

Vulnerability assessment of building material against river flood water: case study in Malaysia

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Abstract. Flood risk is increasing in Malaysia specifically around river which influencing of climate change. The aim of this study is assessing the vulnerability of building materials by revealing the degree of loss for each structure. There are most five common materials has been assessing namely: brick, concrete block, steel wall panels, wooden wall and precast concrete framing. This research was conducted on 110 buildings, to record detailed attributes of each building in the city of Kuantan. Afterwards, the interviews were conducted with residents of 85 households along with a local authority staff expert. The lowest flood depth that effected on wall building was 25 cm and the highest depth of flood was recorded 150 cm. In general, the interview revealed that the flood lasted for 48 hours. The vulnerability of the structural type of building is determined from the percentages of damage to the wall material resulting from occurrence of the flood. Vulnerability curves were made for these five structural types, by plotting the relationships between flood depth and damage for each structural type. The result shows that by increasing the flood depth wood wall encounter by more damage, which needs more cost to repair. In other hand, Concrete block wall, which consider as one of the industrial building systems has less damage against floodwater. Although, until the depth of 75 cm both Concrete block wall and precast concrete has a same stability. The result of this research can help housemaker to choose the best material for building in flood zone area, which needs less cost in repair stage after flood hit the building.

1. Introduction

Nowadays, cities around the world are frequently exposing to natural hazard such as flooding. Flood become one of the hazards that has a significant effect on human life [1]. As Figure 1 shows the number of natural disasters has been increasing in the last fifty years ago which its cause of climate change. Flood has been introduced as one of the barriers for development any country [2]. Previous research shows that more than 22% of Malaysian population is directly affected by flood [3, 4]. The number of floods since 2014 also has been increasing in many cities around Malaysia such as Kuantan, Pahang and Johor. For example, Malaysia's annual northeast monsoon has claimed two lives in Pahang and forced nearly 12,000 people to be evacuated from their homes nationwide. The number of flood occurrence also has been increased in last few years. For example, February 22 - February 28



2016, January 01 2017 in Kelantan and Terengganu and February 04 2018 are the latest flood disaster in Malaysia [5]. East Malaysia is suffering from climate change consequences such as floods [6].

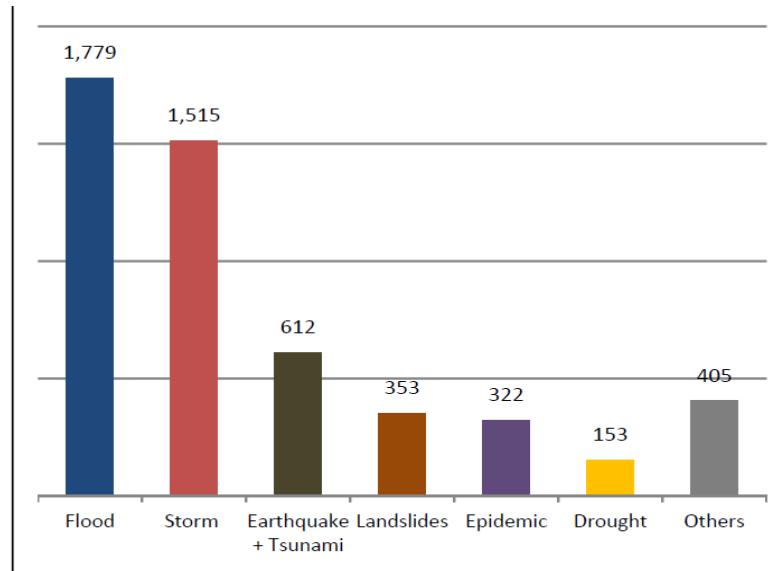


Figure 1. Occurrences of Natural Disaster Events in Asia and the Pacific by Type (1970 – 2014) [7].

Recently there have been two great concerns of flood risk in Malaysia: First, there is a significant increase in the vulnerability of the land due to the nearly uncontrolled growth of the city. The second concern is the increase of flood hazards, which can be attributed to the sedimentation within the embanked riverbed. The most intense climate phenomena related to natural disasters in Malaysia are flash floods and monsoons, affecting flood-prone areas of about 29,000 km² and more than 4.82 million people (22% of the population) while inflicting an annual damage of USD 298.29 million [8].

There are some important studies regarding flood risk assessment. Nadal et al. [9] developed a new stochastic methodology using Monte Carlo simulation to estimate the direct impact of five flood actions on buildings and to determine the expected damage. Scawthorn et al. [10] assessed the HAZUS-MH Flood Model for flood hazard in the United States. The researcher claims that the development of the HAZUS-MH Flood Model puts a powerful tool in the hands of communities, allowing proactive analysis and mitigation at the local level. De Risi et al. [11] introduced a probabilistic and modular methodology to assess the flooding risk for structures in a portfolio of informal settlements through convolutions of flooding hazard and flooding fragility. Bradley et al. [12] assessed the effect of simulated flooding on the structural performance of light-frame timber structures. Load tests were conducted, and results showed significant losses in mechanical strength for the wet and restored walls. Miyata et al. [13] reported the influence of flooding on steel-strip-reinforced soil walls. Balasbaneh, et al [14] assessed life cycle assessment of flood damage in Malaysia and result shows that timber is not preferable choice to construct near riverside. Aglan et al [15] conducted an experiment on buildings to assess the damages before and after flood. effects of floodwater assessed on different flood durations. Previous research by Carol, [6] indicated that floods only damages the wall material and it has not affected roofs. Therefore, the scope of this research limited only on wall materials.

The importance of this research is over the last three decades, flooding is a major risk in the world and nowadays it is becoming common in Malaysia [16]. However, losses due to floods have not yet been addressed properly. Despite high number of flood and many attempts toward finding solution to diminish the flood effect, there is still lack of research in this area. There is also

no role about what material is most preferable to use as building material in flood zone area. In other hand, the exact damage of each material against floodwater is not clear.

2. Flood Damage Assessment Methodology

During the pre-field phase, an intensive literature review was done based on relevant literature studies to develop a concise research basis. This phase provided identification of the research context and the proposed necessary data and methods for data collection and analysis. The scope of this research is focusing on prefabricated building material against flood vulnerability. The fundamental assumption of this research comes from the hypothesis that there is a significant relationship between depth and duration of the flood and the damage to buildings. First step done was developing the database of elements at risk. The database was classified based on literature review and fieldwork findings. In the absence of an accurate building footprint and detailed aerial or satellite imagery of city of Kuantan, the data collection for the elements at risk was mainly done through building inventory and observation. The process of assessment as following: Interviews of flood depths with respondents, collect data of flood depths to get the flood extent, classify the elements at risk and finally data analysis from household interview with depth-damage relationship for each element at risk (structural types of building, building contents and outside properties).

2.1. Building Inventory

In total 110 buildings were recorded during the building inventory. Building inventory is the process to collect information to be used for identifying the elements at risk. Building inventory or sometimes called as close sensing, is doing observations / measurements made from nearby [17]. Building inventory was done by visiting the buildings in the study area with simple random sampling. Simple random sampling aims to obtain data, whereby each element is given an equal and independent chance of selection. This is the most commonly used method of selecting a probability sample [18]. The selection of buildings in the fieldwork was done through choosing one out of three to five buildings from the study area. The result of the building inventory was processed rapidly during the fieldwork in order to get classifications of structural types for stratified random sampling for the interview process. Table 1 shows the quantity for each building structure and its material that has used for data collection.

Table 1. Wall Material based on the Building Inventory Source: Fieldwork Data (2018).

Structure	Wall Material	Number of Building	%
1	brick	32	29
2	Wood	29	27
3	concrete block	20	18
4	steel wall panels	15	13.5
5	precast concrete	12	12.5
Total		110	100

2.2. Interviews

Interview in this research is the process to collect in-depth data of elements at risk, structural types of buildings in detail, building contents, outside properties, flood damage detailed information from households (respondents). Interviews were done based on stratified random sampling with 68 households in the study area. Stratified random sampling was selected as the way to acquire information of the loss data. In stratified random sampling the researcher attempts to stratify the population in such a way that the population within a stratum is homogenous with respect to the characteristic on the basis of which is being stratified [18, 19] used stratified random sampling as a way to capture representative data for each type of object that needs to be classified.

Having identified the classification of structural types from the building inventory, there are four types of building material found. These four types of building material were used to select the households to be interviewed. In total 68 households were interviewed. The interviews used questionnaires and Mobile GIS devices as the tools. The author was accompanied with a local translator who assisted to translate the questions during the interviews. Two main datasets were obtained from the field: first, data from building inventory and second, data from interviews. Table 2 shows the process for determining the Vulnerability of Structural type of building.

Table 2. Working definition for vulnerability of structural type of building.

Vulnerability	Description
0 (no damage)	<ul style="list-style-type: none"> • If the material does not get damaged due to certain level of flood depth • If the material does not need any replacement due to several occurrences of floods and still can function for several years.
0.5 (half damage)	<ul style="list-style-type: none"> • If the material does not need any replacement directly after one flood occurrence and if the material needs to be replaced after several occurrences of floods. • If the materials get damage in a half portion of the entire wall and floor materials for certain level of flood
1 (total damage)	<ul style="list-style-type: none"> • If the material needs to be replaced after one flood occurrence • If the material needs to be replaced because it is totally damaged after flooded with certain depth

Vulnerability means the degree of loss of a given element at risk or a set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss).” [20]. Based on this definition, the value of vulnerability for structural type of building is made on scale between 0 and 1. Three values between 0 and 1 (0, 0.5 and 1) were used to generalize the value of vulnerability (Table 2). If the vulnerability value is 1, it means the total damage occurs only to wall materials and the house owner needs to replace the entire part of the wall. This does not mean that the house is totally collapsed. Yet, other parts of building (for instance ceiling, roof, and columns) remain. Assessing vulnerability values with this concept remains uncertainties due to lack of information and weaknesses in the interpreting the damage. However, this way is still considered the best in the absence of damage data in the local currency.

3. Result

3.1. Wall Material Assessment

Flood physical vulnerability deals with the level of damage or loss that elements at risk or built environments suffer from the occurrence of flooding. The wall material was selected as the way to make building classes for the stratified random sampling. Five types of wall material were found during the building inventory in the study area and two types are conventional construction methods (brick and wooden wall) and the other three types are IBS structure buildings (concrete block, steel wall panels and precast concrete framing) as shown in Figure 2. Four different recalcitrant wastewaters are studied in this paper, namely palm oil mill effluent (POME), pesticide wastewater, and also textile wastewater. These are the few common recalcitrant wastewaters which are difficult to be treated with traditional method. Therefore, the effectiveness of nZVI and ozonation in treating these wastewaters has been studied and reviewed.

The relationships of levels of damage and flood depths were plotted into graphics for each of the five structural type of building. Based on the propensity of the plots for each structural type of building, the average vulnerability curve for each structural type of building was created. It should be noted that the flood depths used to construct the relationships between flood depths and damage are measured of depths inside the house. This section discusses more detailed information than that of the building inventory. Investigation of building could be done in more detailed because being inside of the house, the elements of the inside the house were seen, for instance: floor material and design inside the house.

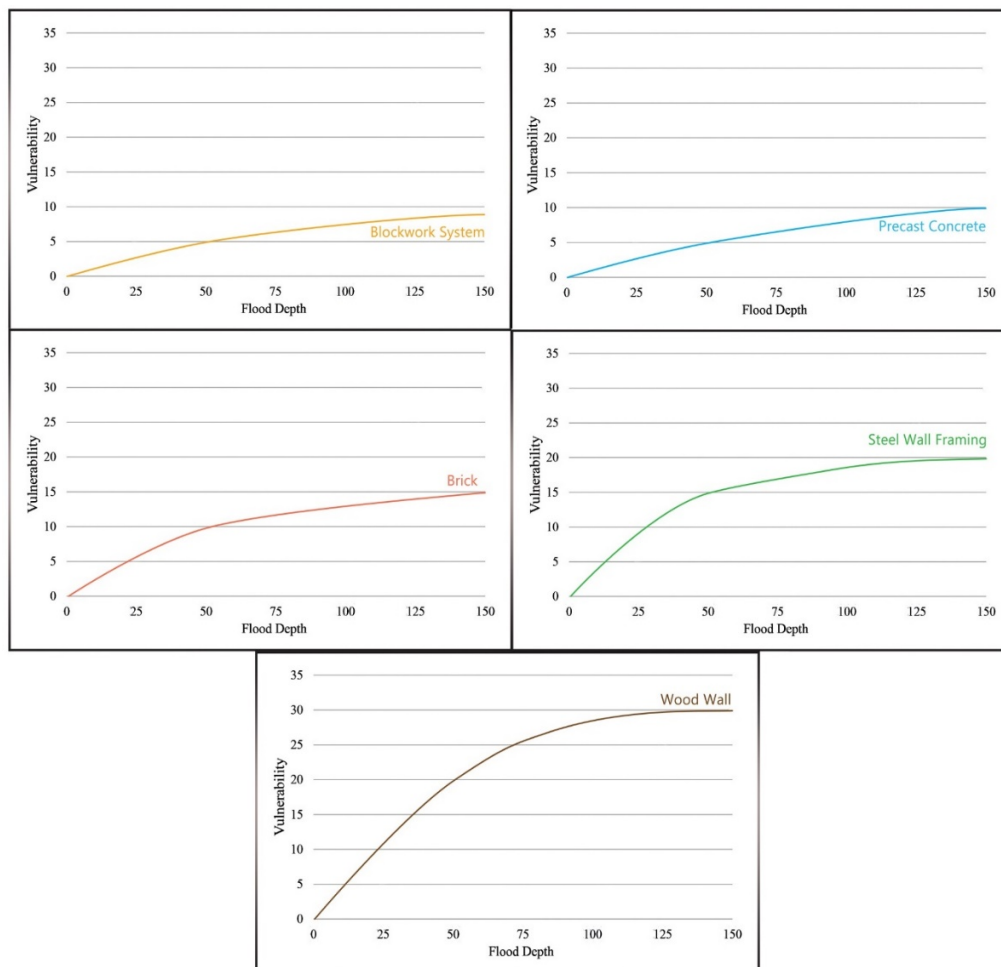


Figure 2. Vulnerability function for each structural type of house source: data analysis.

The first structure is blockwork system as shows in Figure 3 that has a better performance compare to other structures. By rising floodwater to 50 cm only 5% of wall damaged that needs to be repaired, while water rising to 150 cm the percentage of repairing wall material exceed around 9%. Although this structural type is strong against floodwater, some people also spent some money to repair the minor damage. For instance, they repair the house after floods by painting the wall or re-enforcing some holes that took place because of floodwater remaining inside the house.

The second walls are precast concreted frame. This structural type is not so vulnerable to water. Having a strong concrete wall has quite well performance against floodwater. Same as previous wall by raising water to 50 cm only 5% of wall needs to be repaired. Precast concrete also resists in higher flood depth and reach to only 10% damage in 150 cm floodwater. Brick is other types of material that has been using frequently in construction in Malaysia. By raising of floodwater to 50 cm, the damage

assessed 10 percent of the wall and by increasing the water to 150cm the damage of wall material exceeds to 15% of whole wall surface. Steel wall framing is one of the IBS system that recently has been built around the world and its advantage is related to the low waste of construction and fast built and therefore, this is the incentive for this research to assess this structure against the floodwater. Steel framing shows vulnerable against flood even within the 25 cm of rising water. In 25 cm the wall damaged by 10% of wall surface which this shows higher vulnerability compare to the precast concrete or brick wall. By increasing the depth to 100 cm and 150 cm the damage rises consequently to the 18% and 20%. This structural type is also very prone to water because the gypsum sandwich inside the wall can easily get damaged because of water.

Wood is one of the most applicable material in rural area as part of traditional construction material in Malaysia [21, 22]. Although there is many researches in literature [23, 24] that advised to use wood in construction industry instead of concrete or brick due to its low carbon emission but the result of this research proves that timber is not suitable material for flood zone area. According to the flood depth – vulnerability relationship, the wood starts getting damage from flood depth around early contact with water. Subsequently, it gets 20% damaged when floodwater increases to around 50 cm. The wall and material of this type of building are almost damaged 30% when floodwater reaches to 150 cm or more.

4. Result

This research is discussed that how high flood effect the wall materials. Figure 3 shows the comparison between five different structures and their relation of percentage and depth. Wood wall shows the most vulnerable structure against the water flood and it means there are more part of wall needs to be replaced by new material, which it can be inconvenience for house owner. The second wall structure that shows vulnerable is steel wall framing which the damage of this wall is 10% less than wood wall in 150 Cm of flood depth. However, the stability of brick against the floodwater is not as much as blockwork system but still can be acceptable if compare the damage to the wooden wall. The two most resistant wall structure are blockwork system and precast concrete wall, which both of this structure categorized as IBS system. The National Security Council Directive No. 20 (NSCD) is a department that provides the policy and guidelines on disaster management. The result of current research can be used by NSCD toward mitigating of flood damage on construction building. Future research can focus on Social effect of flood damage on resident life since there was evacuation after flood.

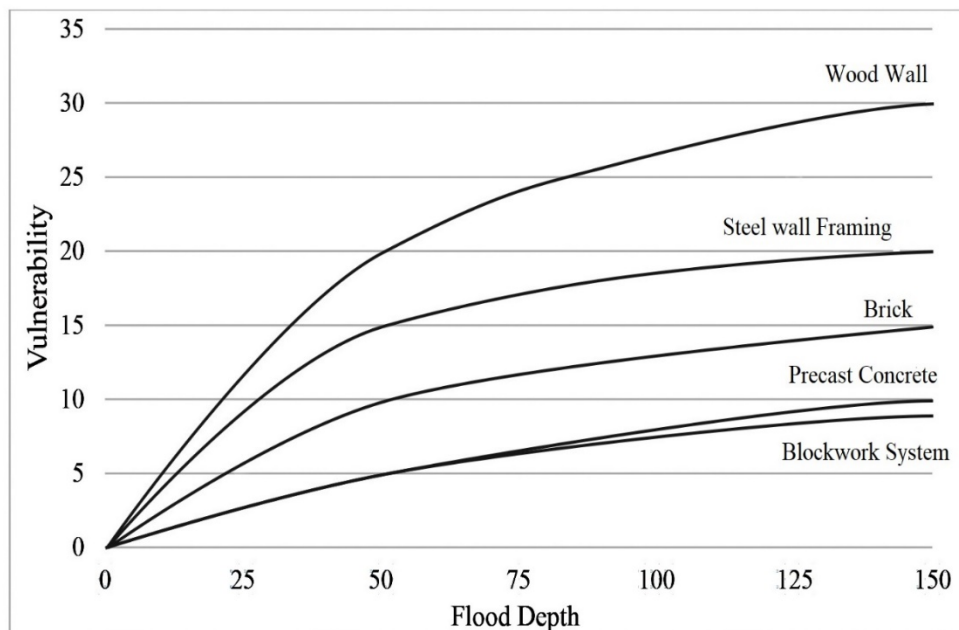


Figure 3. Vulnerability Function for Each Structural Type of House Source in one graph.

5. Conclusion

Flooding occurs periodically in Malaysia and has become a common occurrence. This annual occurrence of floods has given a big impact on lives of humans and other living being. This knowledge is actually valuable as input for making appropriate policies and actions for reducing the damage. Therefore, this research aims to contribute to the analysis of the physical impact and losses (damage) due to floods, particularly in residential areas that has been constructed in flood zone. There are five types of current common practice has been assessed in order to find the most resistant type against flood. The result revealed that wood is not suitable choice to be construct near or in flood zone area and other hand blockwork system is the best option in this case. Wood wall has been damaged 15% more than blockwork in 50 cm of flood depth while, 22% more in 150 cm flood depth. By constructing, the appropriate material as building wall the negative impacts resulted from the flood disasters can be minimized.

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