Guidelines for the Environmentally Friendly Renovation of Urban Houses after Flooding

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Abstract

The environmental impact of recent flooding is immediately obvious. This paper will examine how different levels of flooding impact urban dwellings and propose model methods to rebuild those using environmentally friendly, sustainable designs. The materials and structures damaged by flooding will be considered based on the depth of floodwaters that would affect them. Below 0.3 meters: materials like vinyl, wood, laminated wood, paint, metal, gypsum, fibercement and wallpaper in 'floor and light weight wall systems' will be damaged. Below 2 meters: systems including doors and windows and electrical wiring, materials like stair finishings and stairs' wooden structure will be impacted. Over 2 meters: ceiling, lighting, air-conditioning and telecommunications systems will be affected, if not destroyed.

The study found that the 94% of environmental impact is in the architectural component, mainly striking the wall, floor and roof systems at approximately 44%, 25% and 17%, respectively. It is obvious that one-third of the main proportions of the architectural component, or 43% of the material, is damaged by the flood. Comparing environmental impact of wall's system indicates that the figure of post-flood wall system's exceed an existing by 8%, and rural areas can recover more rapidly than urban.

In conclusion, the study offers 3 sustainability plans: a short-term plan which encourage the installation of water resistant material; a medium-term plan for renovating a structure so it can be adjusted to avoid floodwaters; and a long-term plan that involves community support for sustainable forest manufacture by following the life cycle of wood construction.

Keywords: environmentally friendly, flooding, urban houses

1. Introduction

Climate change is a critical issue that impacts ASEAN people in areas like temperature, natural disasters, and changing seasons. Agriculture is clearly not the only area impacted by seasonal variance; it also affects the entire ASEAN economy by lowering productivity. Several natural disasters have created major problems for the region: most dramatically, the tsunami that killed more than a thousand people in 2004; a series of powerful storms and landslides that destroyed thousands of households over the past year; and the most severe flood on record in this region, from which we are still recovering. Many countries have suffered damages in the past year that would once have occurred over a decade. Thailand lost more than billion baht, more than double the amount lost to natural disasters over the past 10 years. [1] Laos lost over 87 million dollars [2], and more than 8.5 million square meters of arable rice fields. Cambodia lost more than 191 million square meters of rice fields and a total agricultural area of 16 million square meters. The Philippines had more than 24 million people affected by flooding, leaving many homeless and inundating cultivated areas. And Myanmar lost over 1.64 million dollars. [3]

This research continues studies from "Research and Development Project on Environmentally Friendly Innovation and Finished Goods Applications to Support NHA's Future Housing Development Business Model". [4] The study focuses on the environmentally friendly, sustainable approach to repairing urban houses damaged by flood.

The floods have created a combination of ecological and economic concerns. Repairing waterlogged buildings means a high cost of materials and labor, especially if materials have to be imported from other countries. But if each house uses the opportunity to incorporate environmentally friendly design they can embrace sustainability in a way that may eventually offset the cost of living and lead to a better lifestyle.

The flood may have been a blessing in disguise, because it could lead to a better quality of life and the adoption of sustainable architecture, provided the plan is effectively implemented.

2. Objectives

1) To study the damage to urban houses after flooding.

2) To study the environmentally friendly impacts to urban houses damaged by the flood.

3) To propose that renovation guidelines for urban houses incorporate sustainable design elements.

3. Literature Reviews

3.1 Climate change prediction

Changing climate is an imperative research topic. The data studied in the 3-decade period between 1971-2000 found that Bangkok's average temperature was around 25.5°c in winter, 28.5°c in summer and 27.75°c in the rainy season [5], higher by around 2°c than Bangkok's average over the last 30-years. [6] Moreover, IPCC studies found that the temperature in the next century could increase over 3°c and absolute humidity might increase by a staggering 10% [7]. These conditions will affect human comfort, if not survival, soon.

This report will focus on flooding. The sea level, forecast at half a meter higher in the next decade [8], was far below what the 8-year flood level data. The flood level showed a peak flood height of 3.50-5.50 meters, which stayed at that level for over 7 days [9]. Floods in the North, Central, Northeastern and Eastern parts of Thailand were closer to normal levels of flooding at 1.00-2.50 meter [10]. Architectural design in the future should try to counteract the problems caused by the excessive flooding in urban areas.

3.2 Architectural solution for flooding

There are three ways architecture can help counteract flooding. They are:

1. High platform structure - Building a single storey house on a platform at a height of 0.7-2.6 meter costs about 5 million baht. Some examples are 'Khum khun pan,' in Ayutthaya, and 'Ruen kum tieng,' in Chiang Mai.

2. Raft structure - The raft is a 1-to-2 storey structure built from wood, steel or concrete. The Base could be constructed with bamboo, a metal tank, and foam for between 50,000 baht - 29 million baht.[11] The steel structure could be welded in a waffle or crosswise shape like a Lego block [12[,[13] such as 'Sakakrung floating community', in Uthaithani, 'Raft house village, in Pitsanulok, 'Floating House', in Kondor Projektentwicklung GmbH, in Germany, and 'Watervilla Aalsmeer', in The Netherlands.

3. Adjustable structure - A 1-to-2 storey wooden structure and with a 200 liter tank as base would cost about 0.7-21.0 million baht. The one-way track structure would be vertically supported by 4 columns. [14] Other constructions would use a light-weight 10x20x1.2 meter concrete base shaped like a waffle [15] much like the 'Floating house' by the Department of Public Works and Town and

Country Planning and 'Amphibious Houses for Rising Water Levels', in The Netherlands.

There are 3 limiting factors to this study. The maximum building cost was 2 million baht. Next, the material considered is only available in the architecture system. Lastly, the furniture is not considered.

This study focuses on rebuilding environmentally friendly houses. For our purposes I will define each of these as:

1. Urban house - studied from NHA's project [16] which is built for low to medium income people. The homes are built from a reinforced concrete structure with ceramic walls and finished floors.

2. Rural house - studied from rural areas in Thailand. The homes are built of wood and other local materials. A high platform structure will be built at level 0.7-2.6 meter.

3.3 Environmentally friendly

There are two types of environmental impact issues in Thailand. They are energy efficiency concerns, like TREE's and TEEAM, and environmental concerns such as Green Label, LCI Thailand and SCG Eco-value. [4] This research uses environmental impact assessment criteria based on the life cycle analysis concept. Though the studies of life cycle materials have increased in amplitude and awareness internationally, only a few in Thailand have examined construction materials.

The international environmental impact criteria studies are a useful reference because they have better data of life-cycle materials assessment. Possible criteria for this evaluation are selected on the basis of LCA-tool of BEES, U.S. National Institute of Standards and Technology (NIST) and an impact assessment method collection, CML2001, Institute of Environmental Sciences, Leiden University, the Netherlands. The criteria selected, which is CML 2001 followed by a cement lifecycle evaluated in Thailand, are now evaluated and called environmental impact index. All 9 indices selected are as follows;

1. Resources depletion (Res. D) targets the depletion of non-renewable or renewable resources that cannot be renewed in one's lifetime.

2. Global Warming (GW) is the potential contribution of a substance to the greenhouse effect. This value has been calculated for a number of substances over a standard period of 100-years.

3. Acidification (Acid.) is expressed relative to the acidifying effect of Sulfur Dioxide (SO_2) in soil, air and water. Other known acidifying substances are nitrogen oxides and ammonia. Sulfur Oxide (SO_x) has been added, with the same value as SO_2. The time span is eternal and the geographical scale varies between local and continental.

4. Eutrophication (Eutro.), also known as nitrification, includes all impacts due to excessive levels of macronutrients in the environment caused by emissions of nutrients to air, water and soil. Time span effect is permanent, and the geographical scale varies between local and continental. The reference substance is Phosphates (PO_4) from CML2001.

5. Ozone depletion (Ozon.) has been established mainly for hydrocarbons containing combined bromine, fluorine and chlorine, or CFCs. One of the substances (CFC-11) has been adopted as a reference. This category is output-related and measured on a global scale. The geographic scope of this indicator is global. The time span is infinite.

6. Smog Formation (Smog) or Photo-oxidant formation is the formation of reactive substances (mainly ozone) which are injurious to human health, ecosystems and, potentially, crops. The interaction includes Nitrogen Oxide (NO_x) and Volatile organic Compounds, or VOCs, from industry and transportation. The process uses Ethylene to measure the change. The measurements are taken over 5 days and the geographical scale varies between local and continental.

7. Eco-toxicity (Eco. T) refers to the impact on fresh water ecosystems, as a result of emissions of

toxic substances to air, water and soil. Eco-toxicity Potential (FAETP) is calculated with USES-LCA, and describes the fate exposure and effects of toxic substances. The time horizon is infinite. Characterization factors are expressed as 1,4-dichlorobenzene (1, 4-D). The indicator applies across global, continental, regional and local scales.

8. Human-toxicity (Hu. T) concerns effects of toxic substances on the human environment. This criterion measures the level and categories of human-toxicity from carcinogens and non-carcinogens by using both Benzene and Toluene as reference substances. The geographic scope of this indicator is determined by the fate of a substance and can vary between local and global scale.

9. Embodied Energy (Em.) is the sum of energy inputs to make a product from the point of extracting its constituent materials, manufacturing and using it, then reconstituting or disposing of it. This measure is based on the methodology on the research of Sustainable Energy Research Team (SERT), Department of Mechanical Engineering, University of Bath, UK.

The databases used in this evaluation are from SimaPro (Netherlands) due to its input-output databases on construction materials. SimaPro 7.2 simulation software is selected because of its comprehensive databases.

4. Methodology

The methodology can be separated into 4 parts:

1) Gathering the construction materials in Thailand

2) Assessing the environmentally friendly design.

3) Analyzing flood damage

4) Providing guidelines for sustainable development for a post-flood community.

The environmentally friendly assessment tool is developed and simplified by the NHA's project as the application. [4] This application not only illustrates the environmentally friendly pie chart of each system in building, but also shows the whole environmentally friendly comparison of each design.

5. Results

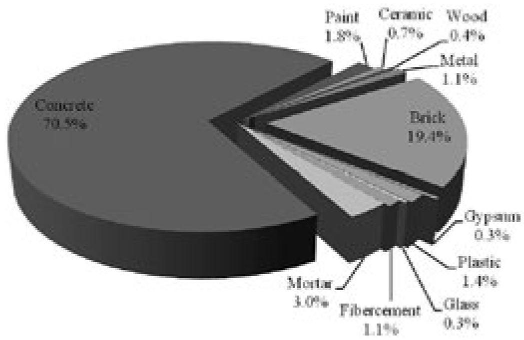
5.1 Construction materials in Thailand

As a result of gathering the construction materials in Thailand, the data can be broken into 4 systems: architectural, structural, electrical-sanitary and landscape.

These systems consist of combinations of 6 main raw materials: cement base product, clay base product, steel and metal base product, wood base product and others. The preparations, manufacturing processes and environmental impacts of the different materials are completely different.

The studies of typical urban houses showed that using concrete was a significant negative impact. Concrete was the most popular material, used 61-76% of the time, followed by brick at 19-24% as illustrated in chart 1 below. [4] If we can reduce the proportion of concrete used in the majority of houses, the negative environmental impact may decline as well.

Chart 1 Proportion by weight of construction material used in 2 million baht urban house



5.2 Materials damaged by flood and their life spans

<u>Materials damaged by flood</u>

The buildings damaged by flood can be analyzed based on 3 flooding heights; below 0.3 meters, below 2 meters and more than 2 meters. (Source: survey by researcher in suburban Bangkok at 19-20 November 2011). The results for each are below.

1. Flood height below 0.3 meters - the footing structures of both urban and rural houses were damaged by long periods of flooding and the resulting landslides. When the flood level reached the level of the first floor in urban houses, the finishing materials, usually wood, laminate, vinyl and baseboard, became damaged first. The footing structure of urban houses is stronger than rural houses which use wood foundations, but they require more stability. If the concrete footing is damaged, the wall systems could be corrupted.

The next areas damaged are the paint and door frames, especially wooden frames which cannot handle being soaked. They bend from the wall and collapse. Metal frames also fall off the wall because rust causes the joints and equipment to lose strength.

Light weight walls like gypsum, fiber cement board, wood stud, steel stud and wallpaper, are destroyed by flooding and overly-humid conditions afterwards.

2. Flood height under 2 meters - The wood skeleton structures and floor structures in rural houses damaged up to the 1st floor level bent and collapsed. Similarly, wall structures that use light weight construction are seriously damaged and moldy. In lower-built urban houses the flood level reaches the window and damages frames, window equipment and electrical systems like plugs and switches.

Concrete and wooden stairs are also compromised by the rising water. Though the finishing is damaged in both structures wooden stairs are far more likely to be weakened than concrete.

3. Flood height above 2 meters - The floors, doors, windows and ceilings of rural houses are damaged at this level. There are many dangers to inhabitants if ceilings are damaged, like collapsed ceiling boards, and decayed ceiling studs made of wood, gypsum, fiber board, aluminum T-bar, wood stud and steel stud. A variety of systems installed in the ceiling structure were partially lost, like the electrical system; lantern and wire, air-conditioning system; AC pipe line, fire protection system; sprinkle, smoke and heat detector and telecommunication system; television, internet and CCTV. All of these damages have the potential to injure inhabitants.

Life span of construction materials

The four phases of construction materials' life span are manufacturing, construction, operation and demolition-disposal. Each phase was analyzed in the 50-year of building life cycle for the life span of a main structure. Concrete's life span is 50 years; wood's is only 15-20 years. Life span results appear in diagram 2.

5.3 Environmentally friendly results of urban houses

The impacts of proportion of each building system are illustrated in chart 2, and are interpreted as follows.

1. Architectural components (AR) with environmental impact of 94.5% in proportion

- Floor sub-system of 88 m^2 of ceramic tiles, parquet 33 m^2 with a proportional environmental impact of 25%.
- Wall sub-system of brick-mortar walls with ceramic and marble tiles of 58 m^2, acrylic paints of 594 m^2 and timber frames with horizontal wood slab, and acrylic paints of 29 m^2 with a proportional environmental impact of 44%.
- Window and door sub-systems of 8 plywood doors, 1 aluminum door, 15 aluminum windows with a proportional environmental impact of 4%.
- Ceiling sub-systems of 168 m^2 gypsum ceiling tile with acrylic paints with a proportional environmental impact of 5%.
- Roofing sub-system of 155 m^2 concrete roof tiles with metal structural frame with a proportional environmental impact of 17%.

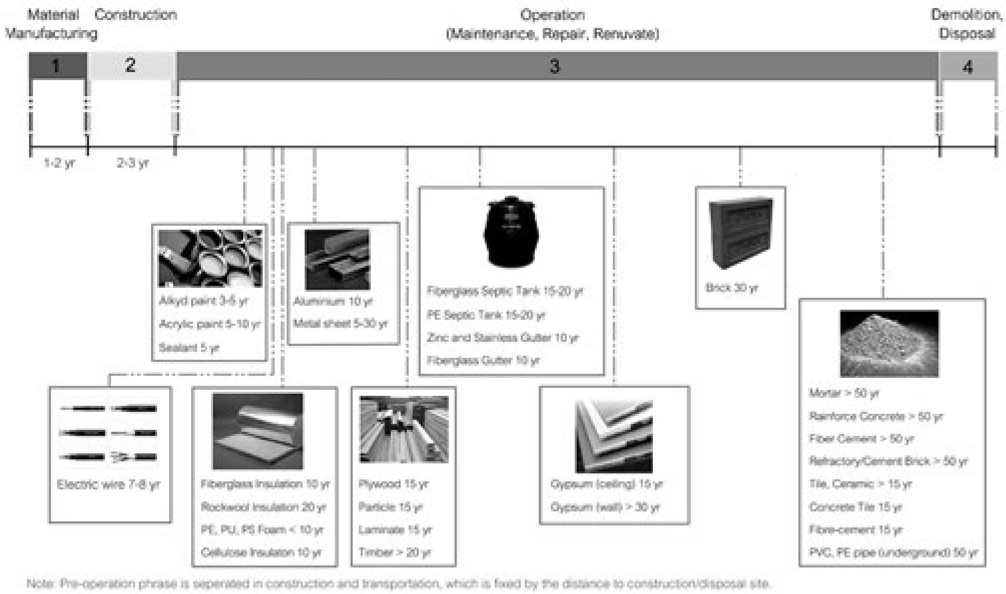


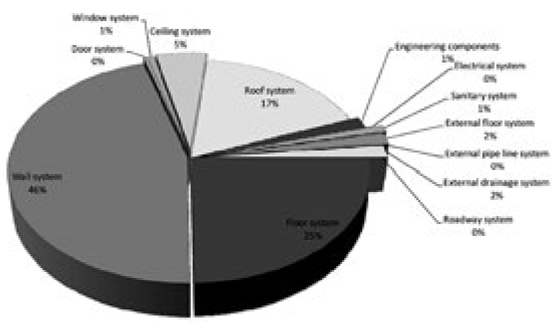
Diagram 2 Life span of products during building life cycle (50 years/life cycle)

2. Engineering components (EG) of 48 m^3 structural concrete, reinforced concrete of 2,771 kg and precast floor plank of 165 m^2 with a proportional environmental impact of 1.5%.

3. Electrical and Sanitary components (E/S) of 119 m electrical wire, 1200L sanitary septic tank and 30L grease trap with a proportional environmental impact of 1%.

4. Landscape components (LA) of 149 m^2 of finished concrete and 104 m concrete pipeline with a proportional environmental impact of 3%.

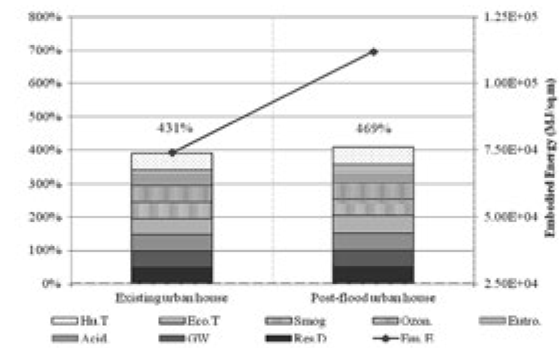
Chart 2 impact proportion of each building system in urban house



6. Discussion

The main environmental impacts in the architectural system of urban houses are due to materials used, especially in the floor, wall and roof systems. Unfortunately, one-third of these materials, like parquet, acrylic paint, a wall with wooden studs, and roofing can be destroyed by floods. In addition, these materials are not only expensive, they also require complicated manufacturing and high production technology. The results show that the materials damage 9 of the measured environmental areas, leading to greater resource depletion, higher carbon emissions, global warming and embodied energy used, creating more acid and toxic contaminants to environment and humanity.

Chart 3 impact proportions between existing wall system and post-flood wall system in urban house



To focus, wall systems which provide environmental impact 46% of an urban house can be analyzed in 2 systems by replacing materials. Heavy weight wall such as ceramic tile, brick and acrylic paint found that the paint is an only flood damaged material. However, light weight wall consisted of wood stud, wall board and acrylic painting found totally damaged by flood. The environmental impacts are reported that the post-flood wall system's total figure exceed to existing wall system's by 8%, showed as chart 3. It seems to be a little effect, if we concentrate the environmental impact of just only the wall system in an urban house. Nevertheless, if we concern the combination result of every system and house in the community, the totally impacts are very high.

The community's economy is also affected. The demand for these materials for urban renovation could possibly exceed supply and require outside importation. In contrast, renovating rural houses which seem more seriously damaged requires readily available materials that are low cost and can be environmentally friendly. However, deforestation should be accounted for in any rebuilding plan. The sustainable forest could be developed and supported for the future local economy. For example, horizontal timber wall could be replaced with locally-grown bamboo.

7. Conclusion

Research showed that rural houses were more damaged by flood than urban houses. However, the environmental impact around rural houses was lower, as was their recovery time. Specific results follow.

Table 1 Impacts and recovery time of urban and rural houses

Impacts	Urban	Rural
Waste from construction materials	high	high
Toxicity	high	high
Absorption landscape	high	low
Community density	high	low
Renovation materials	Expensive	low cost, local items
Recovery time	slower	faster

The guideline for environmentally sustainable post-flood renovation consists of 3 models:

1. Short term model - renovate the residence with new materials that are resistant to water and low cost materials like timber and interlocking sand block.
2. Medium term model - renovate the structure into flood-proof architecture. For example, high platform structures, raft structures and adjusting structures. The existing structures should be examined by an expert before they are rebuilt.
3. Long term model - Cooperation should be fostered with the timber industry so that the wood used for building materials can become a locally supported, sustainable business. The study [4] found that wood is an environmentally friendly material at the top of the building hierarchy, with low embodied energy that is renewable with the forest cycle. If the embattled communities can introduce the sustainable commercial forest cycle, a sustainable economy will follow. The European countries are strong examples of a sustainable forest industry exporter, like Finland, Denmark, Sweden, Canada and the United States.

8. Acknowledgement

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