

EFFECTIVENESS OF MOBILE FLOOD WALL BARRIER THROUGH HYDRAULICS PHYSICAL MODEL TESTING

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ABSTRACT

Globally, flood barriers have been developed as a flood defense system for structures or buildings to minimize water intrusion through doors or openings during flood. These flood wall barriers can be designed as permanent or mobile applications depend on the criteria or space needed. However, in Malaysia, there are still lacking of the mobile type of flood wall barriers to be utilized in urban area, thus, Humid Tropics Centre (HTC) and National Hydraulic Research Institute of Malaysia (NAHRIM) have invented locally three types of Mobile Flood Wall Barriers (MFWB) namely NADI 1 (adjustable to door size for individual residence), NADI 2 (fixed to gate for government premises) and NADI 3 (fixed to door size for individual residence). A hydraulic physical model testing was conducted to determine the water tightness and the effectiveness of the MFWBs. The assessment is aimed to check on the water losses under hydrostatic pressure against MFWBs. From the testing, it was found that NADI 3 is the most efficient type compared to NADI 1 and NADI 2 even though it is non-adjustable to door size. The results also depicted that MFWB meets its purpose in blocking and preventing the floods water entering the premises up to 1 metre depth of water. These local inventions are viable and can be utilized in urban areas to reduce the flash flood impact and maximized the evacuation time for the flood victims.

Keywords: Flood, Mobile, Flood wall barrier, Physical testing

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1 Introduction

Floods are one of the common occurrence types of hydrometeorological disaster that affect human, environment and societal activity (Jonkman, 2005; Renato et al., 2008; Jiang et al., 2009; Mohammed et al., 2018). In addition, property damage and loss of valuable individual properties may have detrimental psychological impacts on flood victims (Philip et al., 2017). Floods can also cause mortality and loss of human life depends on the severity of floods. Flash flood for example, causes much higher average mortality than fluvial floods, due to the issues with the sewage framework and can extensively weaken soil and cause mudslides, damaging homes, roads and properties (Norashikin et al., 2018).

Protecting surrounding area will reduce the damage made by the water and soil from the flood and thus protect the area from the hazards of floods. There are some techniques in preventing the water from coming in including sandbags, water tubes and fences. Globally, the most recent invention relates to flood wall barriers have been developed as a flood defense system for structures or buildings to protect human and properties. These flood wall barriers can be designed as a permanent or mobile application depending on the criteria or desired spaces (Koppe and Brinkmann, 2010). Mobile flood wall barriers are simpler and quicker to install than sandbags that were used in conventional methods as flood protection (Dario and Giuseppe, 2016). In addition, these flood barriers are practically indestructible and efficient as it is easy to transport and required little storage area when stacked (Davis, 2018). However, further consideration on the selection will be depending on the geographical area, the level of protection needed, the flood occurrences in the selected area and the availability of the space surrounding (Liew et al., 2020).

In Malaysia, there are still lacking of the mobile flood wall barriers to be utilized in urban area. Thus, in 2018, a local invention of Mobile Flood Wall Barrier (MFWB) was designed and developed by National Hydraulic Research Institute of Malaysia (NAHRIM), in collaboration with Humid Tropics Centre (HTC), Department of Irrigation and Drainage (DID) namely MFWB NAHRIM-DID (NADI). There are three types of MFWB NADI comprises of NADI 1 (adjustable to door size for individual residence), NADI 2 (fixed to gate for government premises) and NADI 3 (fixed to door size for individual residence). This paper discusses the functions and performance of all NADI types in terms of water tightness and leakage under hydrostatic pressure.

2 Methodology and Design System

2.1 Development of Mobile Flood Wall Barrier

According to Bramley and Bowker (2002), for majority of houses and premises, 0.9 metre of wall height is sufficient enough to retain the flood from entering. Flood depths greater than 1 metre above flood level are likely to result in structural damage of buildings (Keeble, 2003). Thus, these NADIs are designed to hold excess water up to 1 metre high for flash flood protection, and is able to withstand and bear water pressure. The system is easy to assemble and dismantle, lightweight, easy to transport and store during non-flooding season, making it very user-friendly. It also serves as a quick and simple barrier system for houses or buildings.

2.2 Hydrostatic Pressure

The hydrostatic pressure is the pressure that exerted by a fluid at equilibrium at a given point within the fluid, due to the force by gravity. Pascal's principle states that the pressure at a point in a fluid at rest is the same in all directions (Boxer, 1998). Higher depth will give higher hydrostatic pressure due to increasing weight of the fluid. As the height of water increases by time, the pressure will increase too. This was explained and proved by the Pascal's law which states that the deeper the water gives higher pressure due to high mass of water (Nakayama and Boucher, 1999). In this study, hydrostatic pressure is calculated using the formula as follow (Chaudhry, 2008):

$$P = \rho gh$$

Eq. (1)

where

P is the hydrostatic pressure (Pa),

ρ is the density of the fluid (i.e., the practical density of fresh water is 1000 kg/m^3),

g is the acceleration due to gravity (approximately 9.81 m/s^2 on earth's surface), and

h is height of the fluid column (in metres).

2.3 Hydraulic Physical Model

A hydraulic physical model testing was conducted in Integrated Research Space, University Science Malaysia (USM), Engineering Campus, Penang, Malaysia as in Figure 1. For hydraulic physical testing, initial water proofing test and leakage checking with improvement was carried out. In addition, welding and pasted silicone were done to ensure the water tightness for the testing tank and water leakage observed is not due to the leakages of testing tank. The model is then tested to ensure that the hydraulic physical model performs correctly and in good condition during the process of testing.

Water leakages are calculated during the testing in order to evaluate the effectiveness of the flood gate structure during the process of testing. Variances of depth tested were at 0.5 metre, 0.75 metre and 1.0 metre. Observation for water leakages were done at the various angles as denoted in A, B, C, D for NADI 1 and NADI 3 while A, B, C, D, E and F for NADI 2 as in Figure 2. The water leakages of NADI 1, NADI 2, and NADI 3 was calculated by weighing the water from the leakage area. A sponge was placed on the leaking spot to allow the absorption. It was left for 15 minutes before being placed on the weighing scale. The water leakage was then calculated by measuring the weight of the water absorbs by the sponge as in Eq. (2).

$$\text{Mass (kilogram (kg))} = \text{Weight after absorption (kg)} - \text{Weight before absorption (kg)} \quad \text{Eq. (2)}$$

When the water leakage from NADI is flowing out, the water will fill into the beaker and the volume of water will be converted into mass. The volume flow rate was also calculated to determine the quantity of water leaking respective to time. The weight of the spill water was calculated as in Eq. (3).

$$\text{Mass (kg)} = \text{volume (m}^3\text{)} \times \text{density (kg/m}^3\text{)} \quad \text{Eq. (3)}$$



Figure 1. Hydraulic physical model testing for MFWB (a) NADI 1, (b) NADI 2 and (c) NADI 3 at University Science Malaysia (USM).

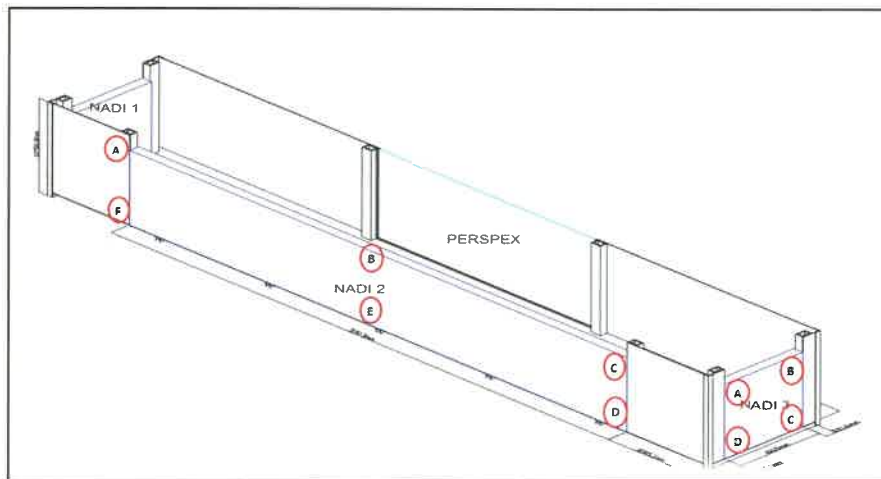


Figure 2. Detail dimension of the constructed physical model for MFWB NADI 1, NADI 2 and NADI 3 .

3 Results

3.1 Hydrostatic Pressure

The hydrostatic pressure was calculated at different height of water depth ranging from 0.1 to 1 metre. The calculated pressure according to water depth is depicted in Table 1.

Table 1. Hydrostatic pressure at different height of water

Water Depth (m)	Hydrostatic Pressure (N/m ²)
0.1	981
0.2	1962
0.3	2943
0.4	3924
0.5	4905
0.6	5886
0.7	6867
0.8	7848
0.9	8829
1.0	9810

3.2 Water Leakage

Figure 3 and Figure 4 show the detail of water leakage test of NADI 1 at 0.5, 0.75 and 1.0 metre of water depth respectively.

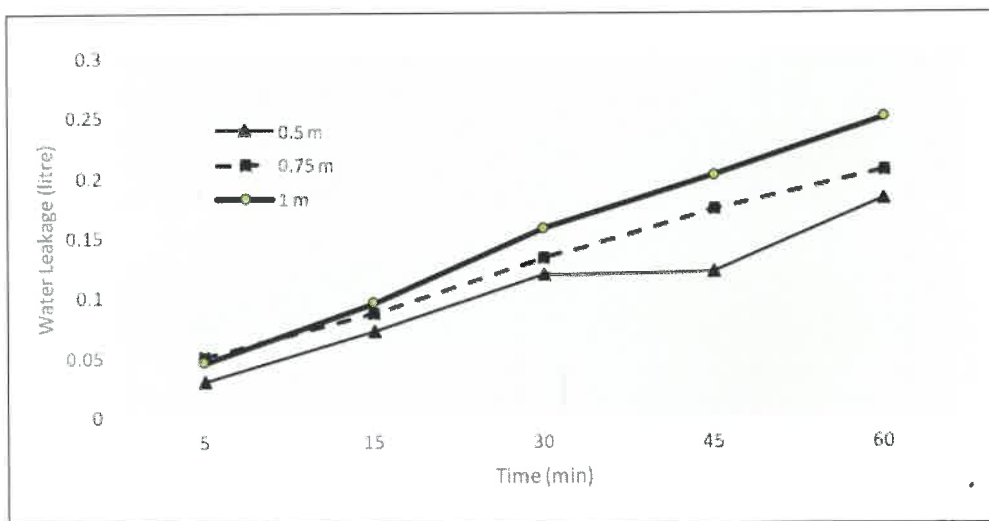


Figure 3. The overall water leakage for MFWB NADI 1

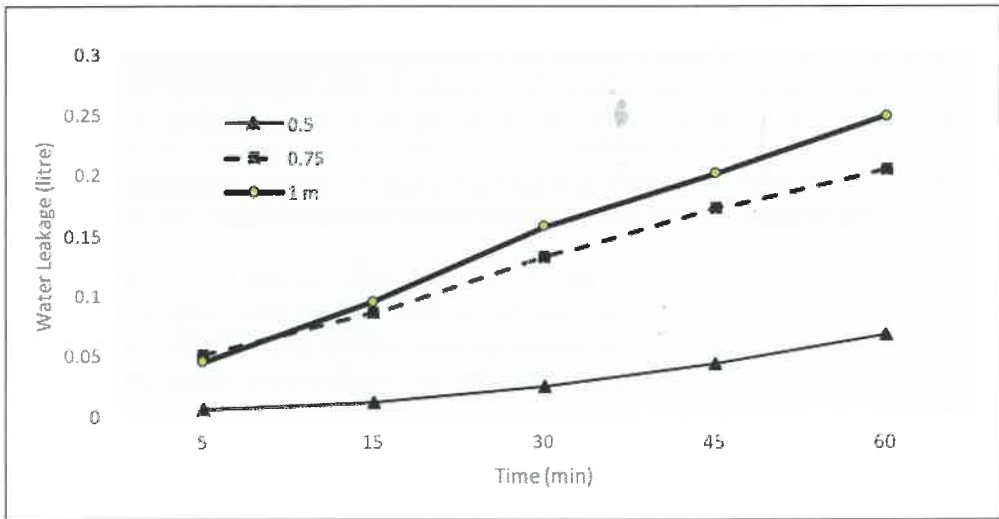


Figure 4. The overall water leakage for MFWD NADI 2

4 Discussion

4.1 Hydrostatic Pressure

When the water level raised up at 0.5 m, the original setup of NADI 2 deformed on the top part as NADI 2 is unable to resist high pressure of 4.90 kN/m^2 as in Table 1. NADI 2 deflected due to the hydrostatic pressure acting against its lengthy barrier wall. This probably caused by the structure of NADI 2 which did not have enough overall strength in order to support or withstand the exerted water pressure.

The design at bottom part of the barrier requires additional support or increase in thickness to withstand these high pressures. A minor modification of NADI 2 was done to create the middle span section as the target pressure is to withstand hydrostatic water pressure more than 9.81 kN/m^2 . Figure 5 shows the modification of MFWD NADI 2.

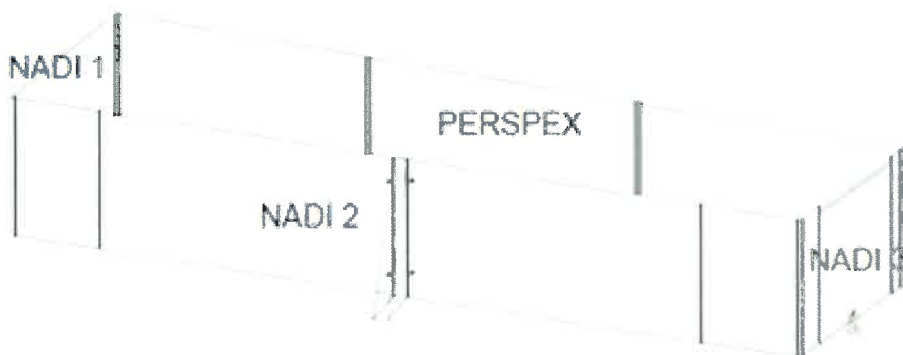


Figure 5. Modification of MFWD NADI 2 t

4.2 Water Leakage

As the time increased, water pressure (water level) is also increased and leads the amount of water leakage to increase. It can be inferred that the longer and the higher of flood inundation, more water will leak through the flood barrier. However, these amounts can be considered small and can be mitigate by mopping the floor. In actual case, the water tightness between the door frame and the MFWBs must be secured. Compared to NADI 1 and NADI 2, although minor leakages were observed for NADI 1 and NADI 2, it is low and acceptable. However, larger leakages are unsafe due to high current during flood and thus interrupt the wall stability (Mohammed et al., 2018).

There was no water leakage observed for NADI 3 during the testing because the clamping mechanism is rigid enough to ensure efficient grip between the door frame and the flood wall. The small structure of the barrier as well as the additional support at the middle of the barrier enables it to withstand high pressure as compared to NADI 1 and NADI 2. Apart from that, accurate dimension during the design stage also contributed to a superior performance of NADI 3.

5 Conclusion

The experiment was successful to ascertain the effectiveness of flood wall in blocking and preventing the seepage of water during flood. The different design between all the NADIs are capable to serve its purpose to be installed in different type of locations which are for houses and public premises. The most efficient MFWB is NADI 3 with the best performance in water tightness and capable of preventing any leakage compared to NADI 1. While NADI 2 can be applied for government premises for a longer length although there are some leakages in NADI 1. The leakages are within an acceptable range and can be utilized to avoid overflow of water.

A further research is highly recommended on the material improvement for ease of maintenance and achieving lighter in weight using recyclable materials or others materials for a higher durability and overall performance.

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