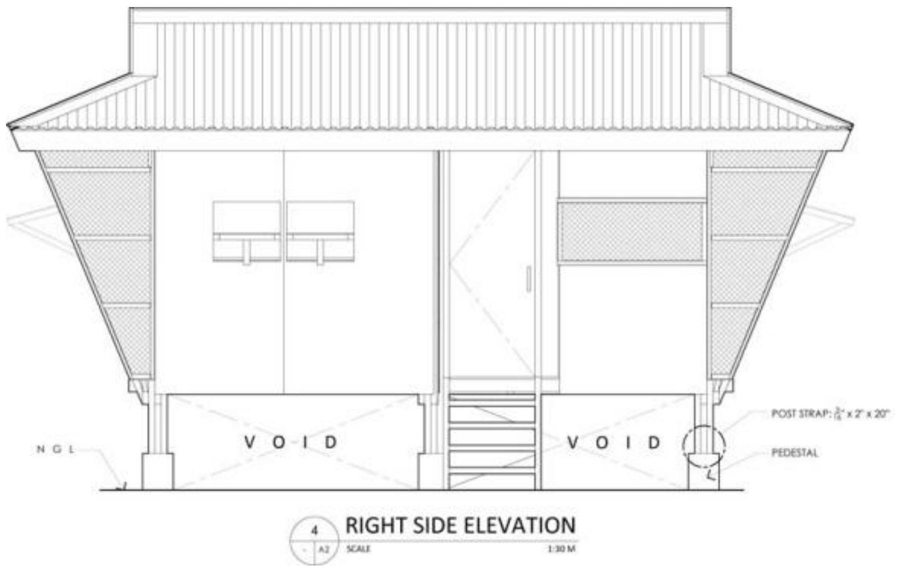

Figure 62. Right Side Elevation.

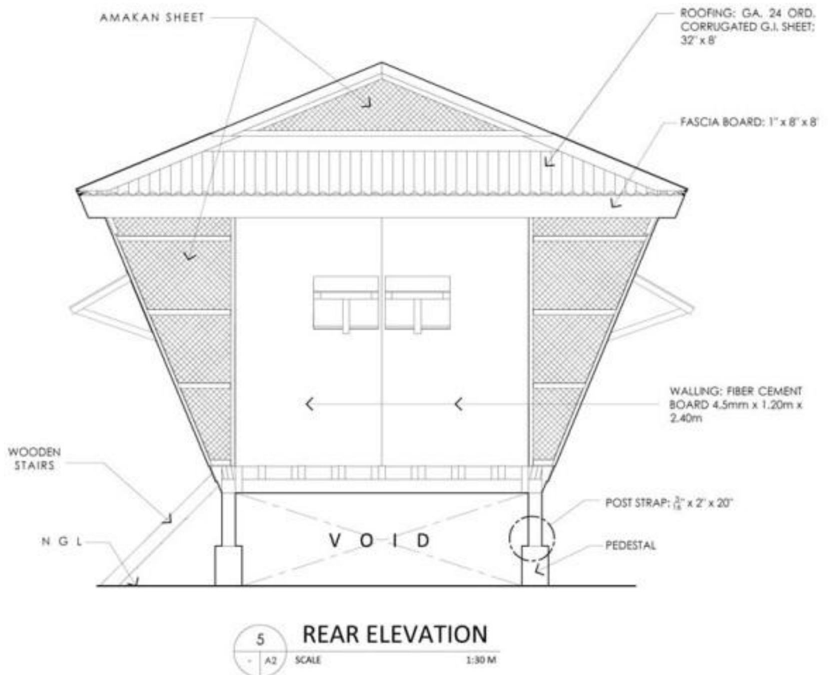

Figure 63. Rear Elevation.

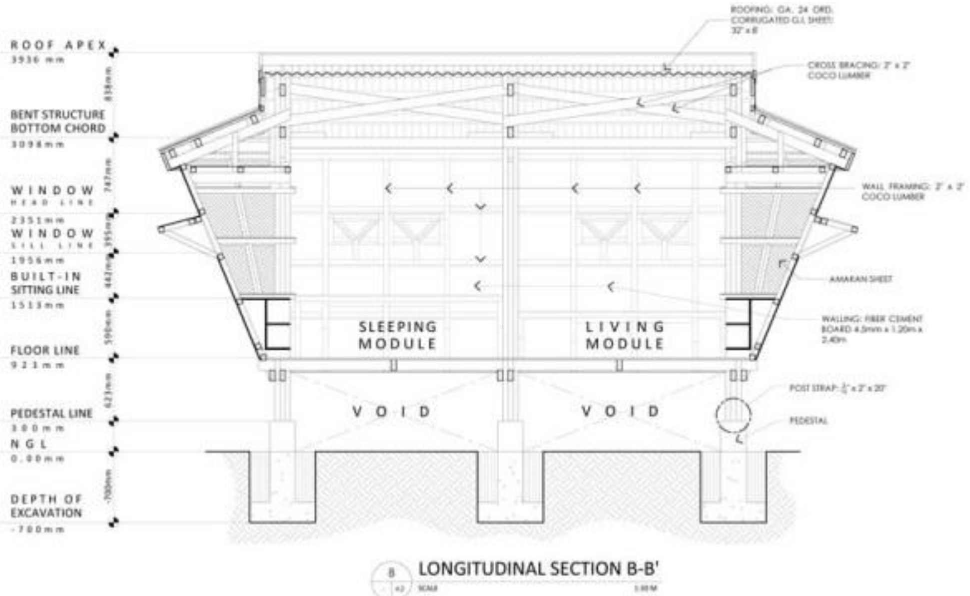

Figure 64. Longitudinal Section.

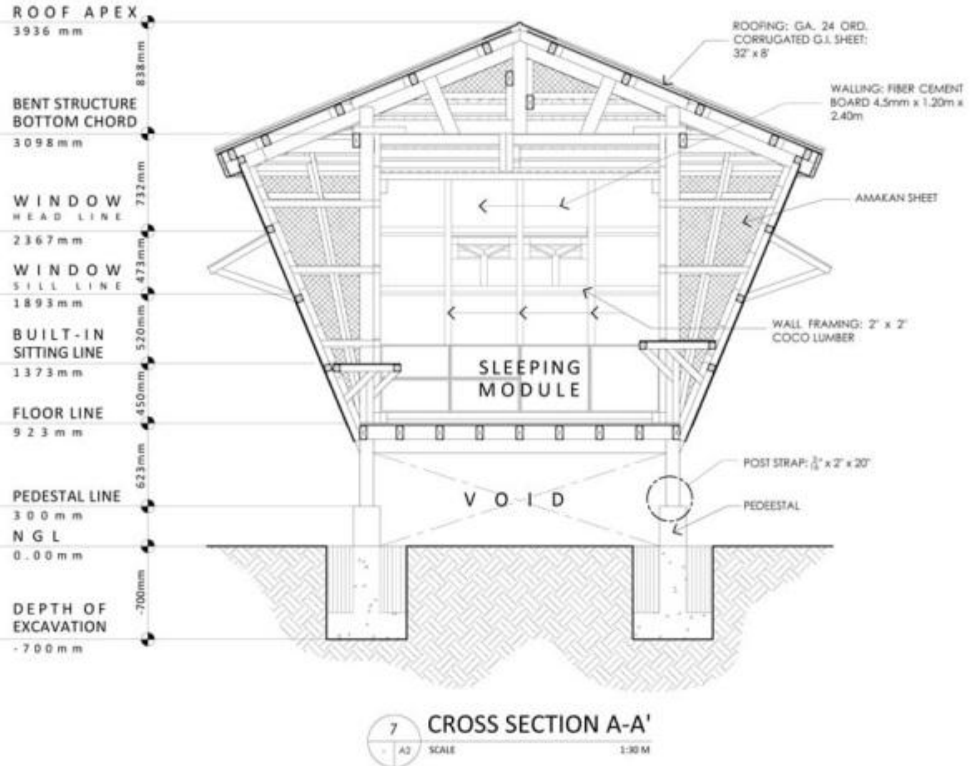

Figure 65. Cross Section.

B. Structural Plans and Details of the Typhoon Shelter

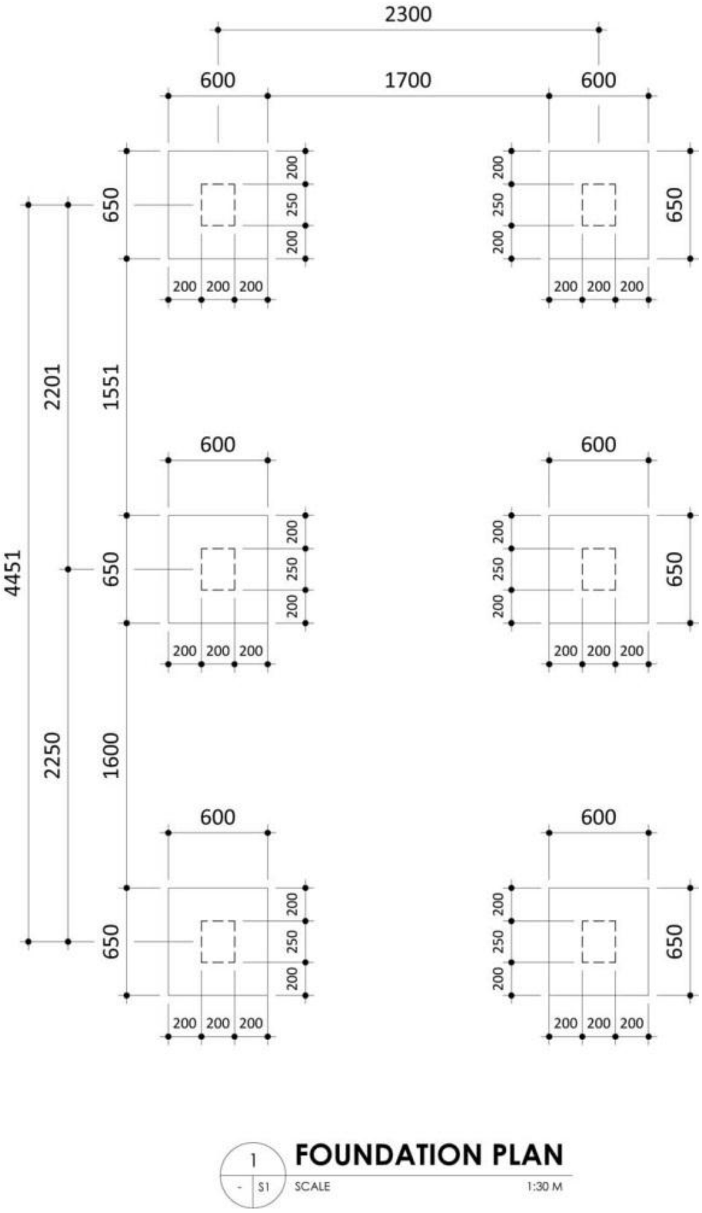

Figure 66. Foundation Plan.

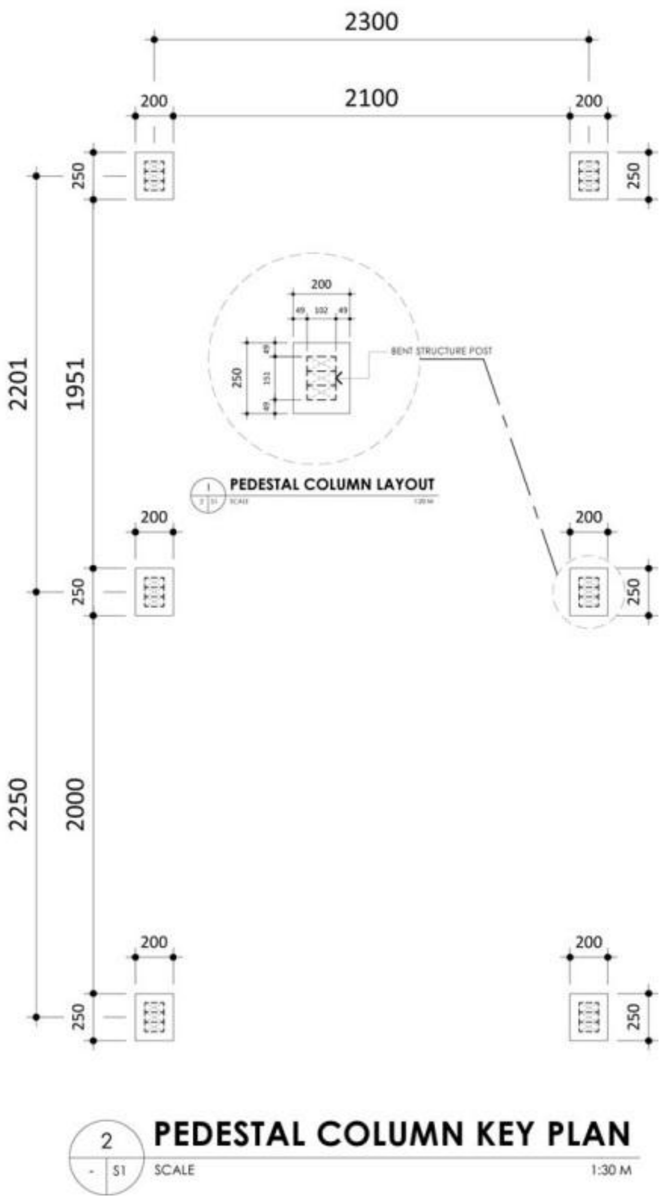

Figure 67. Pedestal Column Plans.

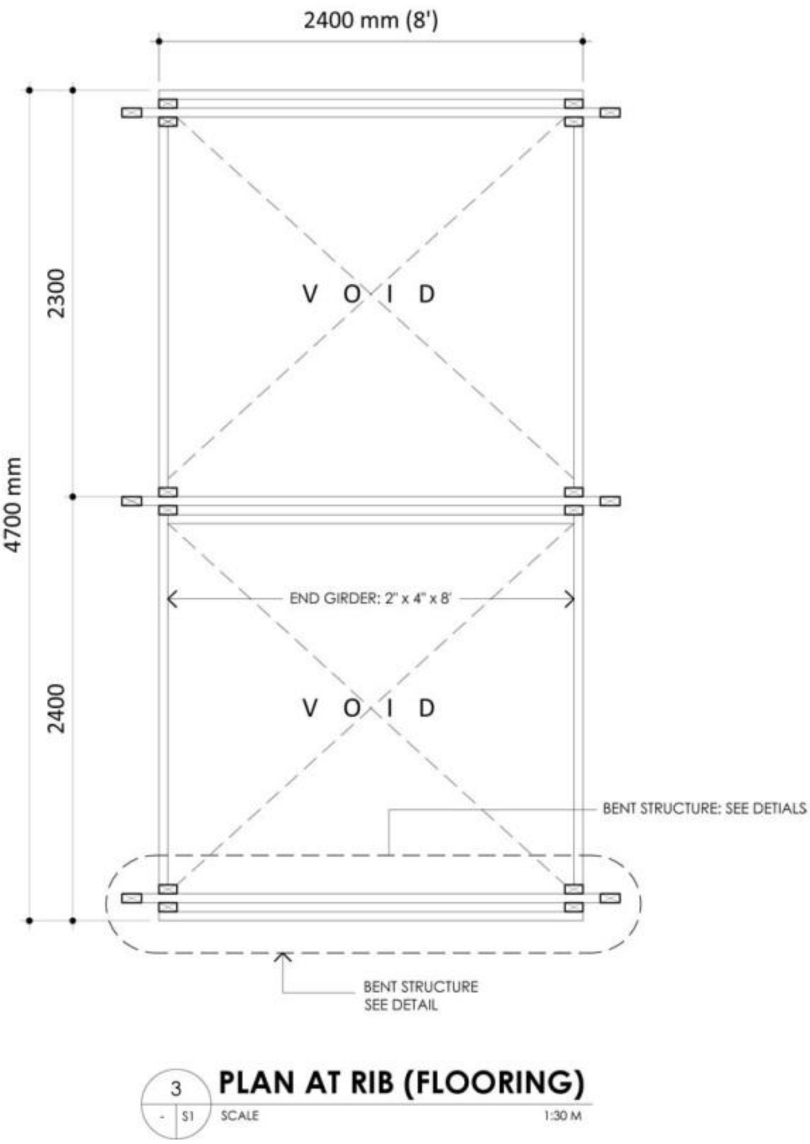

Figure 68. Plan at Rib (Flooring).

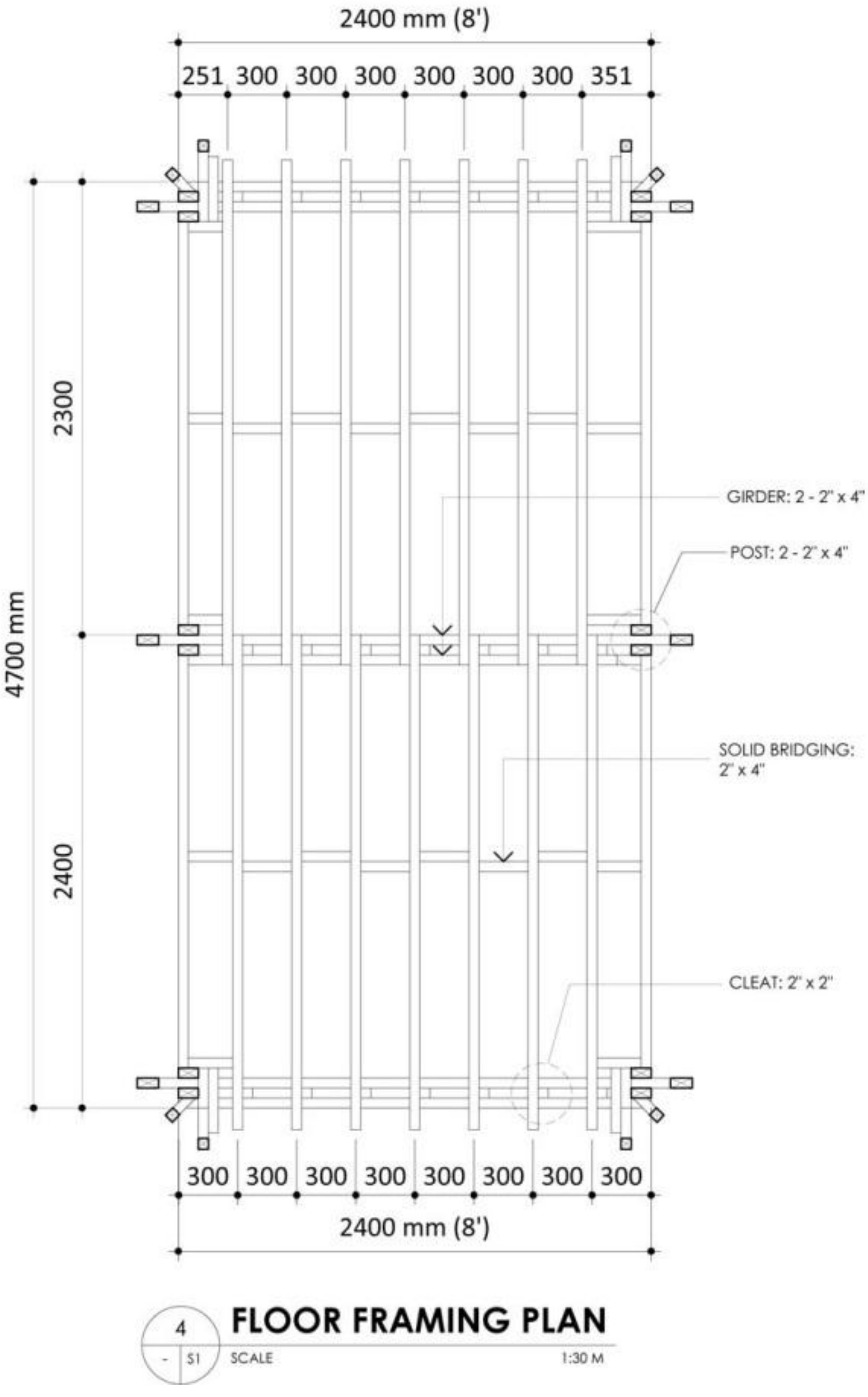

Figure 69. Floor Framing Plan.

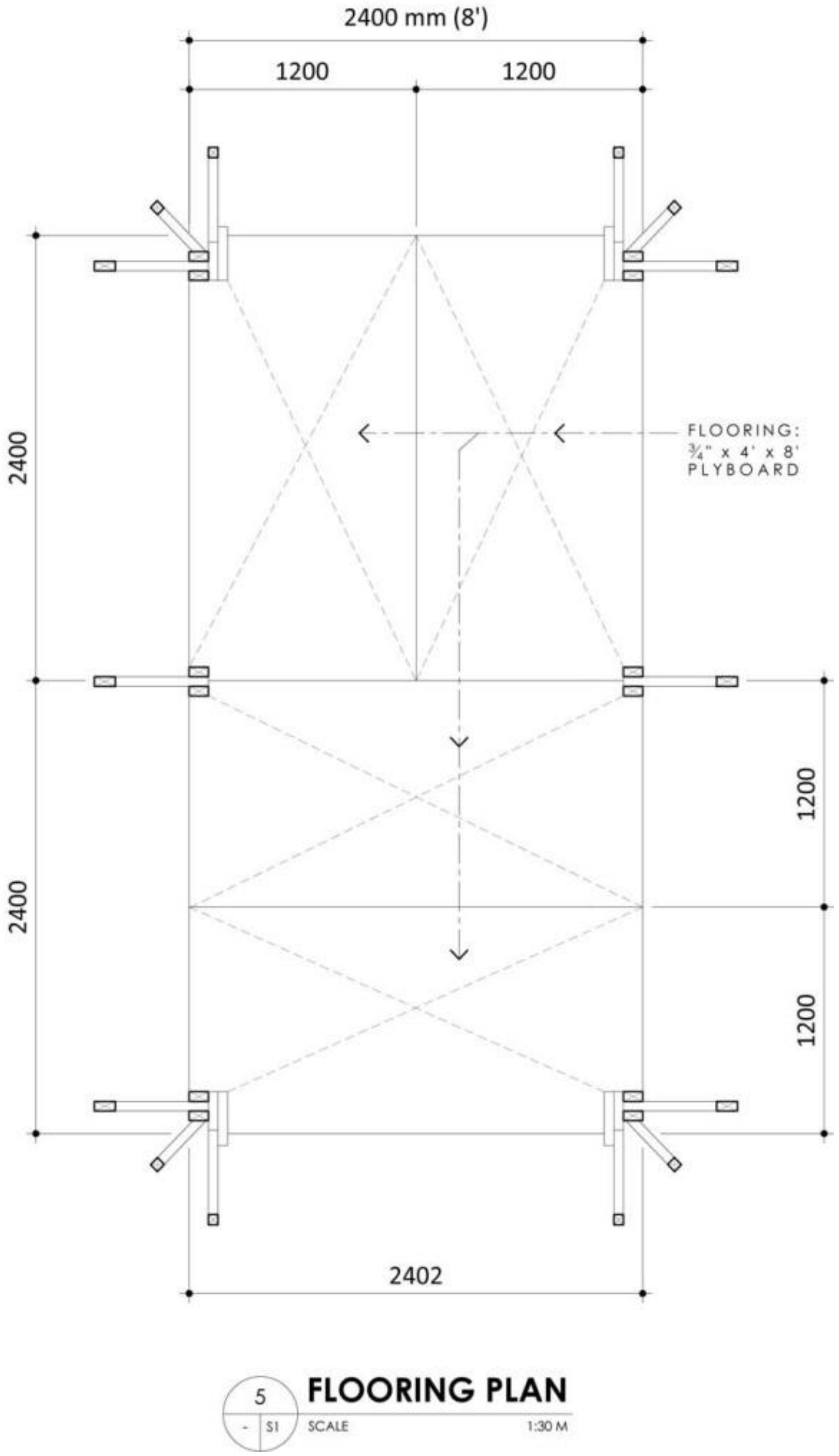

Figure 70. Flooring Plan.

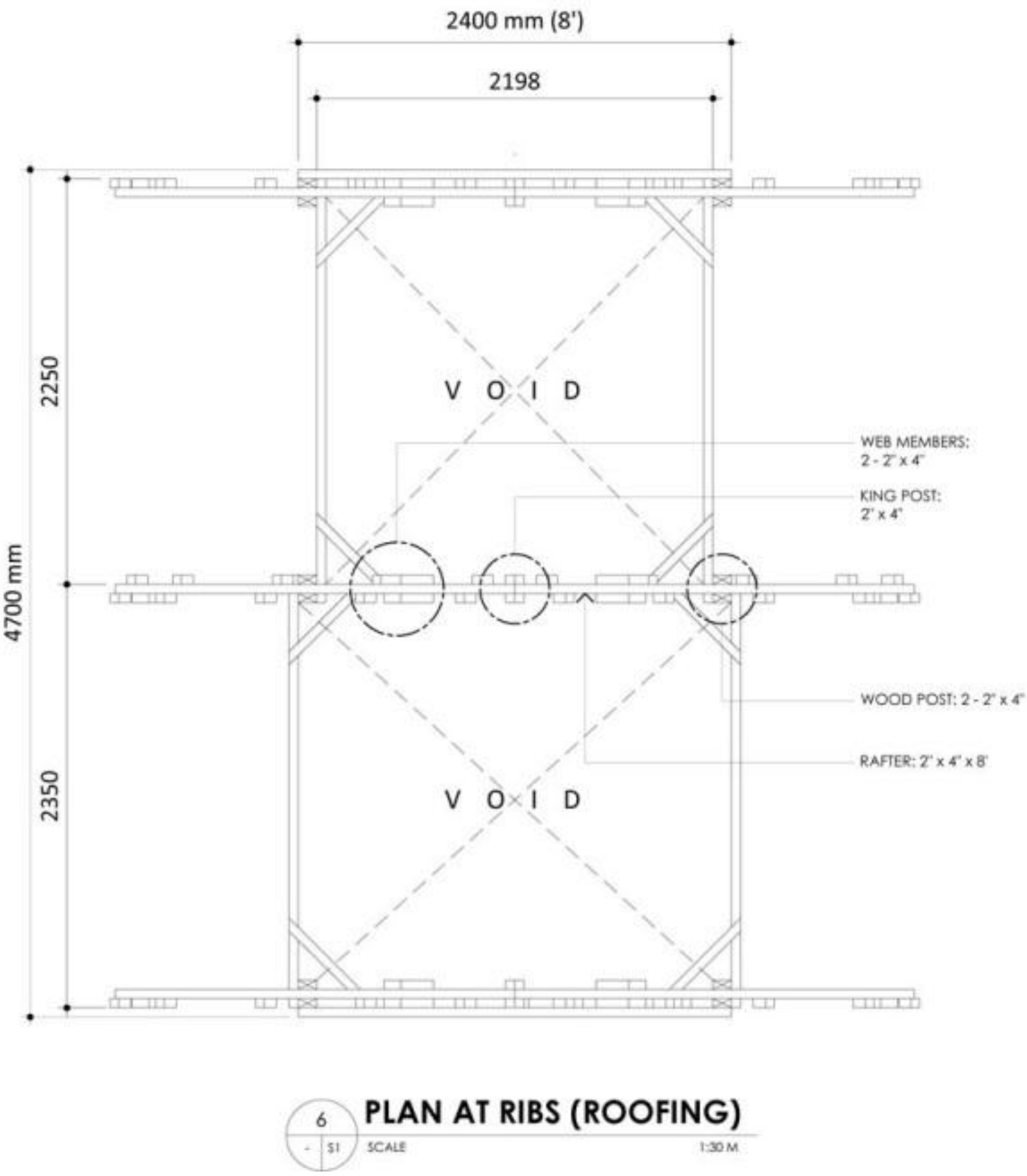

Figure 71. Plan at Ribs (Roofing).

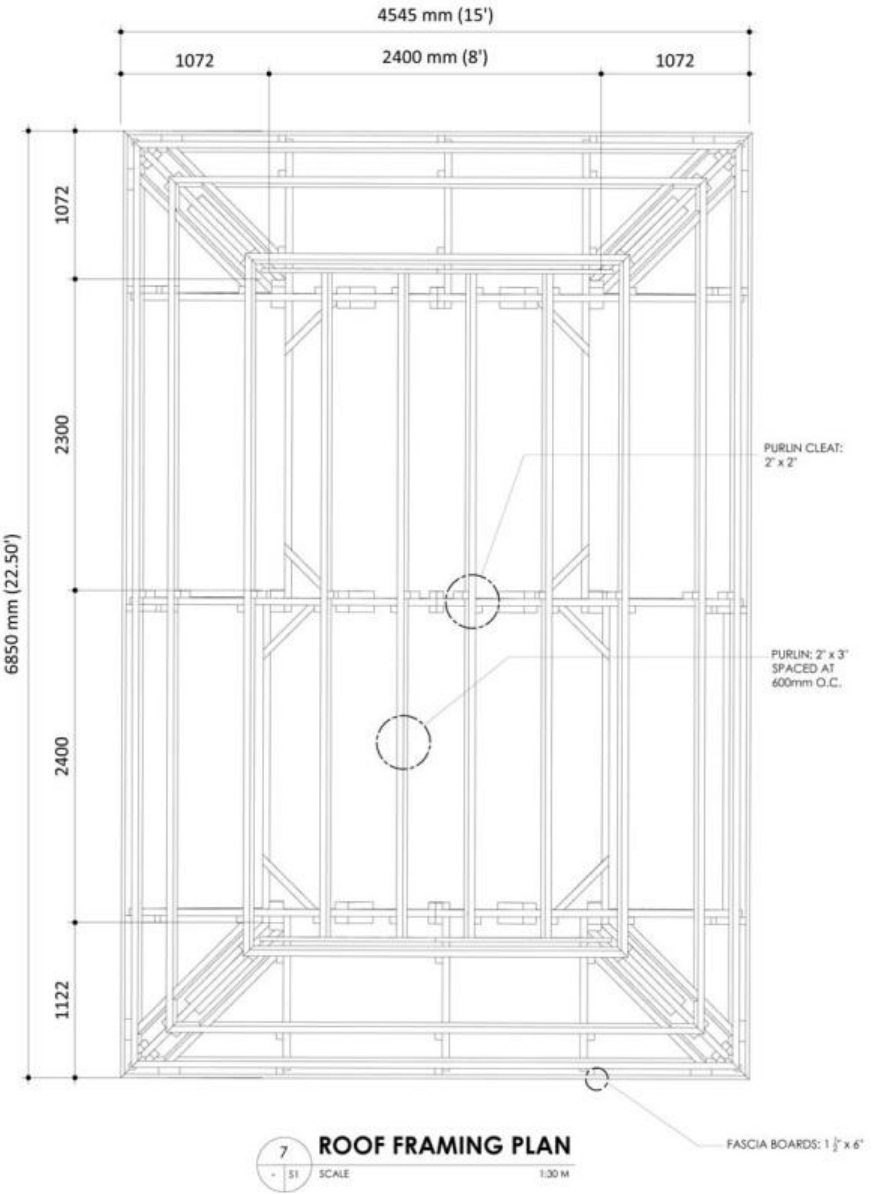

Figure 72. Roof Framing Plan.

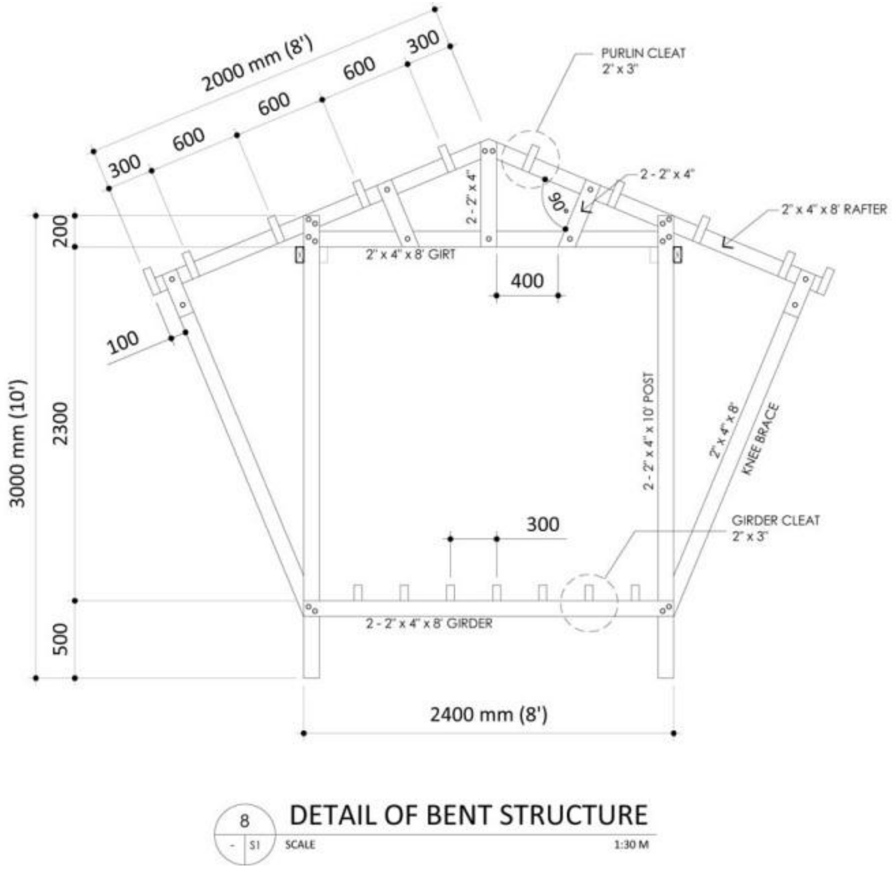

Figure 73. Detail of the Bent Structure.

B. Structural Plans and Details of the Toilet and Kitchen

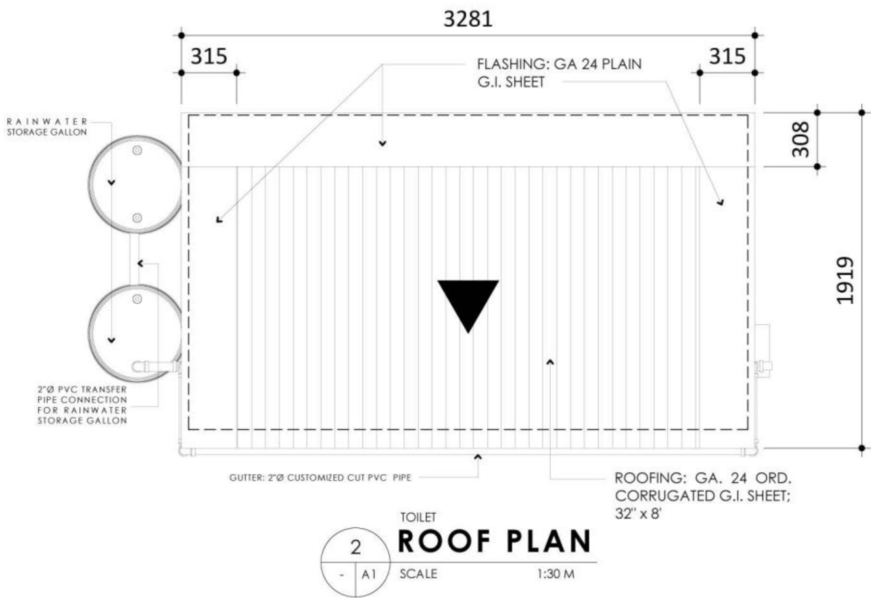

Figure 74. Roof plan of Toilet and Kitchen

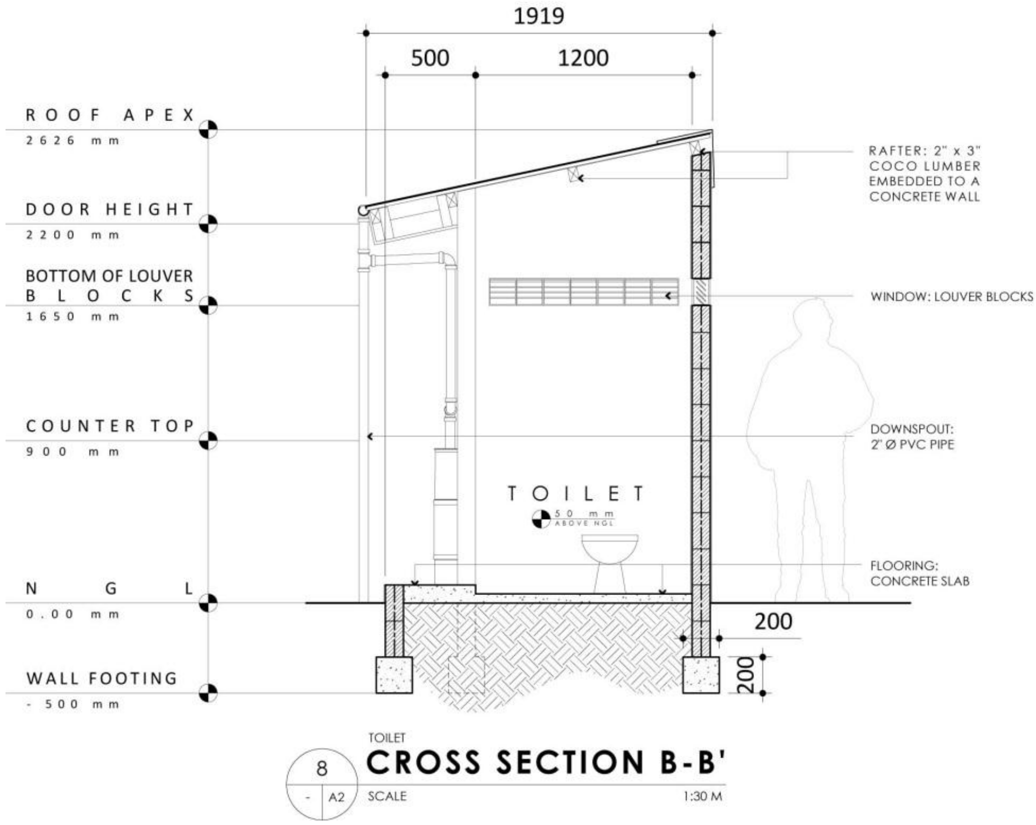

Figure 75. Cross Section of Toilet and Kitchen

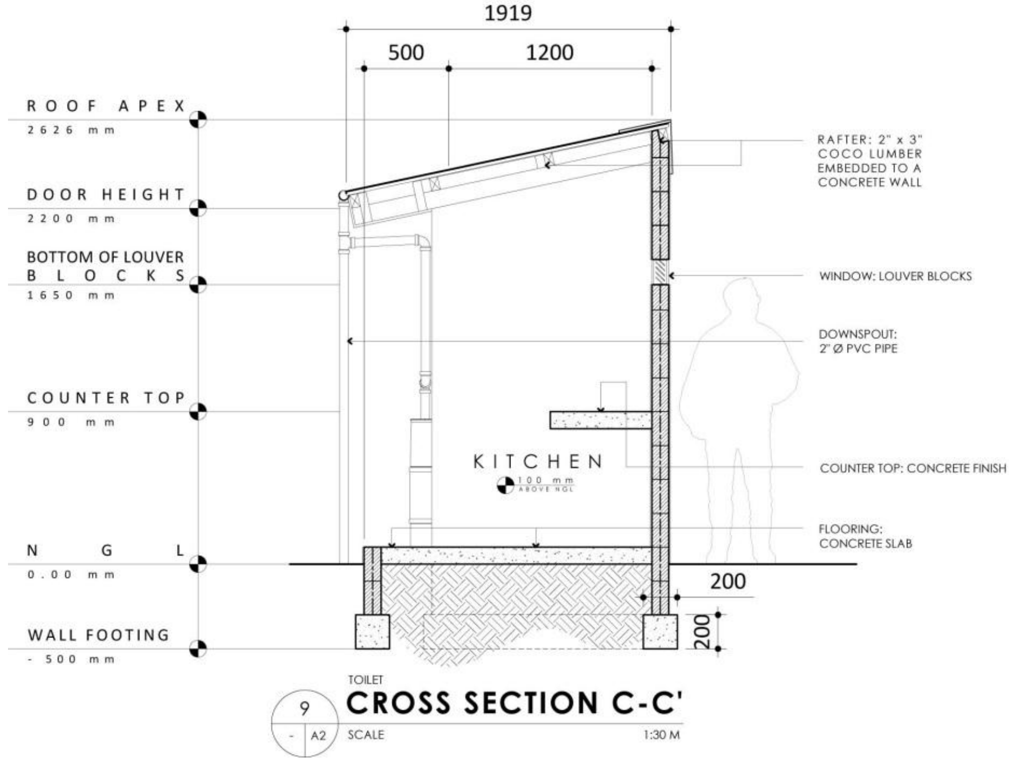

Figure 76. Cross Section of Toilet and Kitchen

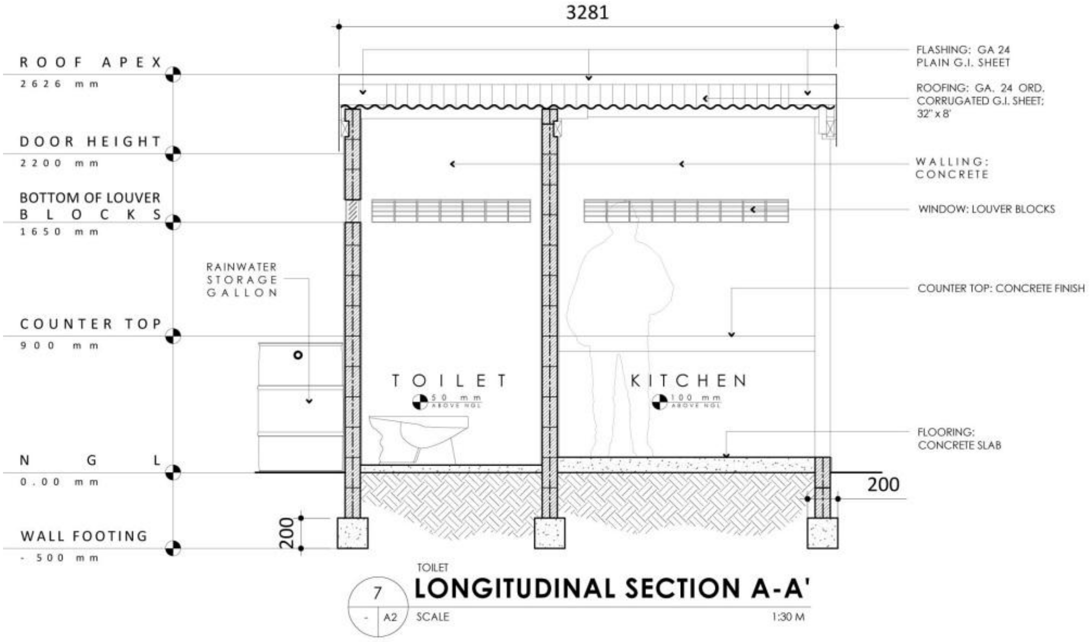

Figure 77. Longitudinal Section of Toilet and Kitchen

D. A Scale Model of the Typhoon Shelter

Figure 78. Scale model of the Ocho Balay Typhoon Shelter. The structural framings are shown here in detail.

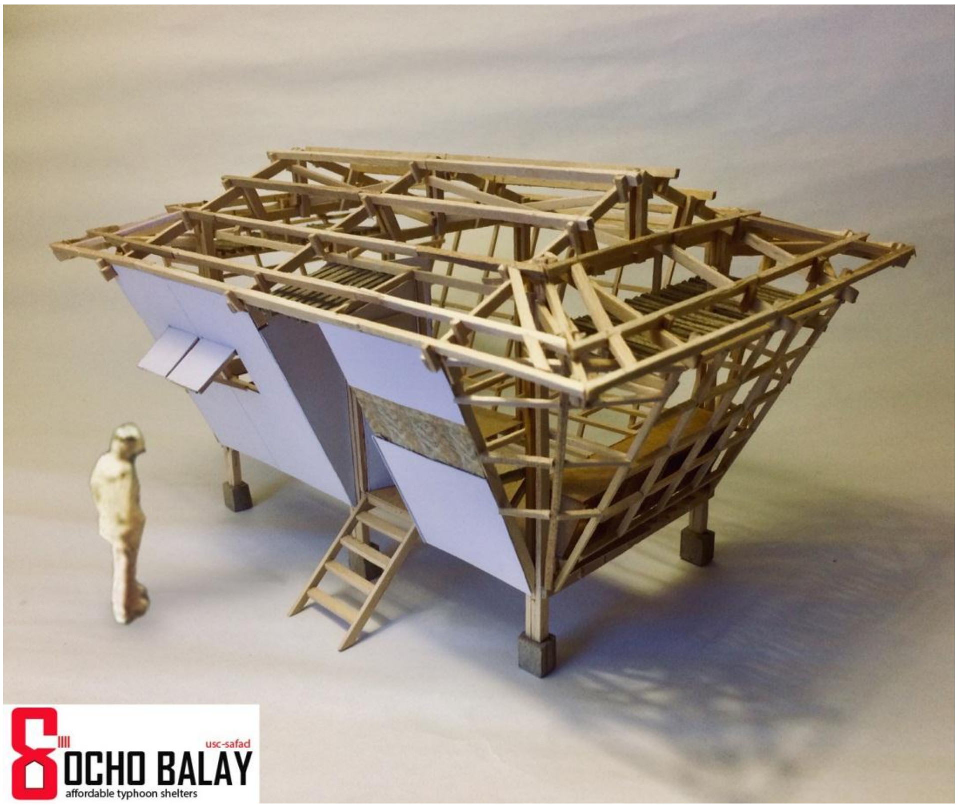

Figure 79. Scale model of the Ocho Balay Typhoon Shelter. The exterior structural framings are shown here in detail.

D. List of Published Papers

(As of January 20, 2019)

1. **The Urban Heat Island (UHI) Phenomenon in Cebu City, Philippines: An Initial Study.**
   Author: Rowell Ray Lim Shih and Dr. Danilo T. Dy
   Journal: Espasyo Journal (Philippines) ISSN 2094-3725 (January 2013, Volume 5, Issue 1).

2. **The Visual Perception and Human Cognition of Urban Environments Using Semantic Scales.**
   Author: Rowell Ray Lim Shih and Dr. Runddy D. Ramilo
   Journal/Peer-Reviewed Conference Paper: The 7th International ASCAAD Conference (Effat University, Jeddah, Kingdom of Saudi Arabia) December 16-18, 2013.

3. **Investigating the Night-time Urban Heat Island (Canopy Layer) Using Mobile Transverse Method: A Case Study of Colon Street in Cebu City, Philippines.**
   Author: Rowell Ray Lim Shih and Dr. István Kistelegdi
   Journal: Pollack Periodica (Dec 2017, Vol. 12, Issue 3)

4. **A Shelter for the Victims of the Typhoon Haiyan in the Philippines: The Design and Methodology of Construction.**
Authors: Danilo Ravina and Rowell Ray Lim Shih
Journal: Pollack Periodica (Aug. 2017, Vol. 12, Issue 2)

5. **Bakwitanan: Design of a Blackboard Convertible to an Evacuation Centre Partition by Participative Design Method.**
Authors: Danilo Ravina, Marc Ruz, Rowell Ray Lim Shih and Dr. István Kistelegdi
Journal: Pollack Periodica (Aug. 2018, Vol. 13, Issue 2)

6. **Community Architecture: The Use of Participatory Design in the Development of a Community Housing Project in the Philippines.**
Authors: Danilo Ravina, Rowell Ray Lim Shih and Dr. Gabriella Medvegy
Journal: Pollack Periodica (Aug. 2018, Vol 13, Issue 2)

7. **A Review and Systematization of the Traditional Mongolian Yurt.**
Authors: Tsovoodavaa, G., Rowell Ray Lim Shih and Dr. István Kistelegdi
Journal: Pollack Periodica (Dec. 2018, Vol 14, Issue 1)

8. **Istambalay: A Mobile Vending Cart and Portable Shelter for the Homeless.**
Authors: Danilo Ravina, Rowell Ray Lim Shih and Dr. Gabriella Medvegy
Journal: Pollack Periodica (Dec. 2018, Vol. 13, Issue 3)

9. **Comfort and Energy Performance Analysis of a Heritage Residential Building in Shanghai.**
Authors: Chu Xiaohui, Ganjali Bonjar, Rowell Ray Lim Shih and Dr. Balint Baranyai
Journal: Pollack Periodica (Jan. 2019, Vol. 14, Issue 1)

E. Conferences and Workshops

1. **11th International Miklós Iványi PhD & DLA Symposium**
   Date: October 19–20, 2015
   University of Pécs (faculty of Information and Engineering)
   Paper title: *Commercial Developments and Urban Sprawl in Cebu City: How Far Can We Go?*

2. **13th Miklós Iványi International PhD & DLA Symposium**
   November 3–4, 2017
   University of Pécs (faculty of Information and Engineering)
   Paper title: *Community architecture: Case studies of Participatory Design in the Philippines.*

3. **Architectural Education Conference (**Paks Conference: Konferencia- időbeosztás, tudnivalók)
   Date: October 25, 2017
   Paks, Hungary
   Paper title: Architectural Education in the Philippines

4. **Annual Conference on Architectural Research and Education (ACARE-15)**
   Date: August 22-24, 2016
   Iloilo City, Iloilo (University of San Agustin) Philippines
   Paper title: Investigating the Nocturnal Micro-Urban Heat Island Phenomenon Using Mobile Traverse Method: A Case Study of Colon Street in Cebu City, Philippines.

5. **Annual Conference on Architectural Research and Education (ACARE-13)**
   Date: May 15-16, 2014
   Mintal, Davao City, Philippines
   Paper title: Urban Sprawl: Urban Sprawl and Strip Development: The Case of Study of the Banilad-Talamban Corridor

6. **Annual Conference on Architectural Research and Education (ACARE-12)**
   Date: February 7-8, 2013
   Legazpi City, Philippines (Bicol University College of Arts and Letters)
   Paper title: The Visual Perception and Human Cognition of Urban Environments Using Semantic Scales.

7. **University Architecture Week 2013 (Principal Speaker)**
   Date: December 2, 2013
   University of Southern Philippines-Foundation (USP-F)
   Paper title: The Urban Heat Island Phenomenon

E. Workshops and Team teaching engagements:

1. *"This Is Me Now"* Workshop
   Date: October 27-30, 2015

2. Team teaching with Prof. Mark Zagoracz
   Date: September 29, 2015
   Location: Research Center at Room A414
   Subject: Introduction to Basic AutoCAD for Civil Engineering students.

3. Team teaching with Prof. Dr. Xin Jing
   Date: September 11, 2015
   Location: Room A-206
   Subject: Architecture Model "A".

F. International Competitions with the DLA students

1. *"Set Foot in Sittard"* (Phidias Community Cooking) International Competition
   Date: November 1 to December 4, 2015

G. The Author

Rowell Ray Lim Shih is an architect based in Cebu, Philippines. He took up Masters in Architecture (Major in urban Design) at the University of San Carlos in 2012. Rowell has been active in the academe since 2011 and has already published several peer-reviewed research papers at both local and international journals. His major is interest is urban design, sustainable architecture, Socialized Housing Solutions and urban climate studies. This study has been undertaken at the University of Pécs in Hungary. One of the basic objectives of the study is the application of an exploratory design and scientific analysis into architectural solutions.