International Journal of GEOMATE, June, 2018 Vol.14, Issue 46, pp.63-69
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.46.7306
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

THE ABILITY OF WALL OPENINGS TO REDUCE FLOOD INDUCED FORCES ON RESIDENTIAL BUILDING

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*Corresponding Author, Received: 09 June 2017, Revised: 11 Aug. 2017, Accepted: 16 Sept. 2017

ABSTRACT: Flood induced forces could threaten the stability of residential building during flooding event. The building will have to face the hydrodynamic pressures and sometime impact load from the debris carrying floods. A study on the behavior of flood water movement through external wall were carried out to identify the various wall opening dimensions and its ability to minimize the flood water forces on buildings. Two types of experiments were carried out. First, a water flow table was used to visualize the water pattern diffusion. Next, flood tunnel was used to measure water velocity reduction response of the various walls. The wall opening configurations were based on the common types of wall opening found in Malaysia. Generally, the results show that walls with bigger openings could withstand the water forces better. This is indicated by the smaller velocity reduction and diffusion when the flowing water passes through the wall. However, the level of opening from the ground could change the overall performance of the various opening sizes as shown by some of the models. Therefore, further studies should be carried out to determine suitable dimensional characteristics and level of the wall openings from the ground. This could produce an optimum impact reduction wall design for residential building in flood prone area.

Keywords: Flood, Residential Building, Wall Opening, Water Velocity

1. INTRODUCTION

Floods are considered as the worst calamity experienced in Malaysia [1]. As the most frequent natural disaster in Malaysia it affected many areas and cause annual catastrophe and damages to infrastructure, property, crops and other intangible loss. There are no official categories of floods in Malaysia but is often broadly categorized as monsoonal, flash and tidal floods.

A study conducted by Kong et al.[2], on urban flooding found that, 28% of respondents concurred that flood is due to improper drainage system, 20% cause is pollution, 18% the management of urbanization and 16% cause is environment factor and 11% weather while 7% because of dam break [2]. Figure 1 below shows the results of their research.

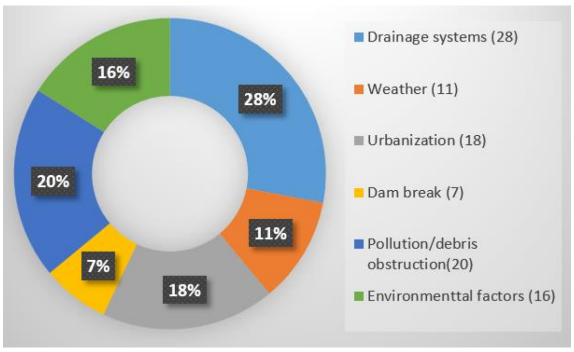


Fig. 1: Public perception of causes of flooding[2]

It can be seen that most Malaysians are less concerned regarding environmental issues especially natural disasters because they assume the issue is a trivial issue which ought to be resolved by the authorities and government[3] and have made little effort to face possible property damage in case of flooding. Flood induced forces could threaten the stability of residential building during flooding event. The building will have to face the hydrodynamic pressures and sometime impact load from the debris carrying floods. Flood impact proofing or reduction can be achieved by making adjustments to building design and building components that could withstand flood forces.

1.1 Building Response and Flood Damage

A research by Vinet [4] concluded that the effects of flooding caused damage to home, shops and industries. Sani et al.[5] research concluded that, there are at least 4 effects of flooding which comprise water damage to houses, disruption of transportation, reduction of income and damage of furniture and other appliances. However, majority of the population strongly believes that, water damage to houses is the main effects of flooding. Hence, it is recommended that buildings should be properly built to avoid building on the floodplain and on the flood prone zones [5]. The main idea in the traditional approach for estimation of direct flood damage monetary terms is the concept of loss functions or depth-damage functions [6]. In actual event, flood damage is influenced by other factors such as flow velocity, debris concentration, flood duration, lead time and information content of flood warning, and the quality of external response in a flood situation [7] [8] [9].

Distributed resistance parameters are needed for local prediction of velocity [10] [11] which might be required for damage assessment or predictions of sediment erosion and deposition [12]. Based on Becker et al. [13] findings, he concluded that structural failure comprises a large portion of the response space for higher depth and velocity combination under flood response scenarios. Thus, by developing a greater understanding of building response to high-velocity floodwaters through this type of behavior modeling, actions could be investigated that may improve resistance of buildings in flood-prone areas. A study by Grundy et al. [14] determine that a large proportion of deaths could be linked to structural failure of buildings since this prevented vertical evacuation from the floodwaters, and damaged buildings created dangerous debris impacts. However, in addition to depth, water velocity has been shown to be a crucial parameter with the potential to cause significant damage [15]. The relationship between the (d x v) factor and flood damage of buildings is the most widely acknowledged predictor of the effect of water velocity. Yet, no further applied theoretical analysis of how swiftly moving floodwaters affect buildings, in terms of structural damage or in terms of their ability to provide for human safety [16].

This study is set out to identify the various wall opening configurations and its capability to minimize the flood water forces on buildings.

2. METHODOLOGY

This study utilizes laboratory scale experiments to generate data for the parametric analysis. The experiments and setups are based on several previous related works in the study of flooding. Ramsden [17] directly measured the lateral forces on a vertical wall due to long waves, bores, and dry-bed surges instead of calculating the force from pressure measurements. A study focuses on qualitative observations regarding the structures response to wave loading was conducted by Arnason [18] in a small hydraulic wave flume with long aspect ratio (the controlled environment), theoretical predictions of wave height and force aligned well with theory. Thusyanthan and Madabhushi [19] have run a research utilizes a small 4.5 m long tsunami wave tank with waves generated by dropping a 100-kg block in the water. One model of coastal structure was designed similar to a common Sri Lankan house and another one structure designed attempted to model a new tsunami resistant structure. This research concludes a need to study on how building configuration could be used to better withstand wave loading.

A study on the effect of flood water diffuser on flow pattern using flow water table by Ghani and Kasnon [20] have concluded that the longer the wave diffusion or the higher the wave amplitude, the more velocity can be reduced. Most closely related to this study is the recent work of Ghani et al. [21] which utilized a hydraulic flume tank with sensors placed before and after the diffusing objects to study the velocity reduction effect in a 3-dimensional hydraulic environment. The research conducted identified suitable shape and dimension of objects and its capability to reduce flow velocity across the road. In order for a building to survive loading forces from moving floodwater exerts on wall have to be reduced. This comprises the external and internal wall of a building. Debris resulted from high impacted external wall may produce a greater load compared to original moving water velocity. Thus, laboratory experiments will be conducted to study the effect of wall opening configuration towards its velocity reduction through walls.

2.1 Laboratory Experiment

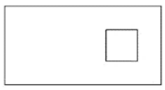
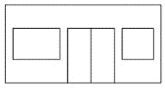
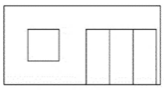
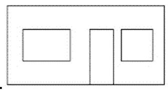
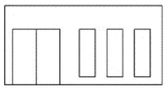
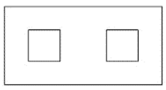
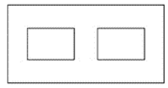
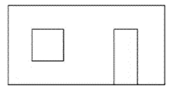
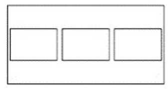
In this laboratory experiment, the equipment must be set up and functions properly include the water visualization table, flood tunnel and camera to take video of the test. The various wall configuration models have been prepared for the experiment purpose. The experiment will be conducted using every type of typical configuration of wall opening of houses in Malaysia and the result gained by observation of the experiment. The wall panel will be varying in configuration of its door(s) and window(s), including their size(s). The size of the model will use scale of 1:50 of the living size. The experiment will only focuses on qualitative observations regarding the flood water breaking, response, or diffuse through wall opening. This research will run two types of experimental test which are (1) flow water table to observe water response pattern through wall opening configuration, and (2) flood tank to measure the velocity response by wall opening configuration. The flow water table experiment will only use the horizontal section of the wall, whilst the flood tunnel experiment will utilized a full height model. Observation method will be used for data collections, which when the execution of laboratory test is running, data will be recorded from the start until the end of the test. The outcome of the water response and diffusion will be witnessed and recorded as collecting data.

2.2 Development of the Wall Model

A series of typical elevation of houses in

Malaysia especially in flood prone and affected areas was selected and illustrated in accordance to laboratory suitability. Flood affected area selected for this case study is in Perak Tengah region which merely inundated by flood in December 2014. Following are the typical elevations in Table 1.

Table 1: Wall Elevation Model

Model	Plan	Elevation
1		
2		
3		
4		
5		
6		
7		
8		
9		

2.3 Flood Diffusion Pattern Experiment

The equipment used in this experiment were water flow table, adjustable stand, water color, camera and double cello tape to represent the section of the walls. See Fig. 2 for the flow pattern laboratory testing instrumentation details.

As the configuration and size of opening are expected to influence the breaking of the flood water, 9 models of different configurations were established for experimenting the performance and reduce the impact towards opposite walls. The experiment were carried out using the 9 patterns of models' sections as shown in Table 1 and the result were acquired by observing the processes. The result outcome will be recorded by video to observe it more clearly without repeating the experiment.

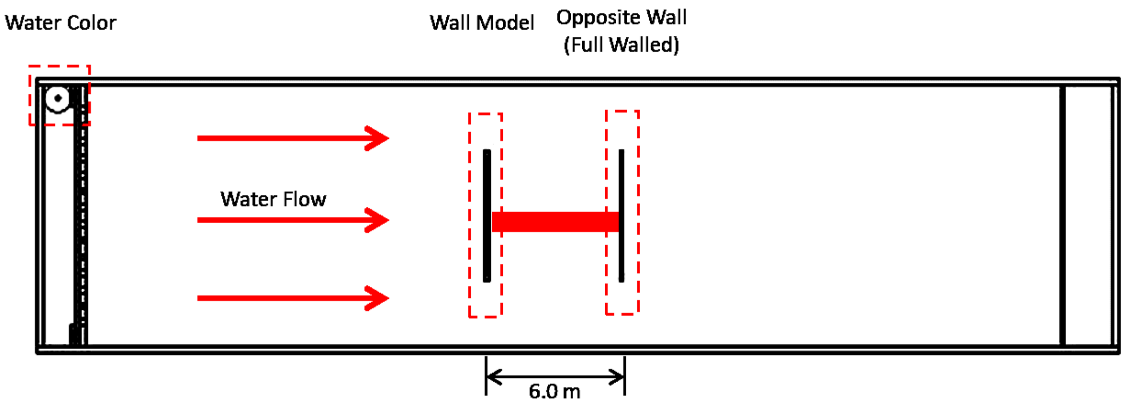


Fig.2: Flow pattern testing

2.4 Flood Tunnel Model Experiment

Creating a flood event under laboratory conditions requires a hydraulic flume and continuously flowing water. The flood tunnel was set up as in Fig. 3 and Fig. 4 in which all the 9 3-dimensional wall models were used to study the velocity behavior effect in 3-dimensional hydraulic condition. Water were circulated into hydraulic flume as configure and time is taken at the external and internal side of the wall to study the behavior of flow occurred when the flood water broke and hit another wall. Velocities (V) of two points were recorded and all the data obtained were compared for every model. This research make use of a small flood tank measuring 1.15m long, 0.3m deep, and 0.25m wide (Fig. 4). Water was allowed to pass through the models whilst data was being collected.

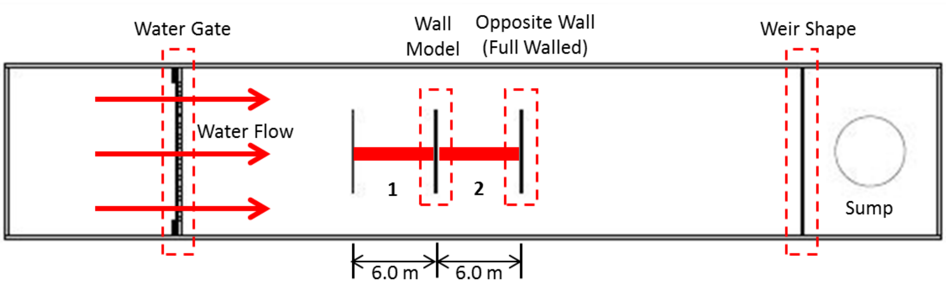


Fig. 3: Plan of flood tunnel model

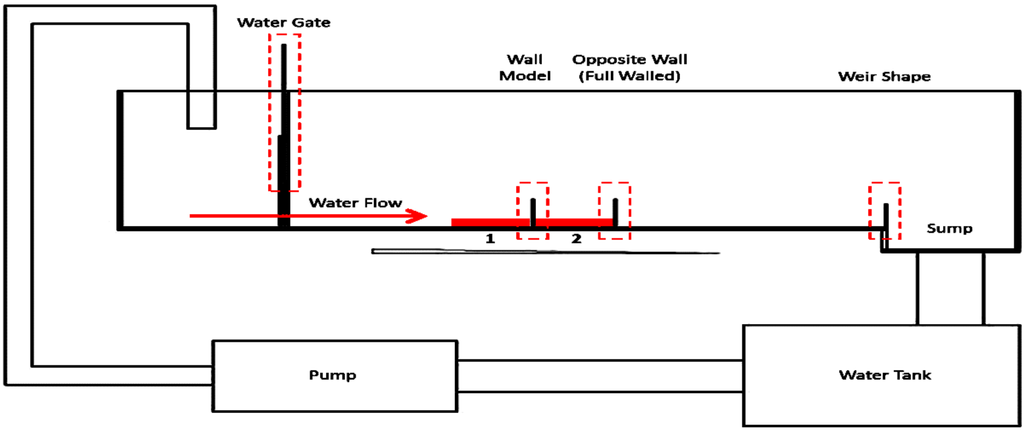


Fig. 4: Flood tunnel model instrumentation

3. DATA COLLECTION AND ANALYSIS

Based on the two approaches, data were observed and recorded for the 18 different models; nine numbers of 2-dimensional models for diffusion pattern, and another nine 3-dimensional models for velocity testing.

3.1 Flood Diffusion Pattern

By using the flow visualization table, the experiments were conducted on 9 models of different wall configurations. The patterns of the diffused flows were then divided into 5 point. Each point of diffusion will be measured, and given a score of 0 until 3 (0-3) which indicates; 0- Not Affected (0.00cm), 1- Poor (0.10-0.60cm), 2- Intermediate (0.70-1.30cm), 3- Good (1.40-2.00cm). The cumulative value of all five points then resulted to diffusion pattern category of each model. The diffusion pattern can be categorized into three categories; (1) low, (2) moderate, and (3) high. The first category which is low diffusion category which obtained less than 7 total value of flow categories score. The second category is moderate diffusion that obtained total value of 8 to 12 score on cumulative flow categories. High category of diffusion described the most diffused flow pattern which cumulated more than 13 score of flow categories. Thus, the experiments observation were been interpreted based on diffusion category.

Table 2: Score and diffusion category

Model	Score	Diffusion Category
1	6	Low
2	10	Moderate
3	13	High
4	10	Moderate
5	8	Moderate
6	11	Moderate
7	12	High
8	12	High
9	9	Moderate

Based on the 9 models experimented, one produced low diffusion, five models categorized as moderate diffuser, and three of them indicated high diffusion pattern. Out of the nine wall configurations, 3 configurations can be considered as the most capable in defusing water flow. Model 3, 7, and 8 are the configuration models that produced the most diffusion. This is because these configurations produced high deflection on most points and have high number of wave amplitude. As a general indicator, the higher the wave amplitude, the more the velocity reduces. However, in this experiment, the magnitude of velocity reduction cannot be verified numerically.

3.2 Flood Velocity Reduction

This experiment focused on the flood water velocity behavior before and after passing through all the nine models. Table 3 shows the before and after velocity.

It can be seen that all nine models produced velocity reduction. The result showed based on those models, the least reduction produced is 2.3% by model 9, and the most reduction by model 8 which is 75.3%. From these results it also can be seen that the reduction can be categorized in few groups. 2 of them which are model 3 and 9 produced a very low reduction, model 1 and 2 produced a reduction in range of 28-30% considered as low reduction, model 4, 6, and 7 with a reduction range of 47-50% which are quite high, and the remaining 2 models, 5 and 8 produced a very high velocity reduction.

Table 3: Velocity reductions

Model	Velocity Before (cms^{-1})	Velocity After (cms^{-1})	Velocity Reduction (%)	Reduction Category
1	18.0	12.61	29.7	Low
2	18.0	12.97	27.9	Low
3	18.0	17.07	5.12	Very Low
4	18.0	9.13	49.3	High
5	18.0	5.69	68.3	Very High
6	18.0	9.49	47.3	High
7	18.0	9.55	46.9	High
8	18.0	4.44	75.3	Very High
9	18.0	12.94	2.3	Very Low

4. DISCUSSION

Based on all the data that have been obtained from flow diffusion experiment, we can conclude that the wall configurations that give the most diffusion are model 3, 7, and 8. However, for velocity reduction of those models are not in the same category. Model 3 produced very low reduction, model 7 produced high reduction whilst model 8 very high. It can be seen too that model 5 resulted a very high velocity reduction while it is only categorized as moderate diffuser. We can conclude that the diffusion performance is not tally with the velocity reduction. This may cause by other factors or parameters itself such as area and width of opening, that will affect the amount of water passed through in a time, or gap between opening such as wall between windows or doors that will act as barrier that diffuse the flow and velocity, etc. Becker et. al [16] suggested that application of uncertainty investigation is favored to gain further perception into how significant building and flood parameters influence response. Nevertheless, many uncertainties in the analysis remain. Building response parameters have been significantly generalized for this research. More detail and reliable damage estimates could be obtained by acquiring more accurate estimations of building strength and response properties [13]. Further study on diffusion versus velocity should be conducted. High reduction of velocity may result from high amount of impact act on walls. Study on suitable impact may exert on walls to produced suitable diffusion and reduce optimum velocity should be done.

5. CONCLUSION

Generally, the results show that walls with bigger openings could withstand the water forces better. This is indicated by the smaller velocity reduction and diffusion when the flowing water passes through the wall. However, the level of opening from the ground could change the overall performance of the various opening sizes as shown by some of the models. Therefore, further studies should be carried out to determine suitable dimensional characteristics and level of the wall openings from the ground. This could produce an optimum impact reduction wall design for residential building in flood prone area.

6. ACKNOWLEDGEMENTS

This work is supported by Universiti Sains Malaysia and RUI Grant No: 1001/PPBGN/814283.

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