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Effect of Flood Water Diffuser on Flow Pattern of Water during Road Crossing

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Abstract. One of the methods to reduce the velocity of flood water flow across roads is to design obstacle objects as diffusers and place them alongside the road shoulder. The velocity reduction of water flow depends on the diffusion pattern of water. The pattern of diffused water depends on the design of the obstacle objects. The main purpose of this study is to investigate the design of obstacle objects and their water diffusing patterns and their capability to reduce the velocity of the flood water flow during road crossing. Variety of designs and orientation of the obstacle objects were tested in the environmental laboratory on a scale of 1:20. The results are classified into three distinguishable patterns of diffusion. Finally, two diffuser shapes and arrangements are recommended for further investigations in full scale or CFD model.

1 Introduction

A flood is an overflow of water that submerges or drowns land. In a general community flooding scenario, the rise in water level causes neighbouring water bodies and some road segments in these areas to be flooded [1]. When the water body flood reaches a water level higher than its normal storage level, it will flow to the surrounding areas. In the process, the flowing water interacts with roads, covering road segments. The primary effects of flooding include traffic obstruction, damage to buildings as well as other roadway structures, and in extreme cases, loss of life. High velocity flow also causes damage to the road pavement and other transport infrastructures. Mobilization of aid or emergency evacuation in response to the flood, will be affected by not only the flooding but also the damaged structures.

The detrimental impact of flooding on roadways is not so easily determined. There are many impacts from flooding [2]. In the United States, the Kentucky Transportation Cabinet (KYTC) estimated their June 2011 floods that impacted the state cause USD30 million in damages to the state's roadways. Future flooding events will lead to further monetary costs and impair the operational structure and integrity of the state's roads [3]. The loss of critical infrastructure produces negative effects over the short-term and long-term.

The primary effects of floods are those due to direct contact with the flood waters. Water velocities tend to be high in flood roadway crossings. The high velocity flood water that crosses roadways consequently results in difficulties in mobilization, damage to vehicles and road structures as well as endangering people's life. Furthermore, flood water could cause traffic congestion and in extreme cases, sweep people and vehicles away.

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The high velocity of water flows can be diffused by suitable objects or structures for safer crossing and preventing damage to road structures. There must be a method to decrease the energy and velocity of flood water during road crossing. The method must slow down the flow of water to allow for smooth mobilization and to prevent damage.

2 Methodology

The methodology used in this study was laboratory experiments. The experiments were conducted in the environmental laboratory and data was collected through observation. The apparatus used in this experiment were water flow table, water colour, adjustable stand, camera, and double adhesive tape to represent the shape and size of 2D obstructing objects. The apparatus set up is shown in Figure 1.

Figure 1 : Test setup

Before doing the experiment for actual observation, pilot tests were conducted. The purpose of the pilot test was to help in finding possibilities for improvement and identifying possible hiccups before the actual experiment was conducted. It was also to obtain typical water flow patterns as a result of the obstructing objects. This helps 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 Figure 2

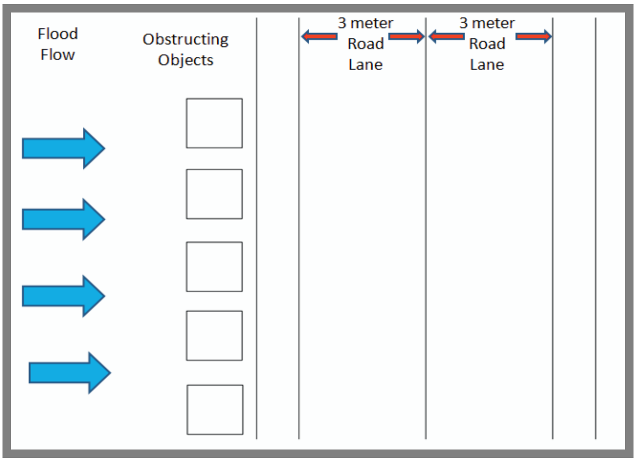


Figure 2. Water flow simulation

The 1:20 scale was finally chosen as the experimental scale because it gave a 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 adhesive tape. The road shoulders are marked to represent 1 meter dimensions on site and the roads are marked to represent 3 meters on site. Figure 3 shows how the adhesive tape was used in the diffuser model, was fixed on the flow water table.

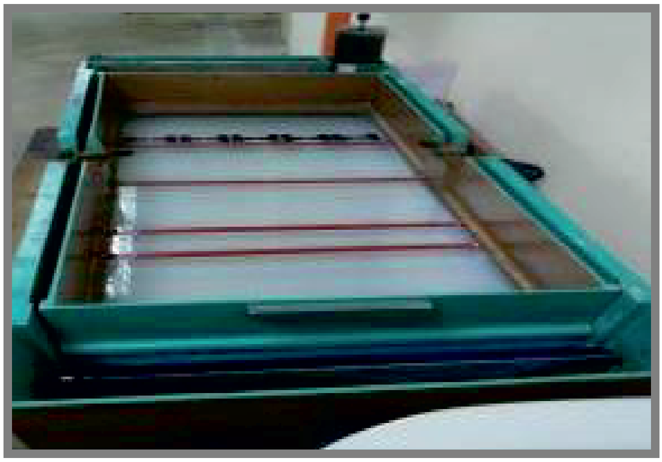


Figure 3. Diffuser model fixed on flow water table

Video observations were made for every test and the patterns were identified. The camera was securely held by an adjustable stand vertically above the table to record flow pattern to be analysed and classified later. Figure 4 shows the position of the camera to record the video of the experiment. Notice the diffusing objects just below the camera.

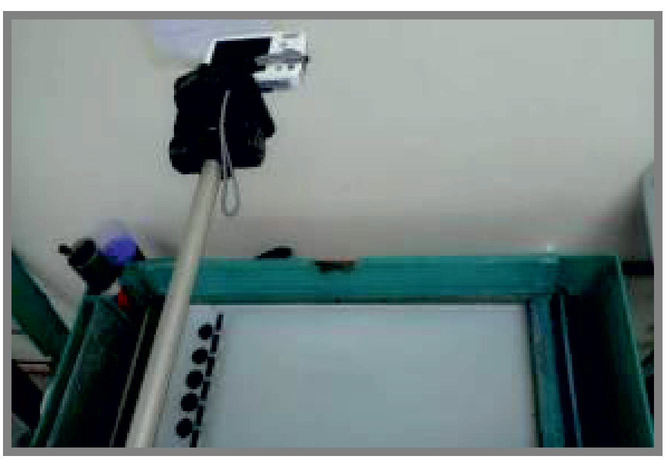
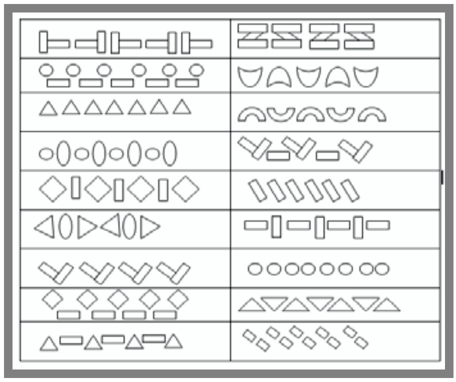


Figure 4. Position of camera to record video

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 experiments were conducted using the 18 pattern and size of diffusers as shown in Table 1 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.

Table 1. Diffusing objects and pattern



3 Result and discussion

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 a higher amplitude indicates a 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 occurring until it reaches the road shoulder across the road. The amplitude of the waves are maintained the same until the end of the road shoulder. Figure 5 and 6 shows one of the result categorized as category 1.

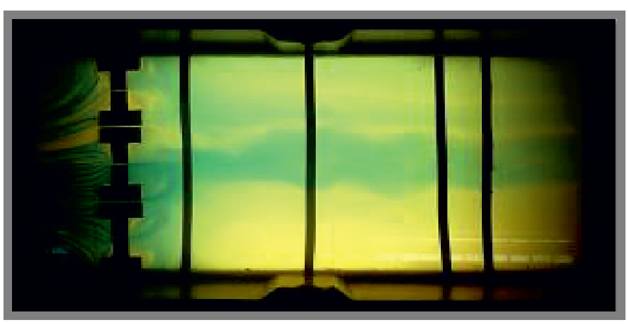


Figure 5. Diffusion Pattern Cat 1

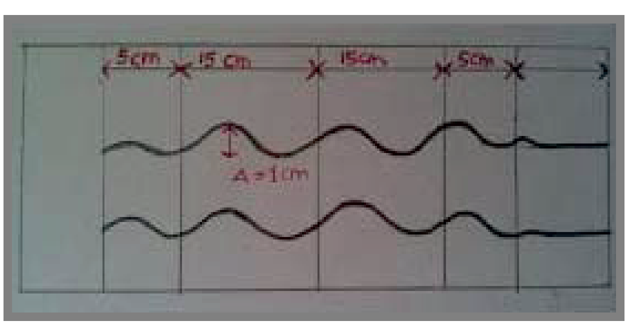


Figure 6. Diffusion Pattern & Wave Amplitude Cat 1

The second category is described as the diffussion pattern (wave) of the water flow after passing through the diffuser model occurring until the middle of the second lane and then becoming a straight flow to the end of road shoulder. The amplitude of wave remained similar until it diminished into a straight line again. Straight line flow similar to the flow before the obstruction is considered high velocity flow. Figure 7 and 8 shows one of the model classified in category 2.

Figure 7. Diffusion Pattern Cat 2

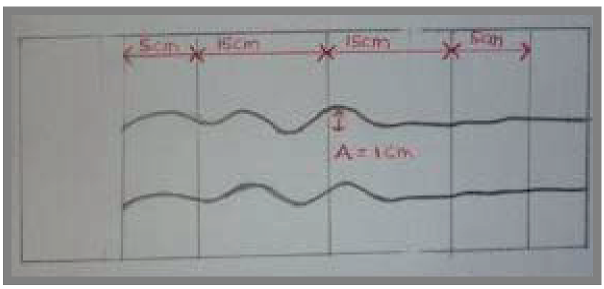


Figure 8. Diffusion Pattern & Wave Amplitude Cat 2

Category 3 is described as the diffussion 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 the road crossing or no significant change occurred in its flow pattern (straight flow). The amplitude of the waves are also small. Figure 9 and 10 shows the diffuser model that classified as category 3.

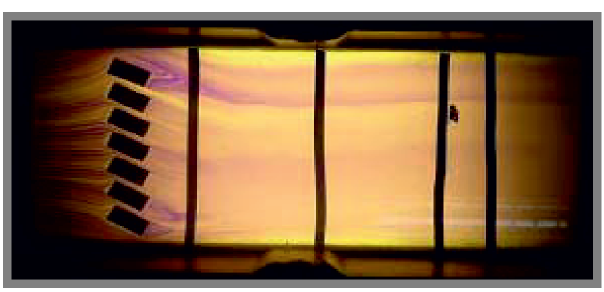


Figure 9. Diffusion Pattern Cat 3

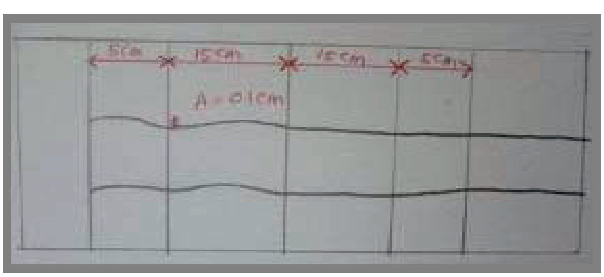


Figure 10. Diffusion Pattern & Wave Amplitude Cat 3

4 Conclusions and Recommendations

Out of the 18 obstruction patterns, two patterns can be considered as the pattern with the most capability of reducing water flow velocity. Figure 11 and 12 shows the recommended model that gave good effect on reducing the velocity of water flow across the road. They are two of the shapes from category 1. This is because this object arrangement produced wave diffusion patterns until the end of the opposite road shoulder and had a high number of wave amplitude. The longer distance of the wave diffusion, the more the velocity is being reduced. The higher number of wave amplitude, the more velocity reduces.

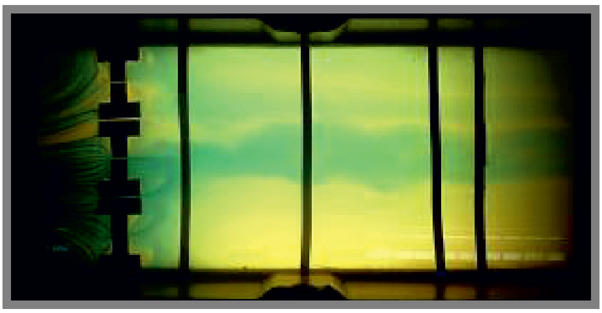


Figure 11. Recommended Diffuser 1

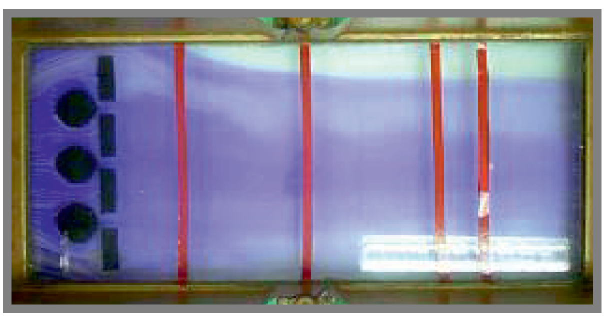
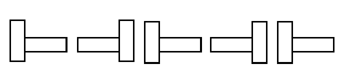
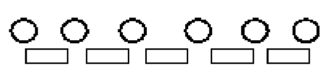


Figure 12. Recommended Diffuser 2

The two diffuser shapes and arrangements can be graphically illustrated as in the following Table 2.

Table 2. Recommended pattern and arrangement

Shape and Pattern 1	
Shape and Pattern 2	

It is recommended that the study of these two types of arrangement be carried out in a 3D environment where water pressure and velocity can be measured across the roadway. It is also recommended that similar modelling is done using suitable Computational Fluid Dynamics software to verify current findings as well as to better setup a 3D physical model or full scale investigation.

Acknowledgement

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