Think Pacific Foundation - Action Project 51-26

Design a cyclone-proof home for a Fijian village

Project Proposal
By Abigail Faulkner

Executive Summary

Every year in Fiji, tropical cyclones cause damage to properties and loss of life, and cause huge struggle to the people of Fiji. Low cost housing in Fiji is often built quickly and not to standard, and these houses are often severely damaged by natural disasters. Often, homes are rebuilt quickly and cheaply, however, they become damaged again quickly, continuing the cycle of hardship.

Improving living standards and quality of life in rural areas in Fiji is part of Fiji's 20 year development plan. The Think Pacific Foundation aims to support this development in Fiji rural communities, alongside supporting the UN sustainable Development Goals.

I have proposed an option for a home which could be built in a Fijian village which is both sustainable and affordable, as well as being strong enough to withstand natural disasters. The design also takes into account aspects of traditional Fijian architecture, and realizes the importance of the communal lifestyle of Fiji.

Contents

Section 1: Project Information

- **Name of the Organisation** Think Pacific Foundation

  Think Pacific Foundation is an NGO and a registered Fijian charity that supports a number of volunteer projects. Think Pacific aims to support Fiji's sustainable development in rural communities, and they work in a number of areas such as education and advocacy, sports development, health promotion and infrastructure development.

- **Project Title** Design a Cyclone proof home for a Fijian Village

- **Project Summary** Natural disasters result in huge personal and economic struggles for Fijian people. Within this project, we would like you to design a Fijian house that could be built affordably within a village. You have creative freedom in designing the house, exploring whether it's possible to combine new engineering concepts with traditional Fijian knowledge. Consider affordable options and whether it would be possible to make a single room 'cyclone-proof' where a family could remain safe during a storm. Bear in mind Fijian's communal nature when designing the rooms and open spaces.

- **Project Timeframe** 2 weeks for each of 4 phases (8 in total)

- **Prepared By** Abigail Faulkner

- **Attached Documentation** See appendix (reports and Fijian NBC)

Section 2: Project Summary

I am a fourth year Civil Engineering student at the University of Auckland and I was inspired to complete this internship with Think Pacific as I heard about it through my University. It is a great opportunity to apply my Engineering knowledge to something practical which is why I decided to join Think Pacific in this journey.

For my Action Project, I am designing a home that is both sustainable and affordable, for a Fijian family. This home should be strong enough to withstand natural disasters whilst still using inspiration from traditional Fijian architecture and the FIjian way of life.
I have explored a few options on types of homes that can be built and researched into the best structures that can be built at affordable prices. The plans provided in the appendix will hopefully be clear for others to follow if they wish to build in FIji.

Fiji is located in an area where tropical storms will typically form and lies on the path of many cyclones. The Pacific Cyclone season is usually between November to April every year, and Fiji will, on average, experience 2-3 cyclones in this time.

Currently in FIji, as well as other areas in the Pacific, low cost houses are often severely damaged by natural disasters such as cyclones, floods, earthquakes and landslides. The impact of these disasters causes huge damage to the lives of Fijian people, even causing loss of life. Often, homes are rebuilt quickly and cheaply, however, they become damaged again quickly, continuing the cycle of hardship. Strong winds have often blown roofs off houses, or even the whole house off its foundation.

In 2016, tropical cyclone Winston devastated Fiji, damaging or destroying around 30,000 houses and 495 schools. The biggest cause of this was that buildings were not up to the correct standard and/or were not properly being maintained. Many buildings are not up to the standard of the Fijian National Building Code (NBC).

Traditionally, houses in Fiji are called Bure and were constructed of a wooden frame with woven mats attached over the frame to make walls. The houses were bound together using ropes made of coconut fibers, and they would have a thatched roof made from pandanus or palm leaves. The Fijian Bure would have a high sloping roof shape as it was widely believed that the higher the roof, the closer they were to God.

Bures are strong and well-designed, however, they are difficult to repair and maintain, so often if there was damage, the residents would build a whole new structure. In a cyclone, a common problem is that the roof blows off the house, leaving the rest of the structure intact. If this occurs, residents would often run to shelter under the roof to wait out the cyclone. Since a bure is constructed from light and flexible materials, collapse or damage to the house rarely causes major injury, however, it can be very inconvenient to those living there.

The National Building Code for Fiji (NBC) was completed in 1991, and enacted in 2004 through the Public Health Regulations in 2004, however, many houses within the iTaukei lands were exempted from these regulations due to government and cultural issues. There is a strong need for cyclone proof houses in this region.

The aims and objectives for this project are to provide a housing solution for Fijian Villages that still takes elements from traditional Fijian architecture, whilst incorporating modern practices that are stronger, more durable and cost efficient.

Section 3: Project Methodology

3.1 Project Approach Summary

There were three different types of houses that I considered, amongst other factors, when it came to design; bure, timber frame, and concrete block house. Each type had advantages and disadvantages but it was important to compare all options to see which would work best.

First, I looked at the Fijian Bure. The bure is built from local materials and can be built quickly, however, it is not always able to withstand cyclones as the roofs are often found to blow off the walls and they are difficult to repair and maintain. Often, these homes are rebuilt again from scratch once damaged, but the cycle often continues once the next storm comes around.

Next, I considered houses built of concrete blocks. Whilst concrete can be expensive, it is very long lasting, and if built properly, it is also very strong and can easily withstand tropical storms. However, if not built correctly, these houses can be the most dangerous type since the heavy materials used can crush those inside if it falls. These types of houses tend to be more expensive to build as well as the concrete needs reinforcement with steel.

Timber frame houses are another type that are popular in the pacific as they can be built to withstand cyclones and are generally flexible enough to withstand earthquakes too. These houses can be built quickly and can even be moved sometimes, however, with lumber shortages and rising costs, timber houses are no longer as affordable as they used to be and cost almost as much as a cement block house.

However, given the location of Fiji and the availability of materials, I have designed a timber frame house, as this would likely be the best in Cyclone and Earthquake scenarios (which fiji are prone to both) as they present lower risk than concrete block if failure did occur, and can still be made strong and long lasting. In fact, a well built timber frame home can last for 100 years or more. Another positive of choosing timber is that it can be built much faster than a concrete block house, which means there will be lower cost overall as a shorter project means less labor costs and less chance of delay.

3.1.1 House Layout and Design:

The exterior of the house is very basic in shape to avoid complexities that will add cost and difficulty to the project. Also, a simple rectangular building is the strongest shape in a cyclone so that wind pressures are evenly distributed. Internal walls that span from one side of the building to the other provide additional lateral restraint and prevent outside walls from caving in, however, keeping the Fijian way of living in mind, I have still designed a large open living/kitchen space where families are still able to gather and be communal. The bedrooms are smaller as a result. The house is also only 1 story, as a second story provides greater risks and requires stronger foundations.

The designed floor plan can be found in Appendix, figure 1. Traditionally, FIjian kitchens are separate from the houses as a detached small building, however, these are not generally built sturdily and are often wiped out during cyclones. The debris from these additional structures often causes damage to the main house which would otherwise have been able to survive the storm. Taking this into account, the kitchen is part of the main house in a well-ventilated corner. A bathroom is also included as part of the main house instead of a separate structure.

In total, the house interior is 7m by 8.5, which gives 59.5 m^2 of floor space, with the majority of that being living space. The Fijian Building code states that habitable rooms must have at least 6 m^2 floor area, so I have designed the bedrooms to be slightly bigger than this but still kept them small.

I have also looked at options for a cyclone shelter as I think that within the foundation would be the best option as it would be made from concrete blocks. Shelter below the house means that even if the roof is blown off during a cyclone, the occupants of the house are still protected.

3.1.2 Foundations

I have designed the house to have concrete masonry block foundations with a cyclone shelter built within. The footings must be at least 300mm below ground level, and the concrete block will extend 600 mm above ground level to protect the wood from dampness. See figure 1 below for an example of how the foundation should look, bearing in mind that our house design has a timber floor rather than concrete.

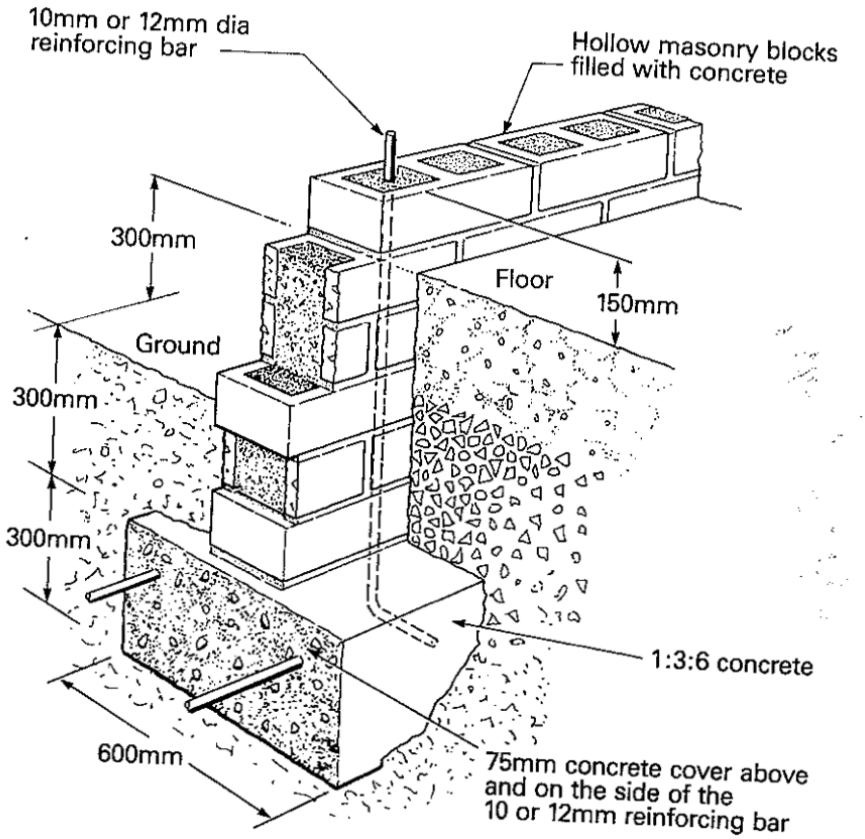


Figure 1: Masonry block with concrete footing foundations (Mayo, 1988).

3.1.3 Floors

Concrete flooring is not necessary for structural strength and is an added and unnecessary cost, therefore, timber flooring is a better option. Earth floors would be a low cost and sustainable option, however, due to the house being slightly raised with room for a shelter underneath, this isn't a feasible option. Floor joists with cost efficient floor boards, such as local wood or bamboo flooring is sufficient.

The floor joists are recommended to be 150x50 mm at a spacing of 450 mm. Figure 2 below details how the floor joists should be connected to the block wall in order to be sufficiently strong.

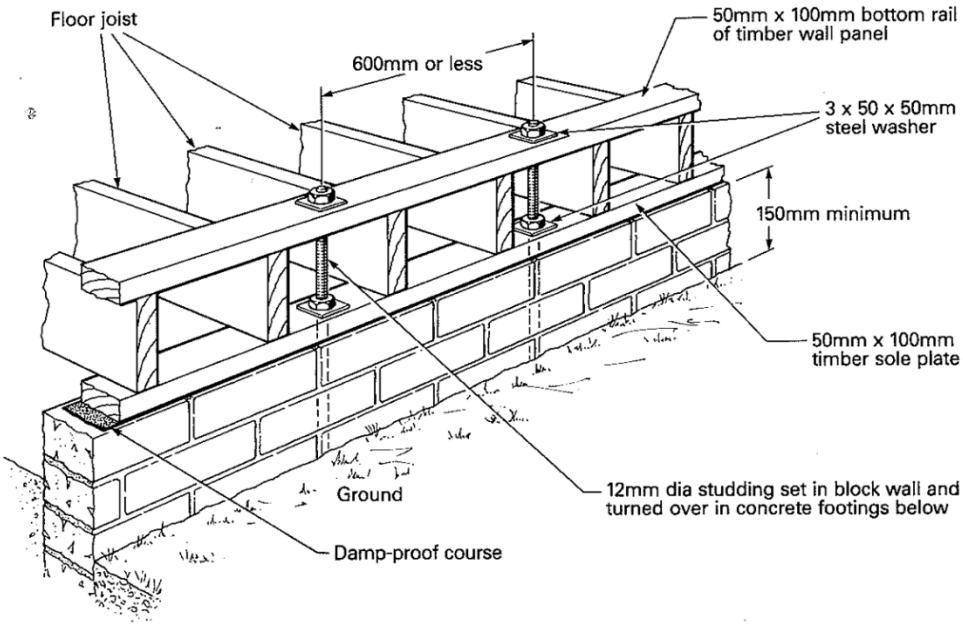


Figure 2: Floor joist connections to masonry wall (Mayo, 1988)

3.1.4 Walls

The exterior walls will be a timber frame with a weatherboard. The Fiji NBC states that rooms should be at minimum 2.1 m high and the recommendation on average 2.4 m high. Our walls are 2.4 m in height. The frame is constructed of 150x50 mm studs (vertical) and 100x150 mm nogging (vertical), both at 600 mm center spacing to provide adequate strength.

Unfortunately, timber has become much more expensive in recent years due to supply shortages, however, Fiji has a large forestry industry so it would be possible to source wood that is locally grown, saving on transport and import costs. Less travel is more sustainable.

Insulation should be added to save costs on heating or cooling, and can be low cost. There are many sustainable options for insulation that could be considered.

An interior wall which is across the whole building is also in place for added strength. A simple timber frame of 150x50 mm studs at 600mm center spacing, with woven mats or plasterboard to cover, is sufficient for this. I like the idea of using woven mats, similar to what would be used in a bure, as they can be made locally and sustainably and helps us to bring in more of Fiji's culture to the house design. As interior walls don't need to be weather tight, this option is a great sustainable and affordable one.

3.1.5 Roof

The proposed roof option is a metal Hip Roof with a 30 degree angle, and no overhangs, as overhangs provide too much risk in high winds. Metal roofs can last 30-40 years and are often recycled or recyclable, making them a sustainable and affordable option. They also do not require as much maintenance and are not as specialized of an option as the thatched roof of a traditional bure. Another positive is that they are also fire resistant and can reflect heat in the summer. A common problem with metal sheet roofing is that they can lift off and fly away during cyclones, causing damage to other buildings. This generally occurs because too short nails are used so we must ensure that we are using nails of at least XX mm in length.

The roof area could be minimized by decreasing the angle of pitch to lower the cost, however, it is suggested to use 22 degrees as the absolute minimum angle in order to prevent lift off in high winds.

To be sufficiently strong, the roof will be constructed of 150 x 50 rafters at 900 mm spacing, and 75 x 50 purlins at 750 mm spacing. The metal sheeting for the roof needs to be well connected using roofing screws with cyclone washers to every second crest of the roof sheet. Additional screws should be used to every crest at the top connection of the ridge, and at the bottom as well as at the eaves.

The proposed roof cross sectional shape can be seen below in figure 3.

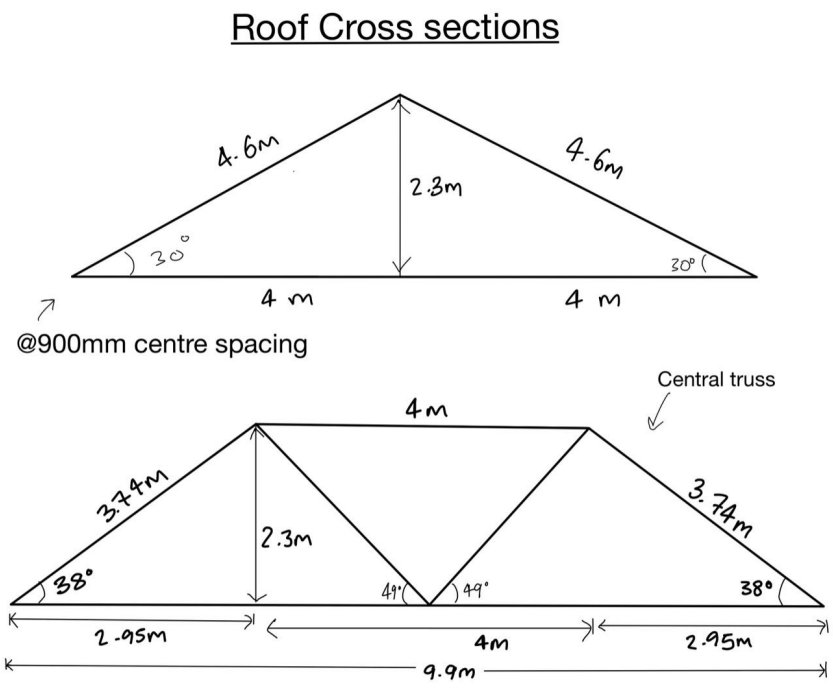


Figure 3: Roof Cross Sections

3.1.6 Windows

Glass windows with shutters which can be closed in high winds is the best option, as this will provide added protection to the house during a cyclone by preventing the build up of internal pressures caused by high winds. There are a number of local companies in Fiji which manufacture shutters. Local options are often best in terms of sustainability and supporting local economies.

South facing windows need shade for summer, however, overhangs on the roof can be dangerous as they can be lifted off in the wind, so curtains or blinds are suggested as a cheaper and safer option to keep the house cooler in the summer.

The National Building Code of Fiji states that total openings should not exceed more than 50% of any wall. This has been taken into consideration when designing the windows. However, it also states that openings must not be less than 10% of floor area to allow for sufficient ventilation. The windows should also be positioned at least 600mm from the corner of the house and 900mm from the base of the house, and 300mm from the roof. Window arrangement will be detailed in the drawings below. I have used 8 windows in the design, all of standard sizing 48x48 inch (1220x1220 mm). The sizes and positioning are satisfactory to the conditions stated in the building code.

A detailed diagram of the window layout for the house can be found in the Appendix.

3.1.7 Connections

Steel rods, nails and steel wire for extra strength will be needed.

It is especially important that connections between the house frame and foundation, as well as the roof and house, are sufficiently strong. These are often areas that will fail during a cyclone. As timber frame houses are light, if not properly done, the whole structure can be lifted off from its foundation.

3.1.8 Cyclone shelter

An affordable option for a cyclone shelter is to use the area below the house, since the concrete block foundations are very strong and will provide a safe place to shelter. Figure 4, below, is an example from EF5 Tornado Shelters of what the shelter could look similar to.

Figure 4: Cyclone Shelter Example (EF5 Tornado Shelters, 2020)

Houses in Fiji are often built on mounds of earth, which would make it easier to create a space beneath the house as less excavation will be required, and large excavations are costly and come with risks.

My proposal is to use masonry block foundations as they are strong, and the fact that they are already in shape means they are more accessible than having to do a concrete pour on site. The blocks will be reinforced with D16 steel reinforcing bars. Although this is a costly option, it will provide a safe shelter under the house which can be used as a crawl space during a cyclone, where inhabitants can feel safe even if their roof were to lift off in high winds.

Since the timber floor is best laid 600mm above ground level, and the foundations should be at least 600mm into the ground, this provides a space of height 1200mm below the house that can be used during such an event as a cyclone. Whilst this cannot be used as an extra room, as it does not satisfy the minimum requirements in height for a habitable space, an entrance can still be made below the house for the shelter.

3.2 Project Schedule

The main steps that should be undertaken to carry out the project are detailed below:

1) Site Selection
2) Foundation and footings
3) Lay floor 600mm above ground level
4) Stud walls in place
5) Brace corners
6) Make door and window frames
7) Make roof truss
8) Put roof truss onto walls
9) Nail rafters/purlins on roof
10) Nail metal sheets onto the roof frame (1 nail for each ridge)
11) Add boards onto wood frame
12) Windows, doors, shutters

Timber frame houses can be built very quickly, even in a matter of days if you have all of the tools and materials on hand. Since this is a relatively small structure, it would be a fast build and would likely take no more than a few weeks, however, we do have to factor in additional time for the blockwork in the foundations.

3.3 Final Design (Project Deliverable)

The final designs can be found in Section A of the Appendix.

Other Factors to Consider in when building houses in a village are the layout of the houses, the direction of the house (especially when high winds are expected), and whether there will be sufficient drainage for the house. As seen in figure 5, building houses in rows can create wind tunnels which will amplify the effects of a cyclone, whereas creating a zig zag arrangement for the houses in the village will offer more protection as it will prevent wind movements through the houses.

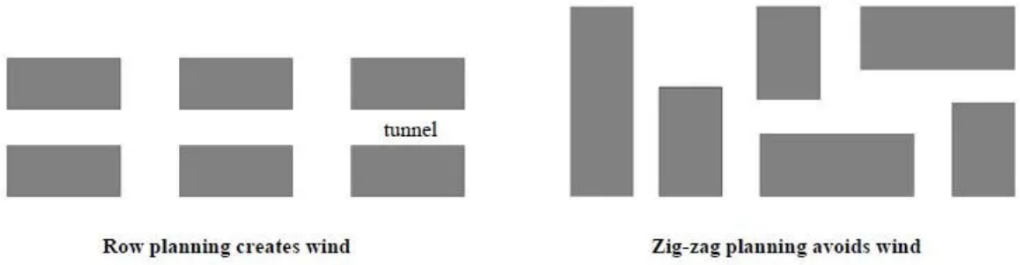


Figure 5: Building Arrangements for Cyclone Resistant Buildings (Thomas, 2020)

Section 4: Project Risk Management

There are many risks associated with this type of project. The construction industry experiences more accidents and deaths than any other industry worldwide, therefore, health and safety must be taken seriously during the project.

Health and Safety on a construction site involves ensuring that everybody who is working has had correct training and induction, and proper protective equipment is being worn.

Selecting a site is also important and should be taken seriously in order to avoid problems later on. Firstly, the site should be flat and level, and not too close to a river, ocean or floodplain, in case flooding should occur. Secondly, one must ensure that the site is easily accessible, especially whilst building work is being completed. Finally, the house must not be built too close to trees that could potentially fall and damage the house and/ or hurt those living there. It is recommended to be at a distance away of at least 1.5 times the height of the tree.

Another factor to consider is accessibility into the house. The house features steps as it is built 600mm off the ground, which could be switched out for a ramp instead. The front door can also be made wider in order to make the house more accessible for those with disabilities.

Section 5: Project Costs

In order to evaluate an approximate cost of materials I have outlined below the basic material costs for the building. The cost analysis does not include the costs of labor or tools/machinery, or plumbing and electricals, but will hopefully provide a rough overview of the construction materials in the current market.

Prices are found using the Fijian Competition and Consumer Commision (control of prices for hardware items) and are displayed in Fijian Dollars.

Foundation and re bars -
203mm (H) x 406 mm (W) x 203 mm (D) masonry blocks. 529 blocks required for a masonry wall 1200mm deep. Cost = $2.69 each, total = $1423.01
Reinforcing bars - D16 reinforcing at 600 mm center spacing.
Footing - cost up to $10,000 for excavation and concrete pour

Timber Frame

100x50 mm Studs at 600 mm center spacing and 150x50mm Nogging at 600mm center spacing. Total required = 137 m + 88 m = 225 linear m = 1.69 cubic m.
Cost = $963.87 per cubic m (standard 150x50 timber) , total = $1628.94

Roof
94 sq m of metal sheeting required.
150x50 mm Rafters at 900 mm center spacing = 93.5 linear m = 0.7 cubic m.
75x50 mm Purlins at 750 mm center spacing = 124.79 linear m = 0.47 cubic m.
Cost (150x50) = 963.87 per cubic m, total = $674.71
Cost (75x50) = 996.05 per cubic m, total = $468.14

Floor joists
150x50 mm Floor Joists at 450 mm spacing = 176 linear m = 1.32 cubic m
Cost = $963.87 per cubic m, total = $1272.31

Wall covering
There are 72.5 square m of exterior wall (excluding windows and doors) which require cover.

Timber floor
73.9 square m interior floor area to cover.

Windows
8 windows at 1220x1220 mm (48x48 in)
8 shutters to cover windows at 48x48 inch.

Doors
3 interior doors, both bedrooms are of standard size 1981x762x35 mm , however, the bathroom has limited space and is fitted with a narrow door of 1981x610x35 mm.
1 exterior door of standard size.

Section 6: Conclusion

In conclusion, the proposed house design is an affordable option for a home which could be built in a Fijian village which could be sustainable, as well as being strong enough to withstand natural disasters. Creating affordable and reliable housing for the rural areas is an important step forward towards Fiji's 20 year National Development Plan, as well as the UN Sustainable Development goals.

Section 7: Appendix

Additional charts, graphs, images, or reports cited in the proposal.

7.1 Appendix A (Diagrams)

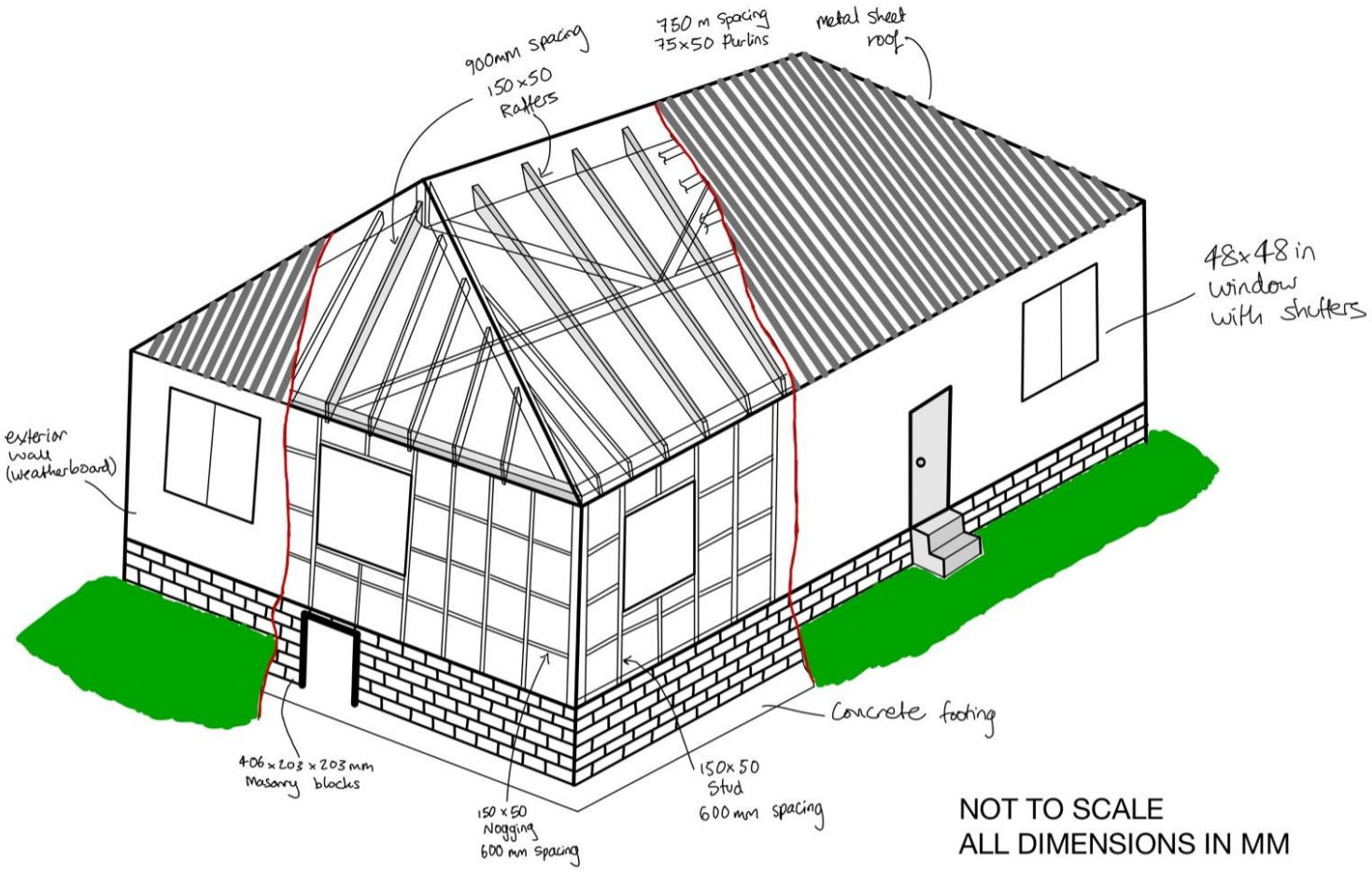


Diagram 1: 3D house drawing with frame

Proposed Floor Plan

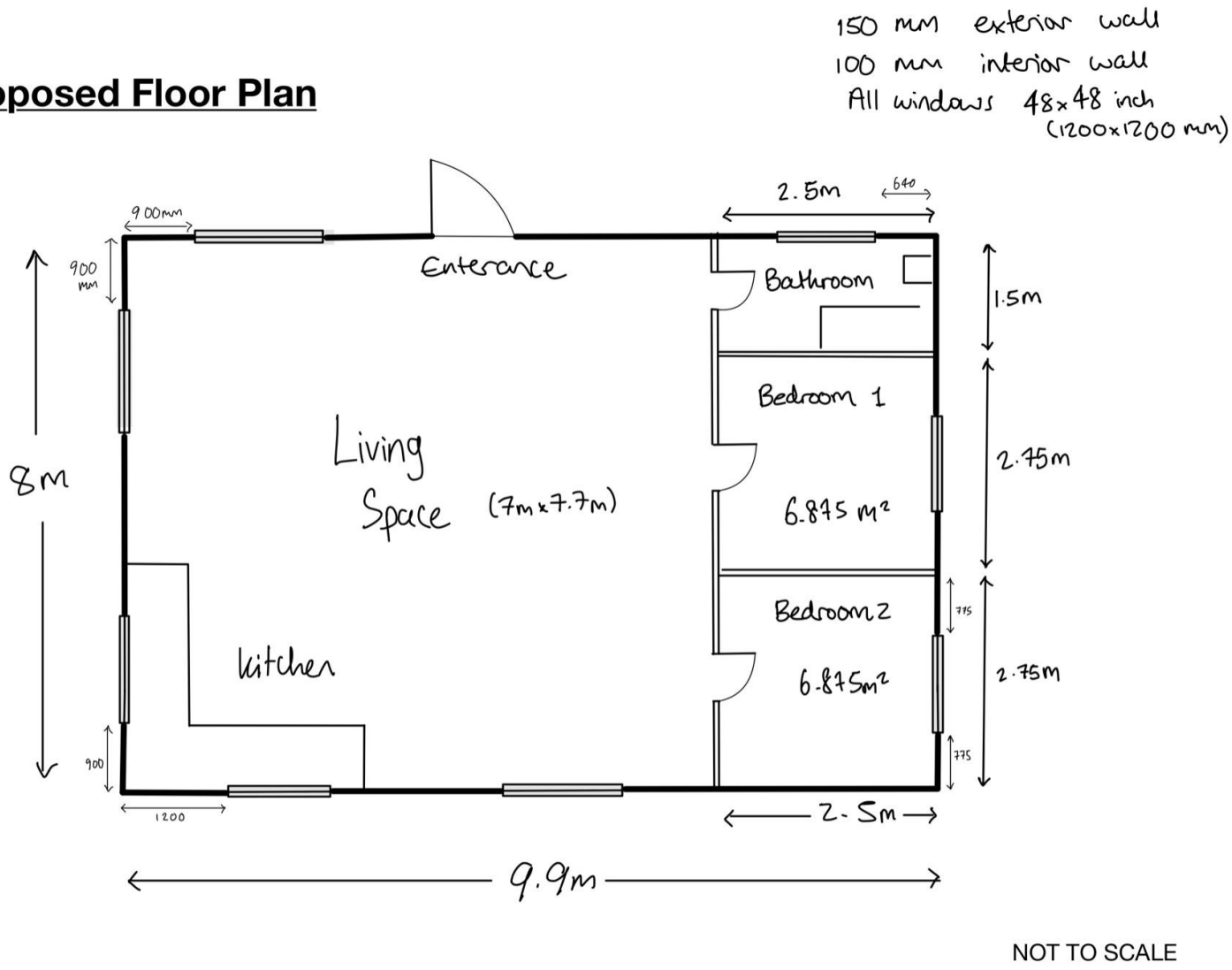
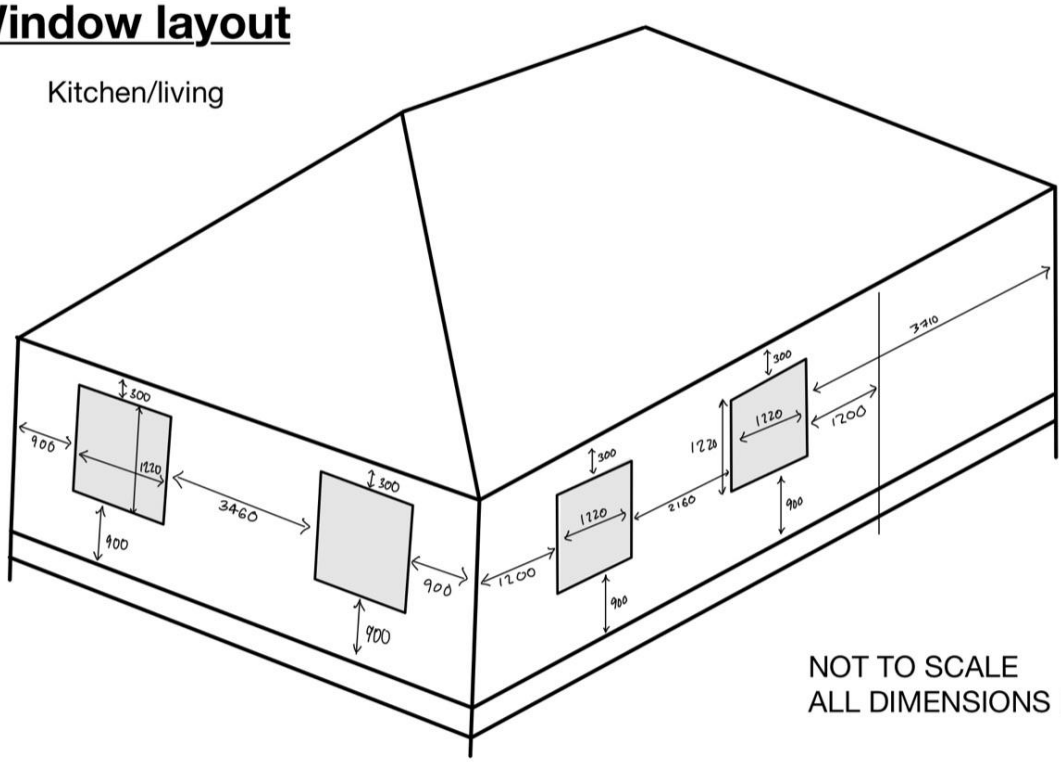


Diagram 2: Proposed Floor Plan

Window layout

Kitchen/living



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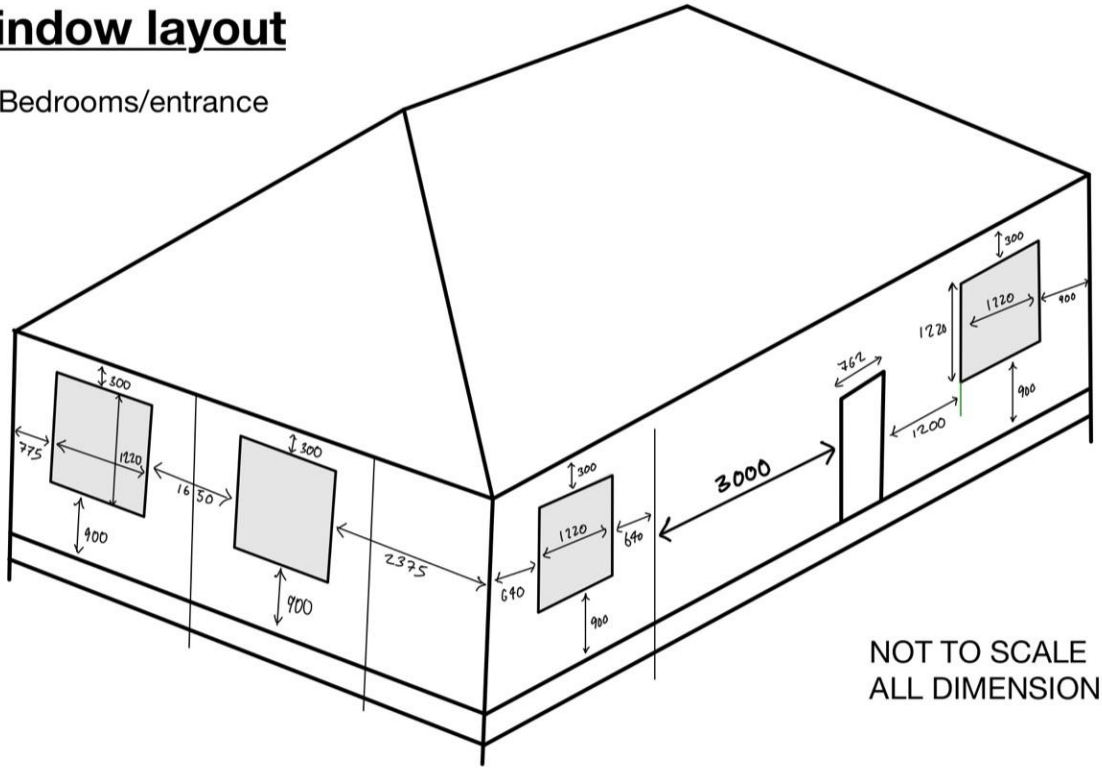
Window layout

Bedrooms/entrance



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ALL DIMENSIONS IN MM

Diagram 3 and 4: Window arrangements

7.2 References

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