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STUDY ON THE USE OF OBSTRUCTING OBJECTS TO DIFFUSE FLOOD WATER VELOCITY DURING ROAD CROSSING

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ABSTRACT: Laboratory experimental investigations were conducted to identify suitable shape and dimension of objects as well as its capability to reduce flow velocity. The first stage of the study was to identify suitable shape and its arrangement. In this test a scale of 1:20 was used in a flow table experiment. The water flow pattern was recorded focusing on the distance and amplitude of the pattern as water flow pass the obstructing objects. The second stage of the investigation involved a hydraulic model investigation. In this investigation, the velocity reduction effects of the selected objects shapes were studied. The results are classified into three distinguishable patterns of diffusion. Two objects shapes and arrangements selected for use in the hydraulic model investigation indicated its capability to reduce flow velocity satisfactorily consistent with the flow pattern in the preliminary findings.

Keywords: Flood, Road Crossing, Water Velocity, Velocity Attenuator

1. INTRODUCTION

In a general flooding scenario, water levels rise causing areas neighboring water bodies and some road stretch to be flooded. The primary effects of flooding include loss of life, damage to buildings and other structures such as roadways and canals. Flooded roads and transport infrastructure make it difficult to mobilize aid to those affected or to provide emergency health treatment [1].

The most regular and frequent type of disaster in Malaysia is flooding. When large amount of rainfall occurs, and the fact that it is more frequent these days, especially over a short period of time - drain, rivers and low lying areas will be filled with waters. With the ever increasing and higher frequency of events, the rainfall runoff will turn into floods or flash floods. In its way to lower area and finally the sea, the floodwater will cross urban, residential, industrial and agricultural area causing damages not only to properties but also creating hindrance for escape and blocking emergency access to the affected areas.

Road infrastructure is the main access for escape and emergency supplies. In flood events, some part of low lying roads will be inundated creating blockage for vehicle movement. Statistics clearly point out the high risk of driving in and around flooded roads and low lying areas [2].

Intensive literature search indicated very few previous works or information related to how floodwater exerts pressure on crossing vehicles or human and how the pressure can be attenuated. Most of previous and current works deal with flood risk assessment and mapping; scour of channel, river, bridge piers and drains; policy and structural measures for flood control and abatement; and flood prediction. Figure 1 illustrates typical situation of floodwater during road crossing and how it affected the vehicles.

Fig.1 Dangerous crossing [3]

Yazici and Ozlay [4] proposed an evacuation route modeling to deal with transportation route planning during flooding - in other words, how to avoid flooded area. Meyer and Weigel [5] suggested an adaptive physical and management systems as an approach to mitigate potential problems. Physical approach of adaptive systems was studied by Pisani and Francesco [6] in the form of a moveable bridge that can be adjusted during floods. Meanwhile, Cai and Rahman [7] studied the used of road barriers as part of an emergency evacuation systems. A conceptual study of using Submerged Floating Tunnel (SFT) was carried out by Grantz [8].

Drobot et al. [9] described the risk factors of driving into flooded road. They have also found out that more than half of flood fatalities involved vehicles driven into the floods. Cai et al. [1] and Kouyi et al. [10] used computer simulation to predict flood level on potentially flooded road and the distribution of discharges through cross road intersections. Fairweather and Yeaman [11] studied the influence of flooding on road pavement deterioration and recommended further research to better predict pavement failure. The question now in most flood event especially in Malaysia, at least, is how to make sure access for escape and emergency supplies can be safely provided.

Flowing floodwater exerts a pressure on an object such as a car or person. The pressure will be higher when the water depth increases. Friction between the tire and the slippery pavement will be reduced. Water, sand, or mud tends to replace the frictional forces that stabilize the vehicle.

In order to maintain the stability of a vehicle, forces from flowing floodwater crossing roads must be diffused to a minimum. This paper reports the result of investigations on the possibility of using road furniture as velocity attenuating objects.

2. EXPERIMENTAL SETUP

Methodology used in this study was laboratory experiments. The experiments were conducted in the environmental and infrastructure laboratory and data were collected through observation and electronic data logging systems consist of sensors.

2.1 Flow Pattern Experiment

The apparatus used in this experiment were water flow table, water color, adjustable stand, camera, and double cello tape to represent the shape and size of 2D obstructing objects. The apparatus were set up as shown in Fig. 2.

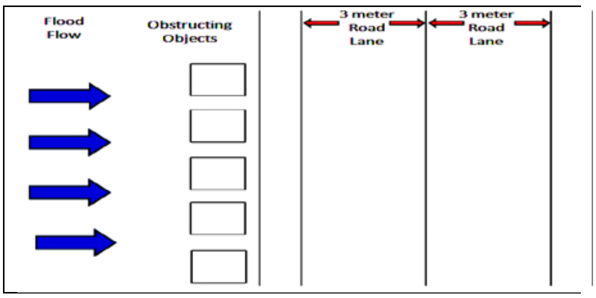


Fig. 2 Flow table set up.

Before doing the experiment for actual observation, pilot tests were conducted. The purpose of the pilot test was to help in finding some possibilities for the improvement possible hiccups before the actual experiment is conducted. It was also to obtained typical water flow pattern as a result of the obstructing objects. This will help to ensure that the experiment can be conducted smoothly and will produce high quality meaningful results.

Three pilot tests using the scale of 1:50, 1:30 and 1:20 were carried out. The dimensional arrangement of the road surface for water flow simulation is as shown in Fig. 2 below. The 1:20 scale was finally chosen as the experimental scale because it gave the better presentation of diffusing effects. Tapes were carefully assembled on the water flow table for each test and the diffusing patterns were recorded by video camera.

The road shoulder and road are marked by the cello tape. The road shoulders are marked to represent 1 meter dimension on site and the road are marked to represent 3 meter on site. Figure 3 shows how the cello tape as diffuser model are fixed on the flow water table.

As the shape, size and arrangement of the various obstructing objects are expected to influence the diffusing capability of the systems, 18 such cases were established for testing. The experiment were conducted using the 18 pattern and size of diffusers as shown in Fig. 3 and the result were obtained by observing the outcome of the experiment by video. The diffusing pattern varies with the shape, orientation and size. The maximum size of diffusing object is 1 meter to scale of 1:20.

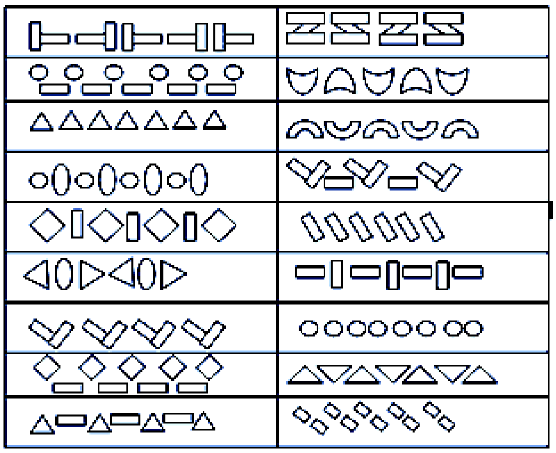


Fig. 3 Diffuser shapes and patterns.

2.2 Hydraulic Model Investigation

The experiment were set up as in Fig. 4 in which two best object shape and pattern established from flow table experiments were used to study the velocity reduction effect in a 3D hydraulic environment.

Water were circulated into hydraulic flume as shown and sensors were placed before and after the diffusing objects. The sensors were also placed at the beginning, middle and end of the road cross section to study the variation of flow after it passed through the diffusers. Velocity (V) was recorded and readings were compared at every four locations of the road scale. This experiment maintained the scale of 1:20 and it correspond to 3 m width two lane road (i.e. road = 3m@15cm, road shoulder = 1m@5cm and diffuser model = 1m@5cm).

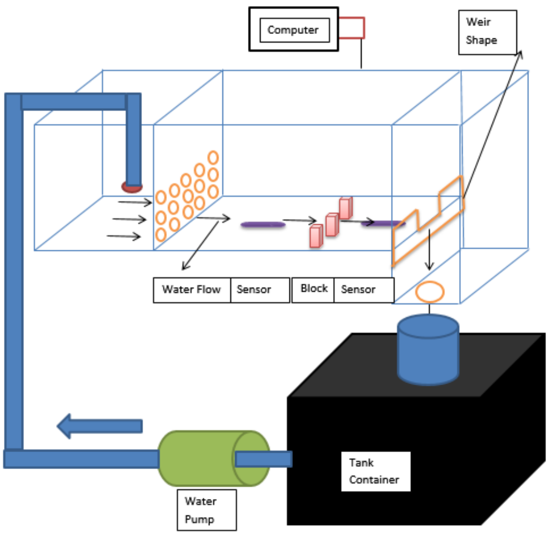


Fig. 4 Hydraulic model investigation.

3. RESULTS AND DISCUSSION

3.1 Flow Pattern

Based on the pilot tests carried out to identify diffusion patterns, two major characteristics of the diffusing water were identified and used as criteria for classification. The first characteristic is the “wave like” flow created by the obstructing object indicated that the water flow is being slowed down as it travels longer from one point to another. This include how long the wave like form remains while crossing the road. In some case, the wave diminishes before it reaches the other side of the road. In addition, there is also the amplitude of the wave in which higher amplitude indicating longer travel path.

The diffusing pattern can be divided into three categories. The first category is described as the diffusion pattern (wave) of the water flow after passing through the diffuser model is continuous until the road shoulder across the road. The amplitude of the wave are maintain the same until the end of the road shoulder.

The second category is described as the diffusion pattern (wave) of the water flow after passing through the diffuser model continue until the middle of the second lane and become straight to the end of road shoulder. The amplitude of wave remains similar until it diminished into straight line again. Straight line flow similar to the flow before the obstruction is considered high velocity flow.

Category 3 is described as the diffusion pattern of the water is very little based on the smaller and shorter “wave like” flow created after the obstruction model. In this case the flow became straight again at the beginning of road crossing or no significant change in its flow pattern (straight flow). The amplitude of the wave are also small.

Out of the 18 obstruction patterns, two patterns can be considered as the pattern with the most capable of reducing water flow velocity. Figure 5 shows the recommended model that gave good effect on reducing the velocity of water flow across the road. They are two of the shape from category 1. This is because these object arrangement produced wave diffusion pattern until the end of opposite road shoulder and have high number of wave amplitude. The longer distance of the wave diffusion, the more velocity is being reduced. The higher number of wave amplitude, the more velocity reduces.

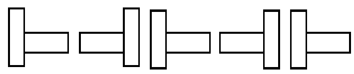
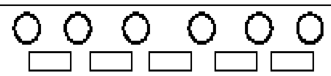
Shape and Pattern 1	
Shape and Pattern 2	

Fig. 5 Two best diffusing objects.

3.2 Hydraulic Performance

The hydraulic investigations focused on the water velocity characteristics before and after passing through the two selected diffuser objects that have been identified in the flow table experiment previously.

Table 1 details the characteristics of water velocity as it travels before and passing the objects until it reaches the end of the road section. It can be seen that both types of objects produce velocity diffusing characteristics consistent with the earlier flow pattern findings.

Table 1: Flow reduction Effect

Object	Average Velocity (cm/s)			
Type	Before	1	2	3
1	5.12 (100%)	3.98 (78%)	4.96 (97%)	6.31 (100%)

2	6.16 (100%)	3.89 (63%)	4.81 (77%)	6.10 (97%)

Note: 1, 2, 3 are locations along road cross sections as water travel across the model road.

The velocity reduction effect of object 1 can be further illustrated by the following Fig. 6. It can be seen that the amplitude of water flowing waveform are diminishing towards the end of the road section. At point 1, i.e. just after the diffuser objects, velocity was reduced to 78% of the water velocity from before. It regains speed up to 97% of the original flow towards the end of the section and finally regains the full velocity as before.

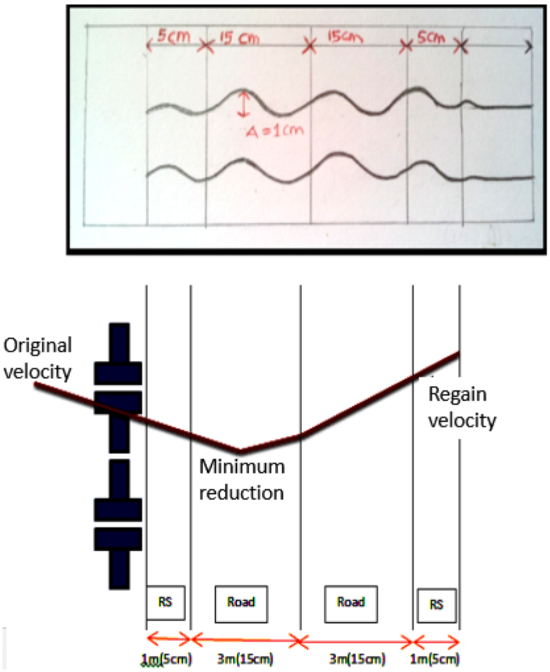


Fig. 6 Flow table pattern and velocity characteristics from Object 1.

As for object 2, flow table pattern is similar to object 1 but the diffusing effect goes beyond the end of road section as can be seen in Fig. 7 and Table 1. At the end of the road section the velocity is at 97% of the original water speed. Also the maximum diffusing effect of object 2 is 37% instead of 22% by object 1. This characteristic indicates better diffusing capability of object 2.

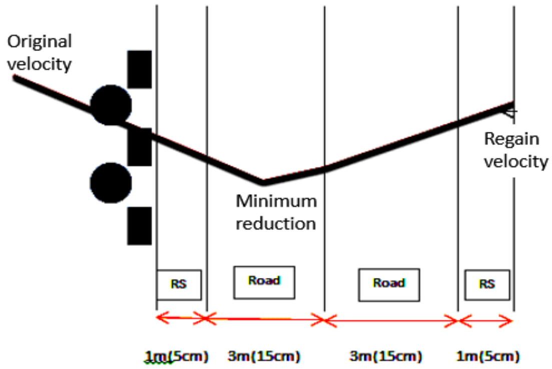


Fig. 7 Velocity reduction capability of object 2.

Possible arrangement of the objects can be illustrated by the following Fig. 8. It can be seen that the objects can be placed as road furnitures in the form of planter boxes or corridor divider.

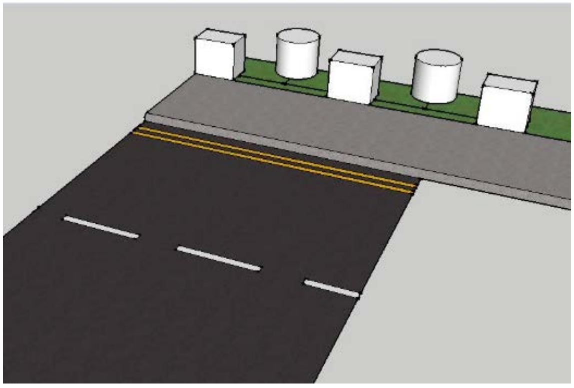


Fig. 8 Practical use of diffuser structures along flood stretch.

4. CONCLUSION

Up to 37% reduction of flood velocity can be achieved by placing suitable objects along flooded stretch. This study has identified a suitable object shape and arrangement to reduce the floodwater velocity when it crosses road section.

5. ACKNOWLEDGEMENTS

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