Resilient Home Design for A Coastal Community of Baan Khun Samut Chin, Samutprakan

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Received: 18 Feb 2021; Revised from: 7 June 2021; Accepted: 22 June 2021
Print-ISSN: 2228-9135, Electronic-ISSN: 2258-9194 doi: 10.14456/built.2021.5

Abstract

Over the last 50 years, Baan Khun Samut Chin village in Samutprakan has long struggled against the rapid erosion of their coastline along the Upper Gulf of Thailand and the forthcoming loss of their entire territory. This serious problem affected to economics, society, way of life, and especially an existence of coastal community. This research proposed an experimental prototype of resilient house design to confront the erosion disaster for the Baan Khun Samut Chin community. By analyzing the problems of physical environment, social, culture, economic factors and construction techniques along with site surveying as well as reviewing theories and other related design projects, the architectural design concept with appropriate solutions was proposed. The proposed design concepts were including 1) durable design by integrating the floating platform of buoyancy structure above the flood line to the fixed structural 4-stilts supporting the light-weight roof, 2) resilient design for 3-meters sea level rising in next 30 years, and 3) low-cost design by choosing local materials and modular coordinating to prefabricated size of building elements. The experimental design of resilient home is expected to be a solution for Baan Khun Samut Chin community and those communities facing the same issues and government agencies with an urgent need for a ready and effective remedy.

Keywords: Resilient Home Design Prototype, Coastal Erosion Problem, Baan Khun Samut Chin Community, Adaptation

1. Introduction: Background & Problem

Located in Phra Samut Chedi district of Samut Prakan province, Baan Khun Samut Chin is a remote coastal community in the Upper Gulf of Thailand (Figure 1). It's just away from the capital Bangkok about 50 kilometers southwest. The settlement of Baan Khun Samut Chin had long started for more than 300 years since Ayutthaya period (Skinner, 1957). Due to its fertile estuary land with high agricultural productivity of Chao Phraya River, most Chinese immigrants decided to set up their trading district here. Later, the government sent an aristocrat to rule over the growing Chinese community, which was later called by the name of "Khun Samut Chin" meaning the lords of Chinese coastal village (Kosit, 2016).

This small and peaceful fishing village has nothing particularly interesting about it, except for the fact that coastal erosion has been eating away at the village shoreline for decades. For over three decades now, its shoreline has eroded more than 5 meters per year, submerging 6.4 square kilometers of land in water (Department of Marine and Coastal Resources, 2018). In the past, around 400 households have once lived in the village but now only 168 households remain have been forced to move further and further inland in every 5-10 years, as the sea has encroached. Moreover, they are almost low-income families and unable to afford home repairs (Witsanu Kengsamut, interview, 2019). A study of aerial photographs from 1952 to 2020 has shown that the village's land have been swallowed by the sea almost 1.1 kilometers (Figure 2) and if it undergoes any more erosion, the village will simply disappear into the sea eventually.

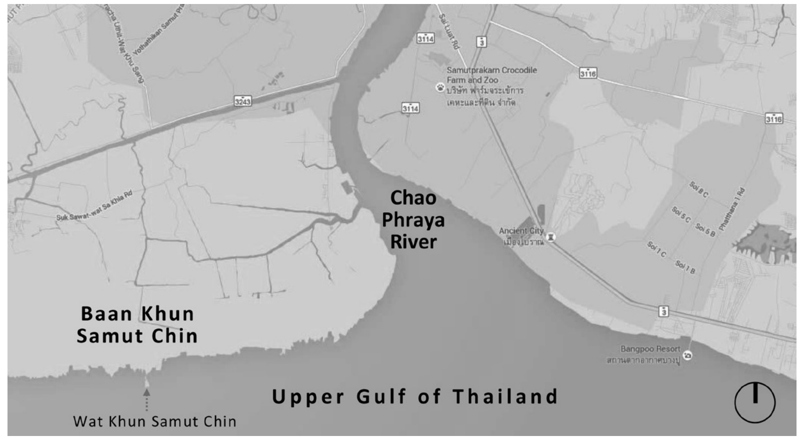

Figure 1. Location of Baan Khun Samut Chin Village in relation to the Chao Phraya River and the Gulf of Thailand (Source: Teamvan, B. (2017))

Figure 2. Over the last 68 years the village's land of Baan Khun Samut Chin have been swallowed by the sea almost 1.1 kilometres. It has left only the community temple, Wat Khun Samut Chin as a reluctant witness to coastal erosion. (Source: Google Earth satellite images modified by authors.)

Some of the houses that once stood along the coast are now left only structure in the middle of water. As well as numerous electricity poles that once ran parallel to the shoreline, are now half visible at a great distance from the coast (Figure 4). The community temple, Wat Khun Samut Chin (Wat Khun Samut Trawat) which was once located far inland at the back of the village, is now surrounded by the sea (Figure 3), as a reluctant witness to coastal erosion. The temple was trapped in the distant water and only connected to the rest of the village by an elongated concrete pathway (Picone, 2015). The temple floor had been raised several times to avoid the flood, as shown by the small size of the entrance crawl-doors and half-seen windows. This situation has attracted the temple to become a tourist spot both for its serious environmental threat issue and historical / cultural significance of community.

Today (2020 during the research period), one example of the critical signs revealing the uncertain future of community's collapse, is a crisis of Baan Khun Samut Chin School. The school has just 6 students and only one teacher left since most of the families have already started moving out to other villages (THAI PBS NEWS, 2019). If the coastal erosion takes place more longer, this community would soon collapse. One way to help restore community sustainability is to solve most of the community's housing problems: fishermen's houses which is the main occupation of the community. Therefore, the main objective of this study was to propose a prototype of resilient house design for the coastal fishing community of Baan Khun Samut Chin, confronting the erosion disaster without migrating to other places.

Figure 3. Wat Khun Samut Chin (Wat Khun Samut Trawat) has now become surrounded by the sea due to land erosion. (Source: Barrow, R. (2016) in https://paknam.com/drone-photos/aerial-photos-of-wat-khun-samut-chin)

2. Research / Design Methodology

The research study, a process of designing a prototype of resilient house in Baan Khun Samut Chin, was based on analysis of physical problem data, field survey, literature review on design theory and related research/design projects, interviews with stakeholders in the community as well as the assessment of design outcome by the community. As shown in Figure 5, the process follows the following five steps:

Figure 4. The remaining structures of some houses are still trapped in the distant water (left) and numerous electricity poles that once ran parallel to the shoreline, are now half visible at a great distance from the coast (right). (Source: photo by the authors)

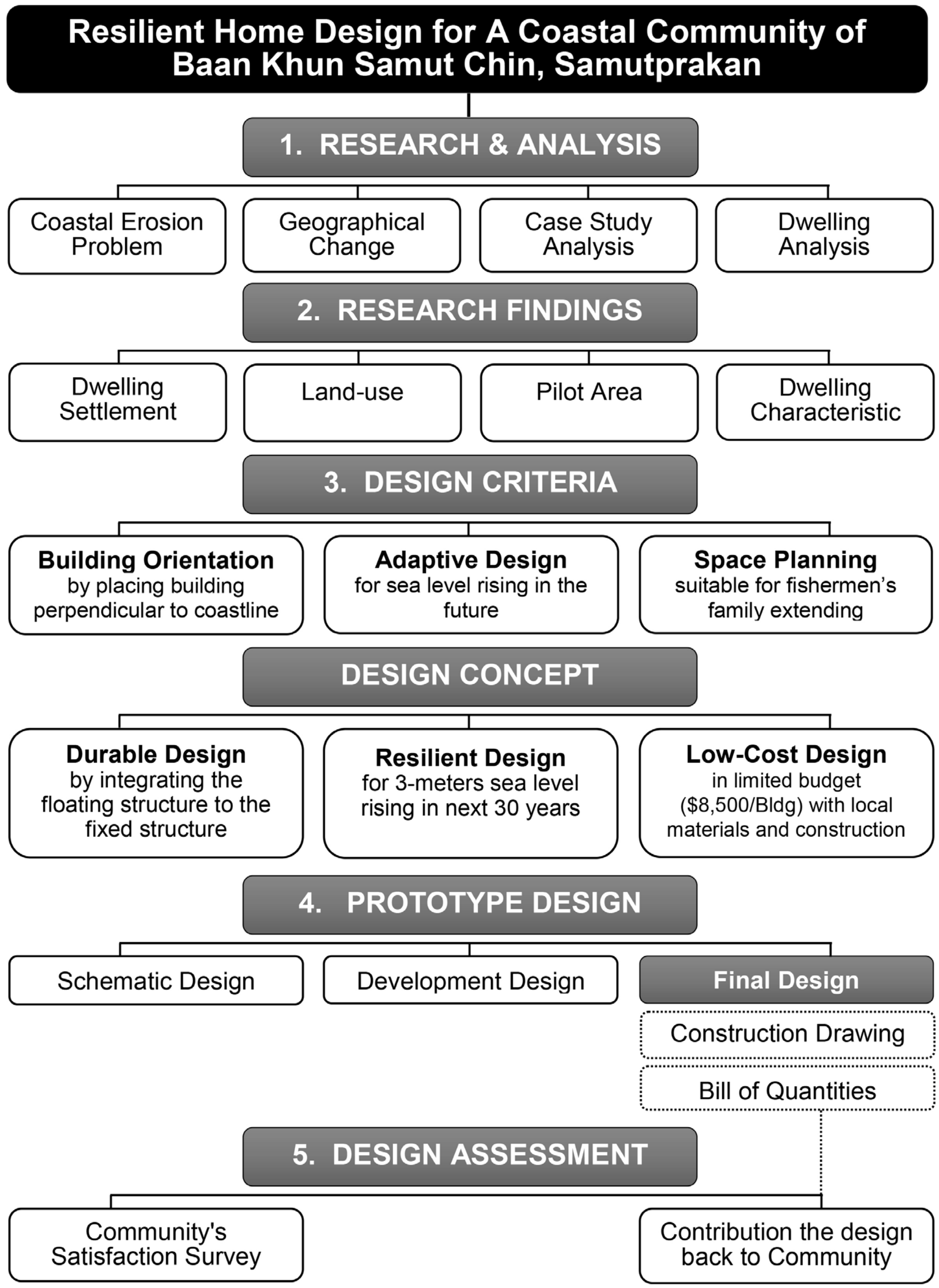

Figure 5. Framework diagram of Design / Research Methodology of Resilient Home Design for A Coastal Community of Baan Khun Samut Chin, Samutprakan

Step 1: Collecting relevant data on physical environments of community (local map evidences, aerial photographs from past to present, architectural survey drawings, data interviews), and related other research/design projects (theories, concepts, design techniques, solutions).

Step 2: Summarizing the research findings that could be applied to establish a design criteria and concept. This process included the analysis of dwelling settlement, land-use, house characteristics from past to present, as well as where the pilot area should be located.

Step 3: Defining the design criteria and architectural concept of prototype resilient house project in terms of the durability of building structure facing to erosion and flooded land, the adaptive ability of functional area forced to be changed in next 30 years, as well as the economy cost related to building material and construction technology application.

Step 4: Designing a prototype resilient house along with the process of Schematic Design, Design Development, through Final Design Stage with structural engineering calculation, and at last, producing the Construction Drawing Package with Bill of Quantities (BOQ) documentation.

Step 5: Assessing the architectural design result by community feedback (with SPSS statistical analysis) and contributing this Construction Drawing Package back to District Authority of Baan Khun Samut Chin for further implementation.

3. From Research Findings to Design Criteria & Concepts

3.1 Changes of Dwelling Settlement Pattern

In this preliminary study, an analysis of village settlement from past to present was conducted to understand the adaptation patterns and density of settlement in this community by converting aerial photographs into figure-ground diagrams. This changed settlement pattern adapted to the coastal erosion will provide a design guideline for community site planning design and building orientation.

From the analysis of aerial photographs and map evidences of the Office of Public Works and Urban Planning in Samutprakan Province, the findings showed that the pattern of settlement characteristics has changed markedly over the past 50 years with houses' relocation driven by the coastal erosion. The community has inevitably adapted their physical environments in order to survive the problem over these years. In 1974, the settlement pattern of nearly 600-700 households (Figure 6 top) appeared to be lying horizontally along the coastline owing to its potential site for both marine trade and coastal fishing careers. Only a few houses far from the coastline had been left isolated without any utilities approach. In the past, the established main pier and the road cut through with infrastructure system was once reached to the coastline community. However, nowadays, numerous electricity poles were just visibly seen in a vast ocean.

Since the severe coastal erosion came in 1991 (Figure 6 middle), the community was hardly able to adapt and deal with it in time. Some decided to move out while the others with fishing career continued to stay till the number of households had fallen by half (300 households remain). A significant change in re-settlement was that each residential unit, that was once horizontally parallel to the coastline, was turned to be located perpendicularly to the coastline. Many buildings have been submerged under water because of the substantially decreasing coastline area. As the eroded area increased, the community was forced to move their houses to a higher ground, one a kilometre away from the coastline. Fishing career were declining and some replaced by shrimp farm, leading to a change in land allocation to a long, thin rectangular shape of shrimp farm perpendicular to the sea. In addition, the community also had problems maintaining a balance between protecting the coastal erosion by planting mangroves and taking advantage of the sea for shrimp farm allotment.

To the present, 2020 (Figure 6 below), only 110 households left in the area, indicated that the ongoing erosion of coastal land has occurred more than 1.1 kilometers. This community would be seriously considered to be in a state of collapse if the erosion problem was still continuing. The settlement has almost changed from the horizontal pattern to be the perpendicular to all coastlines. The community has been aware of the ongoing serious land erosion problem. An attempt to plant mangroves as barrier preventing coastal erosion was re-started. In the maps, it was clearly seen that, in the last 50 years, Wat Khun Samut Chin (black dot in Figure 6 maps) has been the only surviving place, the one islet in the area. This was because the community tried intently to preserve their community temple by building a long concrete footbridge connected from the eroded mainland.

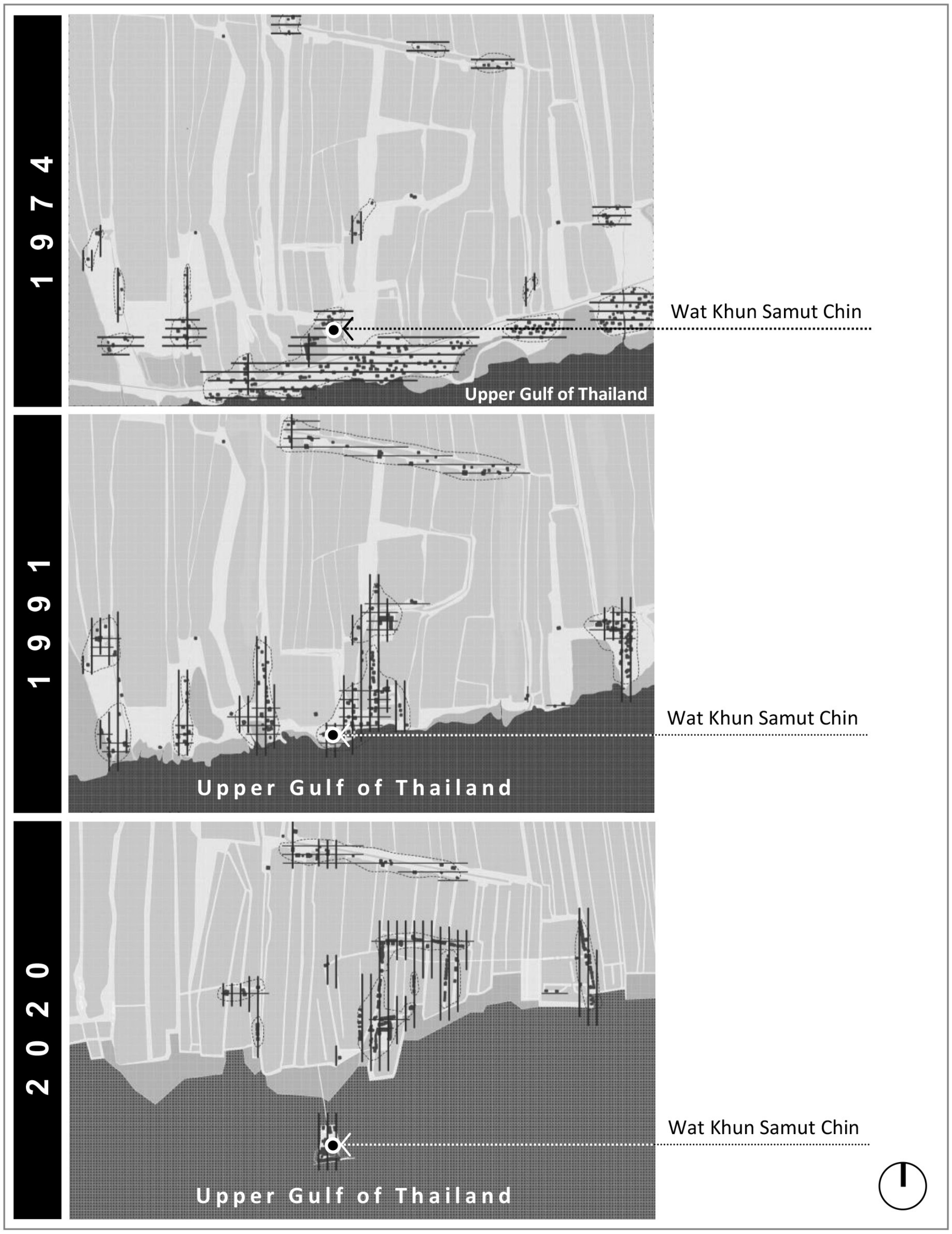

Figure 6. Figure-ground analysis diagrams of dwelling settlement pattern of Baan Khun Samut Chin in 1974 (above), 1991 (middle), and 2020 (below) has changed from the horizontal to perpendicular to the coastline. (Source: Samutprakan Office of Public Works and Town & Country Planning, modified by the authors, 2020.)

3.2 Design Criteria

According to the study of dwelling characteristics, land-use, and especially the research findings about pattern changes of dwelling settlement due to coastal erosion over the last 50 years, and reviews on other related studies. The main criteria have been considered for a resilient home design as follows.

3.2.1 Building Orientation / Structure

Considering the durability, the building orientation should be placed perpendicular to coastline avoiding the blockage of water tide and wave direction. Moreover, the idea of triangular-concrete piled breakwater model called “49A2”, which was already constructed at Baan Khun Samut Chin in 2006, was applied in the design to reduce the incident wave energy (Jarupongsakul, 2012).

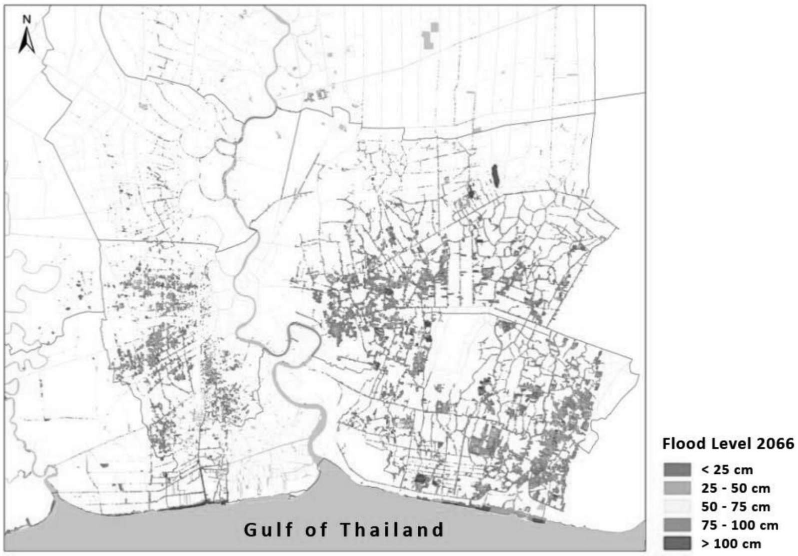

Figure 7. Map showing that the area of Ban Khun Samut Chin will have a sea level more than 1 meter in 2066. (Source: Trisirisatayawong, I. and Cheewinsiriwat, P. (2013))

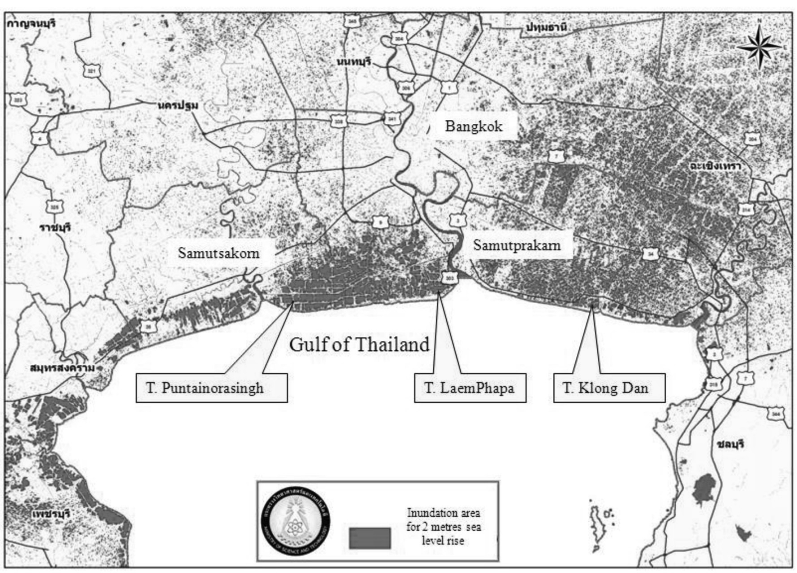

Figure 8. Inundation coastal areas in the Gulf of Thailand for the scenario of 2 meter sea level rise (Source: Climate Change Information Center, Department of Science and Technology (2009) Inundation areas of the Gulf of Thailand for scenario 2 meter sea level rise. Chulalongkorn University, Bangkok. cited in Kulpraneet, A. (2017))

3.2.2 Adaptive Design

Sea level rise is one of the most serious threats of climate change that is currently impacting coastal areas such as Baan Khun Samut Chin village. This is due to the continued increase of sea level from polar glacier melting and sea thermal expansion. The fisherman house should be designed to be adaptable for sea level rising in the future.

Based on the report on Coastal Erosion and High Sea Level Rising due to Climate Change of Bangkok Metropolitan Administration, the sea level will rise by 1 meter in the next 30-50 years (Urban Development Planning Division of BMA, 2013), which is consistent with the Assessment Report of Flooded Area from Sea Level Rise in Upper Coastal Area of Gulf of Thailand (Trisirisatayawong and Cheewinsiriwat, 2013) (Figure 7). During a seasonal flood of this local village, the average water level will rise 1.5 meters per year coupled with 60 cm. land subsidence. Another report of Climate Change Information Center, Department of Science and Technology, Chulalongkorn University, stated that Laemphapa (local territory including Baan Khun Samut Chin) will have a sea level rise of 2 meters in the future (Kulpraneet, 2017) (Figure 8). Therefore, the predictable water level from above data (1.00 m. sea level rise + 1.50 m. coastal flood + 0.60 m. land subsidence) will lead to the formulation of a worst-case scenario for the design criteria that the prototype should be adapted for approximately 3 meters of water level rise over the next 30 years.

3.2.3 Space Planning / Cost Control

The size of construction area and the practical cost control were accounted into the design. According to the study of fishermen's house in this area, a size of single family house were aprroximately around 40 m^2, complying to Global Humanitarian Standards (SPHERE, 2018).

Moreover, along with the calculation from a report on "Applicability of Microfinance for Adaptation to Sea Level Rise Impacts" (Kulpraneet. 2017) to estimate the adaptation cost per household supported by government over the next 30 years, the maximum cost of a house would be not exceeding than 300,000 Baht (around $8,500). Thus, this limited budgets was taken to be a main criteria for space planning design reflecting on lifestyle, cultural acceptability, as well as fishermen's family extending.

3.3 Design Concept

Following 3 main criteria above, the major concepts for architectural design were set on durability, disaster resilience, and low-cost design.

3.3.1 Durable Design

In addition to the perpendicular arrangement of the building to the coastline, an integration between the floating structure and the fixed structure was applied to the structural design of the building. To avoid wave energy obstruction, the less fixed foundations of building was, the more resilient ability of the building was ensured. The idea was to construct the houses in a way to allow them to float on the surface of rising sea level whereas the building's amphibious was still connected to the ground foundations in their own lands as necessary (Figure 9). The fixed structure was applied to reduce their Dead Loads as much as possible, leading to the design that there were only four columns with deep triangular-concrete pile foundation to support only roof structure. The loading weight of buoyancy structure itself or in conjunction with any Live Loads (user's weight, appliances, and furniture) was safely carried by the floors and walls of the house.

3.3.2 Resilient Design

Resulting from the above structural design in which buoyancy and fixed column were integrated, the vertical distance between floor to roof height would allow residents for their living adaptation in the case of sea level rising for 3 meters in the next 30 years, especially on activities related with fishing career. The light weight and easily adjustable material, or possibly folded or rotated, e.g., bamboo curtain and vinyl partition, was suggested for floors and walls' design. Additionally, if in 30-years and when the sea level was rising up to 3 meters, the family might be expanding and having need of more rooms for children, the planning design was prepared to transform an outdoor terrace to be a children bedroom by interlocking between previous hanging wall and raising floor (Figure 9 and 10). The ability to transform a usage area up toward buoyancy level changes would be suitable for fisherman lifestyle in the community under the worsen circumstance of the coastal situation.

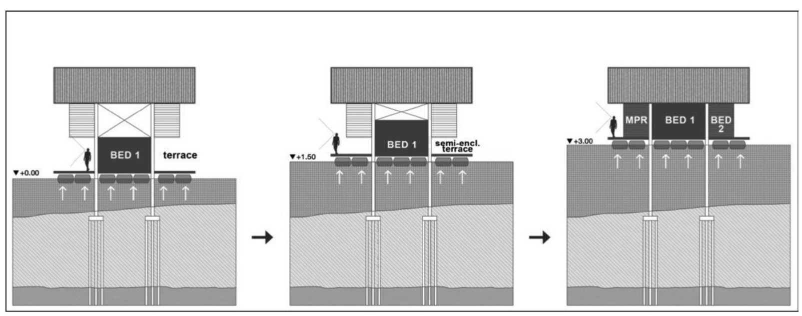

Figure 9. The conceptual idea of longitudinal section shown integrating the floating floor & walls to the fixed column supporting roof above, and how its adaptation from an outdoor terrace to be an extra bedroom when 3-meters sea level rising in the next 30 years. (Source: designed by the authors)

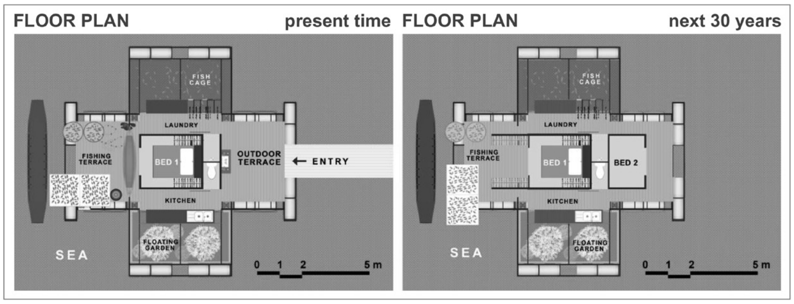

Figure 10. Floor plan of a resilient house shown adaptation from an outdoor terrace (left) to be a bedroom 2 for kid (right) when the sea level rises up to 3 meters in next 30 years (Source: designed by the authors)

3.3.3 Low-cost Design

As the limited budgets of 300,000 Baht/ house unit (approximately 60% compared to conventional buildings in the region), the indoor construction area would be around 36 m2 which was composed of a minimum standard area of 16 m^2 for living space per 2 persons including kitchen, toilet, and bathing room, and a terrace of 20 m^2, equally divided into front and back parts. The front terrace, facing to the sea, was for fishing activity. The back terrace was designed to be multipurpose open-platform which could be transformed into a child's room in the future. The material and construction technology should be practically affordable by a resident. Low-cost and local materials such as bamboo, timber frame, thatched roof/ corrugated cement roof and less expensive cement board, were applied in most parts of building. For dividing each building co-ordinating part such as floor slab, wall panel, column span, as well as steel frames, the modular system with regular prefabrication size should be also implemented for cost saving, effective use of materials, and even sustainability.

4. Prototype of Resilient House Design

The house was consisted of one storey with double-height level at present sea level. If the sea level was rising up, the outdoor terrace would be transformed to be an enclosed another bedroom. The functional utilities were for dwelling unit such as bedroom, toilet, bathing, and service corridor for kitchen and laundry, and for working space such as fishing terrace, floating basket for keeping fish in water, as well as floating vegetable garden. The calculation of the loading capacity on the prototype building was divided into 2 parts; a fixed structure with deep foundation and a floating structure with pontoons. The total load of buildings was reduced by the presence of the fixed structure, with only 4-columns and enclosed roof since triangular-concrete pile foundation acted as anchors tied to their own land. Therefore, the weighting load of the floating structure, both dead and live load, would rely on the number of PE pontoons. The calculation data of the total load (Table 1) showed that 48 tanks of 200-litres Polyethylene pontoons were required for supporting the total weight of the floating house structure at 7,688 kg (5,400 kg of live load + 2,288 kg of dead load), based on a safety factor of 1.2 in the structural stability control examination.

The availability of skilled labour and local construction materials were considered for building the house. The fixed column structure would be the most difficult part since the prefabricated triangular-concrete piles had to be transported by sea for its deep footing construction. However, the latter construction process would be easier and less complicated for locals to build by themselves. The steel structure for buoyancy platform was proposed to be tied with 200-litres Polyethylene pontoon filled with Polyurethane Foam inside. Each of a 14-kilogram pontoon had an approximate loading capacity for 170-200 kilograms and had long-term sea water resistance.

Summary of Structural Loading Analysis		Abbreviations
1.	**Main floating structure** 1.1 Live load = 36.00 m^2 (area of house) x 150 kg./ m^2 = 5,400.00 kg. 1.2 Dead Load Floor Structure = 1,101.20 kg. Wall Structure = 1,014.00 kg. Tank Frame = 172.80 kg. Total = 2,288.00 kg. Live Load + Dead Load = 5,400+2,288 = **7,688.00 kg.** Floating house Structure total weight (G) = **7,688.00 kg.**	LL of housing = 150 kg./ m^2 (based on building regulation)
2.	**Buoyancy force with completely submerged (Fa)** **Fa = (π.d²/4).ρ.g.*L*** = (3.14) x $(0.56)^2$/4 x 1000 x 10 x 0.84 = 2,067.88 N. = 206.78 kg./tank Buoyant force for 1 tank = V-G = 2,067.88 – 140 = 1,927.88 N./tank = 192.78 kg./tank Buoyant force (Fa) = 1.2 x 7,688 = 9,225.60 Number of tanks = 9,225.60/192.78 = 47.85 = **48 tanks** Total Buoyant force = 48 x 192.78 = **9,253.44** kg.	Fa: Buoyancy Force with Completely Submerged (N) ρ : Fluid specific mass (kg/m^3) = 1,000 kg./m^3 d : platform diameter = 0.56 m π : 3.14 g : Specific gravity (m/s^2) *L* : platform length (m) d : inner diameter = 0.84 m. G : tank PE empty weight = 14 kg.
3.	**Structural stability control = Fa – (SF . G)** = 9,253 – (1.2 x 7,688) = 9,253 – 9,225.60 = **27.40 kg. > 0 (Ok)**	Fa : platform floating force (N) SF : Safety factor = 1.2 G : Structure total weight = Floating house Structure total weight = 7,688 kg.

Table 1. Summary of structural loading analysis for prototype of resilient house at Baan Khun Samut Chin, Samutprakan (Source: by the authors)

In a construction planning, each space design was integrated with modular coordinating system to regular prefabrication size. For example, equally divided 1.20 x 2.40 cement board with regular 6-metres steel length was implemented and efficient for cost saving and material usage without any waste. For energy consumption, the house should be sustained by itself as much as possible. The rain-water collecting tank underneath raising platform and solar cell on the roof top were added to maintain energy consuming both sanitary and electrical system without relying on civil infrastructure. The followings were drawings of floor plan, section, and exploded axonometric of resilient house for Baan Khun Samut Chin community (Figure 10-12):

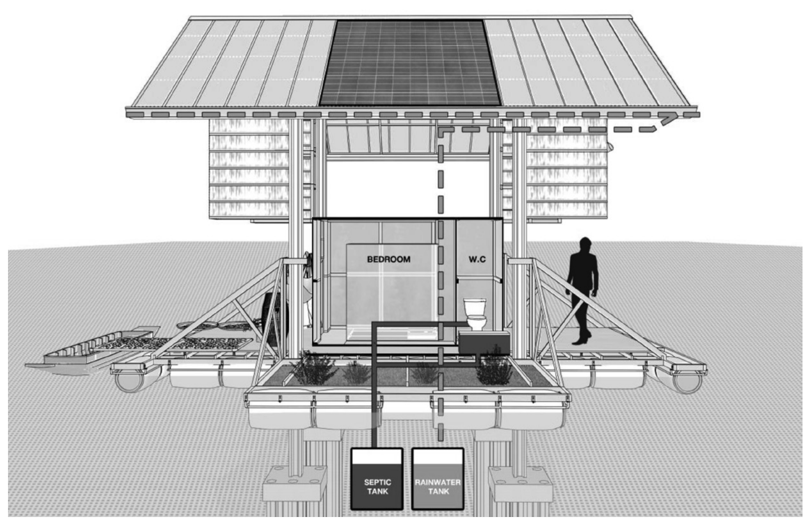

Figure 11. Perspective section of resilient house shown septic tank and rain water collecting tank underneath buoyancy platform, and solar cell on the roof (Source: designed by the authors)

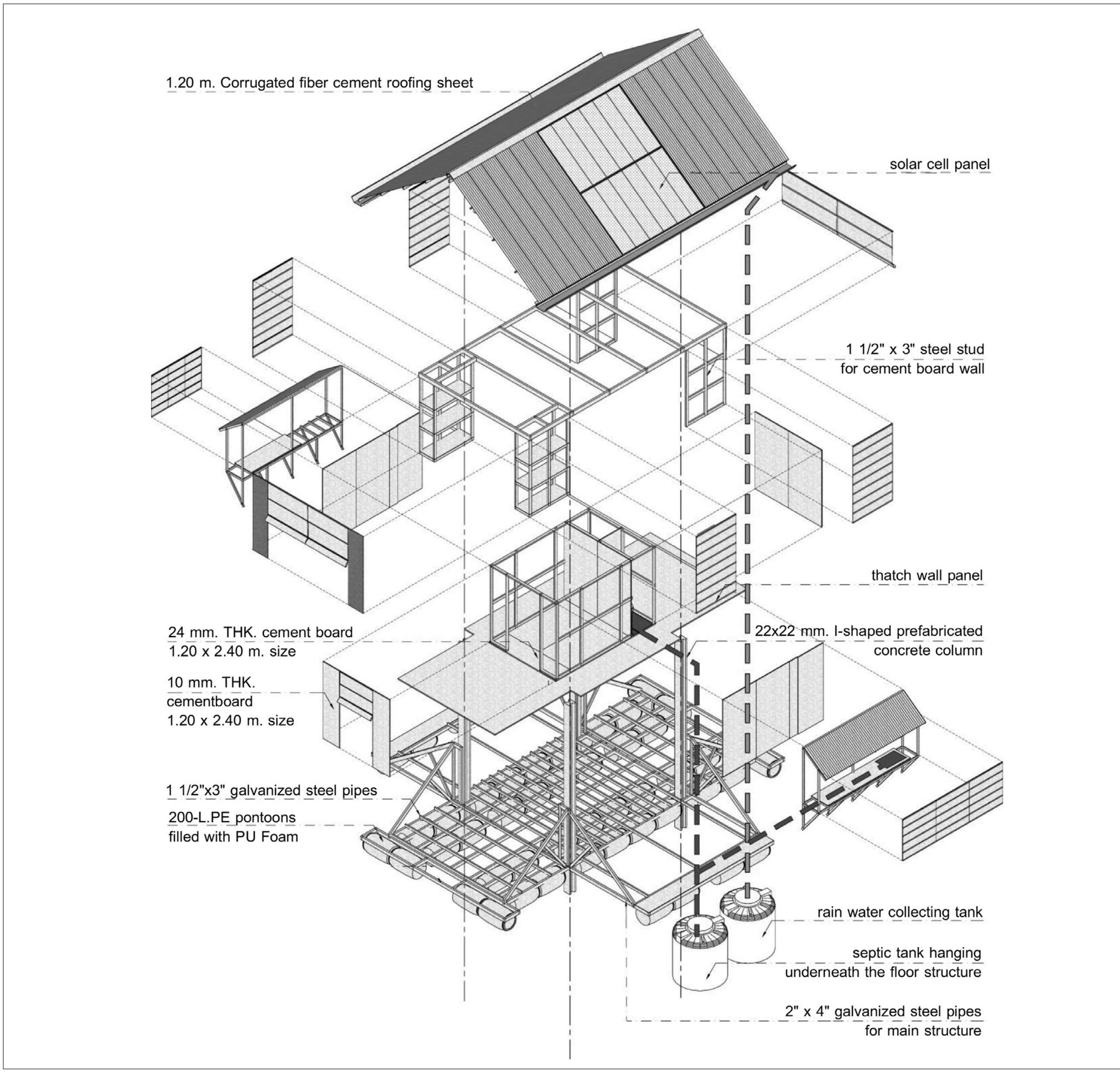

Figure 12. Exploded axonometric drawing of resilient house shown assemblage of each parts of building (Source: designed by the authors)

However, this experimental prototype should have the decision making involving the local community. To assess the reliability and feedback of proposed design, the questionnaires and interviews with descriptive statistics including means and standard deviation were applied with SPSS statistical analysis. The result showed that the community mostly agreed with design concept ranking such as 1) durable design with resistant to sun, wind, rain and especially avoiding wave energy obstruction (M = 4.77, SD = 0.42), 2) resilient design with amphibious capability to sea level changing (M = 4.72, SD = 0.45), and 3) low-cost design that villagers can build by themselves, in conjunction with government support (M = 4.63, SD = 0.84), respectively.

At the end of this study, the prototype design with construction drawing package were contributed back to the community for a further implementation in the near future (Figure 13). Also this experimental prototype won the third prize award in the ASA Experimental Design Competition 2020: “The Everyday Heritage”, which was organized by The Association of Siamese Architects under Royal Patronage (ASA, 2020) (Figure 14).

Figure 13. Community's survey and contributing the design package to Baan Khun Samut Chin Community with the village chief, Witsanu Kengsamut, the on July 16, 2020. (Source: photos by the authors)

5. Conclusion and Suggestions

As we all know that resilience against the coastal erosion, like many other problems, does not just have only absolute solution. It depends on many factors which lead to different approaches and variations in combination of forms, structures, materials, and construction techniques. This design result attempted to meet both of community requirements and site-specific situation of coastal erosion problem in Baan Khun Samut Chin village. However, it has not been yet implemented as an real exercise at the location. To finalize the validation for this experimental design, some additional review and development processes are needed:

1. The parameter between sea level rise and the year duration should be required a more detailed calculation. For this experimental design, the length dimension based on multiple data mentioned in design criteria section, was to determined as the worst-case scenario for resilient design concept of fixed roof and floating floor.

2. The adaptation of the house plan in relation to family expansion over 30 years may be more detailed, for example: a child room needs in the first 10 years, floor extending after a better family economy, as well as a solar penetration during the first 10 years that the roof is raised considerably higher than the floor at low tide, etc. These issues should be considered more with the community in participatory design process.

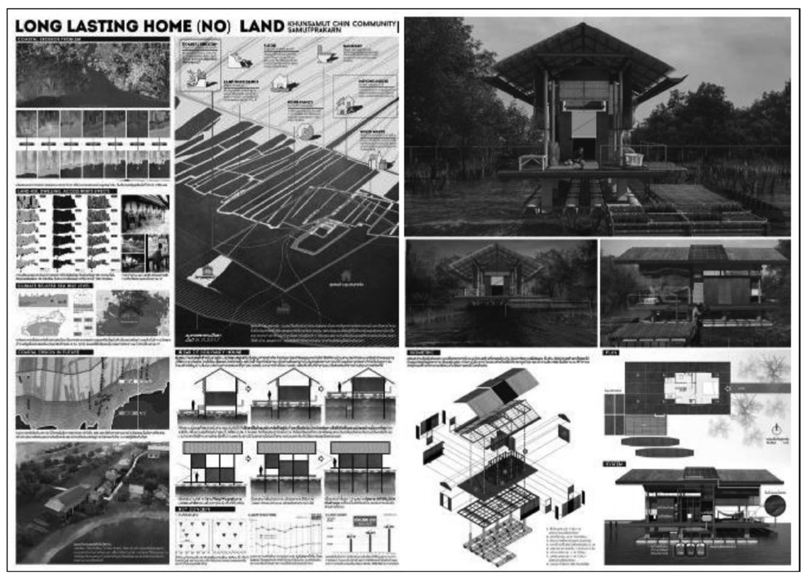

Figure 14. The presentation board of an experimental prototype house for Baan Khun Samut Chin community, submitted on the title "Long Lasting Home (no) land" in the ASA Experimental Design Competition 2020 organized by The Association of Siamese Architects under Royal Patronage. (Source: Boonlue, W. (2020))

3. The engineering calculation should be required to verify exactly again such as the length of building foundations, the effect of friction between the floating platform and the fixed structure in terms of noise and vibration, and the size specification of collecting rainwater tank as well as septic tank.

Hopefully, this experimental design of resilient home is expected to be a solution for Baan Khun Samut Chin community and those communities facing the same issues and government agencies with an urgent need for a ready and effective remedy.

6. Acknowledgement

The authors wishes to thank Assistant Professor Dr. Wijitbusaba Marome and Suriya Umpansiriratana, an architectural consultant for their valuable advice on the thesis project at Faculty of Architecture and Planning, Thammasat University, Professor Dr. Pusit Lertwattanaruk for helpful guidance in structural engineering, Associate Professor Dr. Pramot Sojisuporn for information of coastal waves at Baan Khun Samut Chin, and Dr. Boontawee Teamvan for beneficial review on social perspective of Baan Khun Samut Chin Community. And finally, special thanks go to the villagers in Baan Khun Samut Chin, and Witsanu Kengsamut, the village chief, for giving such great participations during the field survey.

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