Journal of Thai Interdisciplinary Research
Volume 13, Number 5, Pages 19 - 26

# Low income housing adaptation strategies to flood hazard in Chiang Mai, Thailand

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## Abstract

The slums are often situated in hazardous areas which are at high risk of flooding. Despite guidelines for the flood resilient house design, many low-income houses are ravaged by the flood waters. So, what are some suitable low-income housing design concepts for flood resilience? This research found that understanding flooding characteristics, household economy and the existing housing quality is an important step to create affordable housing improvements. It is not necessary for flood resilient housing to use only permanent building materials and structures, and there is no single method that is best for every low-income housing. Therefore, the 3 flexible concepts were established, including eco-robust design, eco-repairable design, and eco-adjustable design.

**Keywords**: adaptation, flood resilience, flooding, low income housing, slum

**Article history:** Received 24 February 2018, Accepted 11 June 2018

## 1. Introduction

Various studies have shown that climate change has increased the number and severity of natural disasters and also flooding disasters. They are becoming more frequent and severe around the globe, resulting in extensive damage [1,2]. The studies of the IPCC (Intergovernmental Panel on Climate Change) have found that the climate in the 21$^{st}$ century will have increased rainfall, possibly causing big storms. Heavy rainfall events will become heavier and more frequent [3]. According to a study of the future climate changes in Thailand showed that the average annual rainfall will increase by 15-25% in terms of distribution, intensity, duration and frequency. This means the risk of severe flood, flash floods and flood disasters may increase [4] which could cause damage to homes, homelessness, loss of human life and other property, sickness, and mental health problems [5,6]. Important factors that influence housing damage and living problems during floods are local geography and physical properties of soil and the soil structure, which affect the permeability of water, absorbency and drainage [7]. In addition, the quality of housing, which consists of material quality to resist against the water, structural capability and housing style, is one of the important factors that affects flood damage [8]. If the houses are not durable and are located in a flood zone, such as low-income houses and settlements, the potential risk of housing damage and other problems from flooding will increase [9,10].

Low income settlements are established and widely distributed in cities around the world. They grow in parallel with the development of the country [11] due to the mutual dependence between low income people and the cities [12]. They differ in size and other characteristics from country to country but they are common in hidden areas difficult to access. The areas are usually vulnerable to disasters and not suitable for living, such as drainage canals, areas under bridges or wilderness areas. Most of them involve illegal occupation of land. There are various types of land tenure such as intrusion or renting [12]. Furthermore, low-income housing is impermanent, dilapidated, has unhygienic environments and poor sanitation which causes many problems in people's lives and makes them more vulnerable to hazards from severe flooding than normal communities [13]. In some flooding situations, they are evacuated because the community and residents cannot accommodate the flood, and after the flood they have to face housing damages which they cannot afford to repair and restore [14].

In Chiang Mai province, 25,459 households living in 132 low-income settlements have been found. The number of households and low-income settlements is the third highest following Bangkok and Nakhon Ratchasima provinces [15]. At present, Chiang Mai province has grown rapidly and become the second largest economic region of Thailand [16]. For this situation, low-income settlements in Chiang Mai are growing with economic expansion. Since 2005, Chiang Mai has faced 4 severe

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DOI 10.14456/jtir.2018.45


**Figure 1** Location of three study areas

**Table 1** Flood information of the 3 low-income settlements

| Community | Year | Flood Depth at Benchmark (m) | Flood Duration (days) | Flow Velocity (m/s) | Flood Frequency (number/yr) |
|---|---|---|---|---|---|
| Bansanku | Regular flood | 0.4 | 5 | 1.2 | 3 |
| | 2001 | 1.4 | 10 | 1.2 | 4 |
| | 2006 | 0.7 | 10 | >1.2-1.5 | 3 |
| | 2011 | 0.9 | 6 | >1.2-1.5 | 2 |
| Kampangam | Regular flood | 0.3 | 3 | 1.6 | 5 |
| | 2006 | 0.55 | 3 | >1.6-2.0 | 4 |
| | 2011 | 0.7 | 4 | 1.6 | 4 |
| Samukeepattana | Regular flood | 0.5 | 3 | 3.4 | 15 |
| | 2001 | 0.65 | 1 | >3.4 | 10 |
| | 2007 | 1.15 | 1.5 | >3.4 | 15 |
| | 2011 | 0.7 | 1 | 3.4 | 15 |

floods with various flood characteristics which are caused by Chiang Mai province’s geography, such as plateau, plain, alluvial plain and basin. A lot of people have become homeless and experienced grave loss, 80% of them are poor people [17]. Although the Thai government has established flood policy and grants to assist flood victims, suffering from flood is still rampant [13]. This study aims to answer the question “what low-income housing design concepts for flood resilience should look like” by studying the low-income settlements in Chiang Mai province as a case study.

## 2. Methodology

Three low-income settlements, comprising 146 households, were selected for this study i.e. Bansanku (21 households), Samukeepattana (64 households) and Kampangam (61 households) as shown in Figure 1. They are low-income settlements established more than 10 years ago, flood every year (flood bed) and have different flood characteristics (flash flood, drainage flood and river flood). Interview data of flood characteristics ( flood frequency, duration of flood, flood depth and flood flow velocity) during 2001-2015, living problems and housing damage during floods, and household information (career, income, living behavior, future housing demand) were collected. Data about geography, contour and traces of housing damage were collected by surveying and observation. The data were analyzed for developing low-income housing design concepts for flooding by using a constant comparative analysis method.

## 3. Results

### 3.1 Flood characteristics

Bansanku is located in a basin area which causes drainage floods for about 10 days with a depth of 0.7-1.10 m, low flow velocity and slow rising. It can even experience two-three floods/year. Kampangam is located beside Maekha canal which has been flooded five times

**Table 2** Effects of flooding on the 3 low-income settlements

| Effects of flooding on the low-income housing | | % of households in Bansanku | | | | % of households in Kampangam | | | % of households in Samukeepattana | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.4 m. | 0.7 m. | 0.9 m. | 1.4 m. | 0.3 m. | 0.55 m. | 0.7 m. | 0.5 m. | 0.65 m. | 0.7 m. | 1.15 m. |
| **Housing damages** | Non-damage | 76.19 | 33.33 | 19.05 | 23.81 | 96.88 | 65.63 | 75.00 | 96.72 | 54.10 | 60.66 | 63.93 |
| | Architectural damage | 23.81 | 38.10 | 57.14 | 47.62 | 3.13 | 23.44 | 18.75 | 3.28 | 32.79 | 31.15 | 21.31 |
| | Structural damage | 0.00 | 28.57 | 28.57 | 28.57 | 0.00 | 10.94 | 6.25 | 0.00 | 13.11 | 8.20 | 14.75 |
| | Broken house | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Living problems** | No-problem | 80.95 | 19.05 | 9.52 | 0.00 | 90.63 | 62.50 | 73.44 | 80.33 | 47.54 | 62.30 | 27.87 |
| | 1 or more problems | 19.05 | 52.38 | 66.67 | 14.29 | 9.38 | 26.56 | 18.75 | 19.67 | 40.98 | 29.51 | 39.34 |
| | Unable live at home | 0.00 | 28.57 | 28.57 | 85.71 | 0.00 | 10.94 | 7.81 | 0.00 | 11.48 | 8.20 | 32.79 |

a year. The water flows slowly from the canal and covers the community which can be called a river flood. The flood is about 0.5 m. and each flood lasts about 4 days because it drains rapidly. These two communities are different from Samunkeepattana, which straddles the Khajae canal. It is in the flood path from Pui Mountain to the low land, which causes flash floods in Samukee-pattana. Therefore, the flooding in Samunkeepattana has high velocity, depth, and frequency (15 times/year), but it has a short duration (only 1 day/flood) as the data in Table 1 shows.

### 3.2 Problems during the floods

The living problems of households in Bansanku begin at a flood depth of 0.4 m, when toilets and electricity breakdown, since most toilets in all the 1 story, elevated 1 story and 2 story houses are built on the ground floor. When flood reaches a depth of 0.7-0.9 m, electricity cannot be used. In 2001, 85% of residents in Bansanku were moved out of the settlement which had a flood depth of 1.4 m. The damaged sections of the housing in Bansanku is usually part of the architectural composition, such as swell, decay and warp of doors and windows, and this damage begins at a flood depth of 0.4 m.

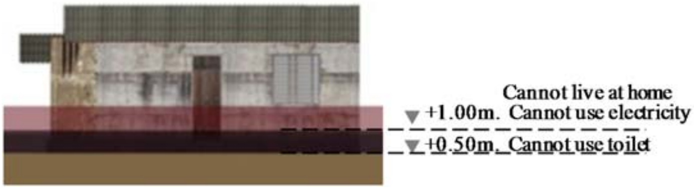
Kampangam residents usually suffer little from regular floods since these floods typically have low depth (0.3 m.), short duration and low velocity. They have fewer living problems at 0.7 m. of flood depth in 2011 than 0.55 m. of flood depth in 2005 because many of households in the community improved their houses.

The average annual flood of Samukeepatana slightly affects the residents' living but doesn't cause much housing damage; however, both effects increased with the rising level of flood. Samukeepatana has floods which are short in duration (1-2 days) but high in velocity. After the flood in 2007 which had a depth of 1.15 m. and a flow of 3.4 m/s, most residents decided to improve their houses, causing the houses to be more resilient. The result is that they were less affected in terms of living and housing damage by the flood in 2011 than the flood in 2001 (Table 2). The damage of building structures such as columns and beams is more likely found after floods than the damage of building architecture such as floors, walls, doors, and windows.

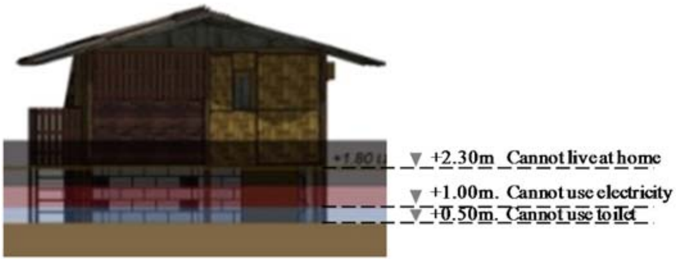
It can be seen that living problems during floods before people have to be evacuated vary with the flood depth. The housing style i.e. 1-story house, 1-story elevated house, and 2-story house is also a factor which affects the living problems as shown in Figure 2. Most of the toilets have problems after 0.5 m. of flood depth, and electricity cannot be used after flood depth reaches 1.0 m. These problems are caused by the location of toilet, which is usually built on the ground floor, and electrical outlets or light switches, which are 1.2 m above finished floor level so all electrical power must be shut down off. However, flood depth does not directly affect housing damage, a flood depth of 0.9 m for 6 days caused less housing damage than a flood depth of 0.7 m for 10 days. Shortage of food and resources rarely occurs during floods there since it is in the city and residents can walk out to get assistance.

### 3.3 Adaptations of people with low incomes

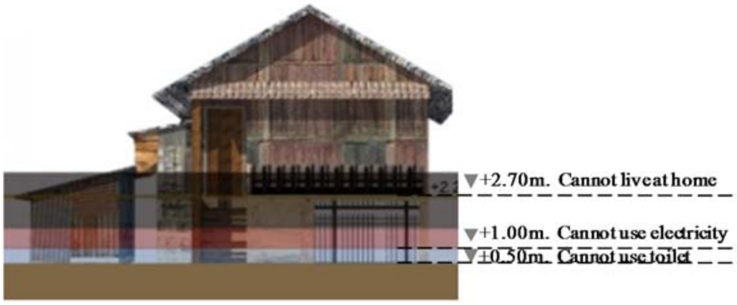
One thing in common amongst people with low incomes is the ability to live simply. In severe floods they have to evacuate from their houses to live at the nearest market, school or other place and adjust to living with no room, no toilet and no electricity. In the case with toilets, they solved the problem by using their neighbor's toilets. Even when they cannot use electricity, they can still live normally in their houses since they have fewer electrical appliances. Although low incomes, they still try to protect their homes according to their ability by learning from problems. They cannot restore their houses instantly after floods but they do it when the household has sufficient funds or they have gotten assistance from authorities. In the past 10 years, housing in the 3 communities improved for different reasons, including damage from floods, storms, and deterioration. House designs and building materials changed in 88.5% of housing stock in Samukeepattana, 47.6% of houses in Bansanku and only 29.7% of houses in Kampangam, from a 1-storey house to an elevated 1-storey or 2-storey house and from non-permanent structural materials to




(A) 1-storey house




(B) 1-storey house with basement




(C) 2-storey house

**Figure 2** (A)-(C) Living problems on difference housing styles

permanent structural materials. Permanent structural materials and temporary architectural materials were usually selected for housing in Samukeepattana, permanent structural materials and architectural materials for the first floor of housing in Bansanku and almost all temporary materials for housing in Samukeepattana. Inexpensive and repairable building materials which can be found near the communities were selected. Most of the housing improvements were made for avoiding damage from a flood similar to the previous flood, and were not aimed at prevention of future flood damage. Therefore, if future floods are more severe, the residents will probably have more problems and have to evacuate from their houses.

### 3.4 Behaviors of people with low incomes

Residents in each community are mostly relatives who are “hill tribe” people and the indigenous peoples of various areas in Chiang Mai. They have immigrated to the city searching for jobs such as street vendors, construction laborers, making hand crafted souvenirs and so on. Therefore, the housing’s function varies according to the household occupation, for example, some households in Kampangam need to have space for making souvenirs (Figure 3) or space for parking vendor carts, which have many styles and sizes such as motorcycle with sidecar. The downstair spaces in elevated houses and the front yards of 1-storey or 2-storey houses are used as the living, meeting and working areas. Some housing areas beside or behind the houses are used for parking, laundry and drying functions. From the survey, it is found that an average 7.0 $m^2$ of housing space is needed per person, which is consistent with the standard of low-income housing of the National Housing Authority of Thailand.

**Figure 3** Basement area of the house used as working area

**3.5 Affordable housing costs for people with low income**

The people in all 3 communities live below the poverty line of Thailand, which is 2,572 Baht/person/ month as shown in Table 3. The affordable rate for housing can be calculated by 10% of the household income according to Thailand consumer price index of low-income people (Government Housing Bank: Academic section , 2013). Therefore, the cost for housing improvement of Bansanku, Kampangam and Samukee-pattana should be 10,750 Baht/year, 9,125 Baht/year, and 12,227 Baht/year.

**3.6 Low-income housing design concepts for flood resilience**

From the study, many factors were found related to housing design against flooding, i.e. flood characteristics, affordability, household problems during floods and residents' behavior. Residents must try to find a suitable design for resisting current and future floods as effectively as possible. They should start by understanding flood characteristics which affect them, since residents in the same village can be affected differently. Therefore, low-income housing design for flood resilience cannot be a fixed model, but can be shown as conceptual design principle which emphasizes key points of being able to accept and live with flooding without significant housing damage. The residents will be able to live during flood and recover by themselves after the situation returns to normal. The design principles can be divided into 3 concepts (Figure 4) which can be integrated for more effectiveness and efficiency.

3.6.1 Eco-robust concept

This concept is for enhancing housing capability to resist flood damage for as long as the flood lasts. The important points are not only allowing the flood to pass through and preventing housing damage, but also reducing the cost. The cost will be reduced by careful consideration of individual housing problem situations. Therefore, it is not necessary to have 2-storey houses with concrete and steel structure. Instead, the houses could be 1-story with non-permanent structures if they are in river floods similar to the flooding in Kampangam. The eco-robust design of Samunkeepattana, which experiences flash floods with short duration, should be 1-storey elevated houses to allow water to move through rapidly. It is not necessary for all parts of the house to be strong, but the basement structure, such as columns and beams, should have strong construction with permanent materials, such as reinforced concrete, steel or hard wood. The architectural parts, such as walls, floors, doors, windows, and so on, can be permanent, non-permanent or reused building materials depending on household economics. The housing in communities with drainage floods, such as Bansanku, does not have to be strong but flood resistant materials, such as PVC, concrete, or brick, should be used in all parts of the building.

3.6.2 Eco-repairable concept

This concept does not only accept flooding but also accepts damage to the house after flooding, which is usually architectural damage. Therefore, the damage can be rapidly and easily repaired with low cost by the owners. For example, houses in Bansanku use permanent structures to prevent erosion during long flood durations but use non-permanent materials such as bamboo walls or plywood walls, which are affordable, available locally, and easy to maintain, in architectural areas (Figure 5). This concept should be used in addition to maximizing living capability during the flood, which is the third requirement.

3.6.3 Eco-adjustable concept

This concept suggests space preparation for living according to the household economy and flood characteristics. Building components or furniture should be useful both in normal and flooding situations by being transformable. For example, in an eco-adjustable design for a 1-storey house with not more than 1.00 m. flood depth and short flood duration, the owners can adjust their high (0.8-1.0m.), strong furniture, such as beds, tables, cabinets, and shelves, to become the floor as shown in Figure 6. The door panels, window panels or cabinet panels can be platforms to be disassembled and moved (Figure 7). In addition, the owners should try to determine the strength, size and arrangement of fixtures before the flood. If existing furniture is not suitable, the owners can build new furniture by using steel frames and plywood panels as shelves in normal situations and become the floor during floods as shown in Figure 8.

For a permanent house with a strong structure, hanging a beam on the column for laying panels such as door and window panels can increase living space

**Table 3** Income and affordable cost

| Low-income settlement | Household income (year) | Income (person/month) | Affordable cost (year) |
|---|---|---|---|
| Bansanku | 107,500 | 2,239.583 | 10,750 |
| Kampangam | 91,250 | 1,901.042 | 9,125 |
| Samukeepattana | 122,275 | 2,547.396 | 12,227 |

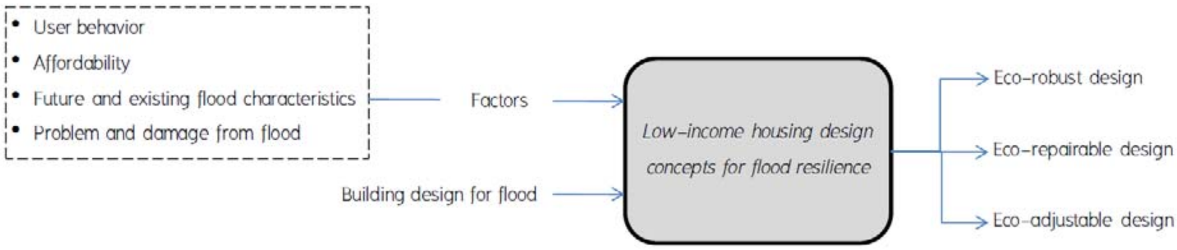



**Figure 4** Framework for conceptual analysis

(A) Bamboo wall (B) Plywood wall

**Figure 5** Examples of non-permanent wall materials

during flood and the house would not be cluttered in a normal situation. This is one example applied from this concept as shown in Figure 9. The columns should be steel, concrete or hard wood and the minimum size of the column should not be less than 0.15×0.15 m., however, the strength of structure has to be checked for safety load. The distance between two columns should not be more than 3m center to center of the columns.

## 4. Discussion and Conclusions

While the 3 low-income settlements differ in size and other characteristics, they have common aspects, such as the settlements are difficult to access and face high levels of disaster risk [12]. They are hidden from plain view of city center but are close to some natural water source, such as Maekha Canal, in business areas, or other undesirable locations [13,14]. They are crowed in poor-quality housing structures built with impermanent material so it is more affected by severe weather conditions than normal housing [18]. During disaster situations, residents are often evacuated from the area because the houses cannot withstand a storm or flood. In addition, there is a limited budget to repair and restore the housing after flood. Damage and problems of each community are different depending on the physical condition of the community, housing and severity of floods [5], as can be seen from the 3 communities studied.

Bansanku faces high flood depths and long flood durations, which cause living problems, structural damage, and non-structural housing damage. The housing style should include raised floors and flood-resistant materials [14] which can be in the flood more 10 days. Kampangam often has floods with low depth and short duration, so it is less affected by the floods. Due to these characteristics, housing in Kampangam can utilize permanent or non-permanent building materials that can stand in a flood for more than 5 days. The houses in Samunkeepattana are highly affected by floods with high flood depth, high velocity, and long duration, so the housing style should be concerned with building strength and form [9]. However, the residents have lacked the financial resources and the knowledge to carry out risk reduction efforts.

The existing adaptation strategies for flood resilient housing, such as exceeding minimum floor levels, constructing multistorey homes and using the lower level for non-living areas, using water resistant materials, designing a garden that will safely redirect water, and raising floor level, include high technology and cost [19,9,20]. In addition, amphibious structures that respond to floods like ships to a rising tide, floating on the water's surface called "floating house", is also recommended by various government. Resilience does not come without cost, so these strategies cannot be afforded by low income people. However, there are some options for low cost resilient housing such as

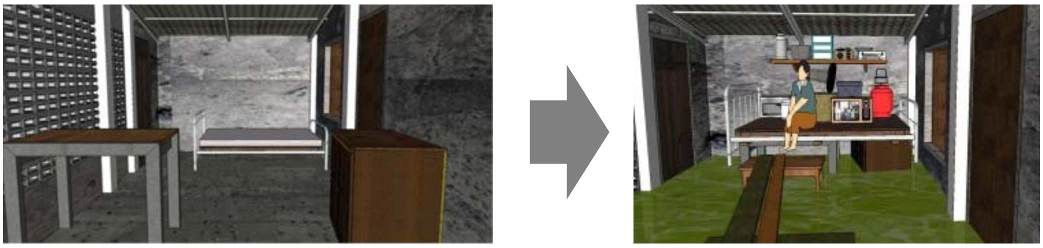


**Figure 6** Furniture attributed to be flooring during flood

**Figure 7** Disassembly door and window hinge

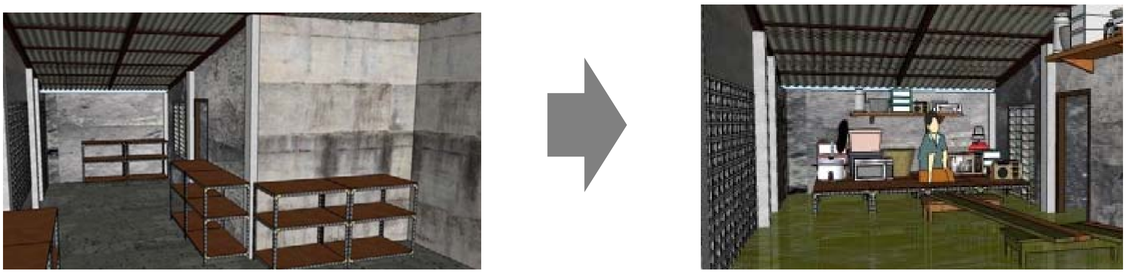


**Figure 8** Shelves transformed to flooring during flood

**Figure 9** Hanging beam on the column for future flooring (door panel or window panel)

utilizing local natural materials and mutual self-help [21,14] which takes a long time and a lot of labors. They are ideal concepts, but not suitable for low-income people in the city who work a lot and don't have enough free time [12]. Therefore, low-income housing design concepts for flood resilience must be flexible. They should be adjusted according to household information and flood characteristics. The concepts have to be appropriate for 1) the economic potential of each household, 2) the environmental context, 3) local regulations, and 4) flood characteristics [14].

Flood-resistant housing concepts were established in order to help low-income people live with floods, including eco-robust, eco-repairable, and eco-adjustable designs. The concepts emphasized allowing flood to pass rapidly through the drainage network while helping residents live through flood and minimize damage after flood. In addition, they are affordable and provide ways in which the residents can use the fixtures and furniture both in flooded and normal situations. Therefore, the low-income people should evaluate their own needs and their vulnerability before deciding which home improving concepts are appropriate for them.

**Acknowledgment**

Financial support from the Thailand Research Fund (TRF) for this research project is gratefully acknowledged.

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