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LABORATORY STUDY ON TSUNAMI REDUCTION EFFECT OF TEIZAN CANAL

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ABSTRACT

During the 2011 Tohoku Tsunami, reduction of tsunami height and velocity over Teizan Canal which is located along the Sendai Plain coast was reported. The present study aims to understand the tsunami reduction effect of a canal by conducting a series of the laboratory experiments both in a tsunami basin and a wave flume. The laboratory experiments showed that a canal reduces the amount of overflowing wave. As the canal depth increases, the amount of overflow decreases. Then, the waveform also affects the amount of overflow. Moreover, the overflowing wave movement around inflow part of a canal could be seen by PIV.

KEWORDS: tsunami, Teizan Canal, disaster mitigation, laboratory experiment, PIV

1 INTRODUCTION

During the 2011 Tohoku Tsunami, there were eyewitness testimonies that tsunami inundation height was reduced due to Teizan Canal (Miyagi Prefecture, 2013). Figure 1 shows a part of Teizan Canal which dimensions are 25 to 45 m wide, 49 km long, and 0.3 to 2 m deep. The red line in Figure 1 indicates a canal wide, which is 45 m. The field data obtained from the 2011 Tohoku Tsunami also showed this tendency. Niimi *et al.* (2013) discussed tsunami reduction effect of Teizan Canal by numerical simulation and video analysis. To understand detailed characteristics of overflowing tsunami over a canal, it is necessary to study the tsunami reduction effect of a canal by laboratory experiments.

In the present study, laboratory experiments were performed in a tsunami basin and a wave flume. In the tsunami basin, the amount of flow over a canal model was measured with different wave conditions and different depths in the canal model. In the wave flume, the fluid motion of flow in a canal model was visualized by PIV.

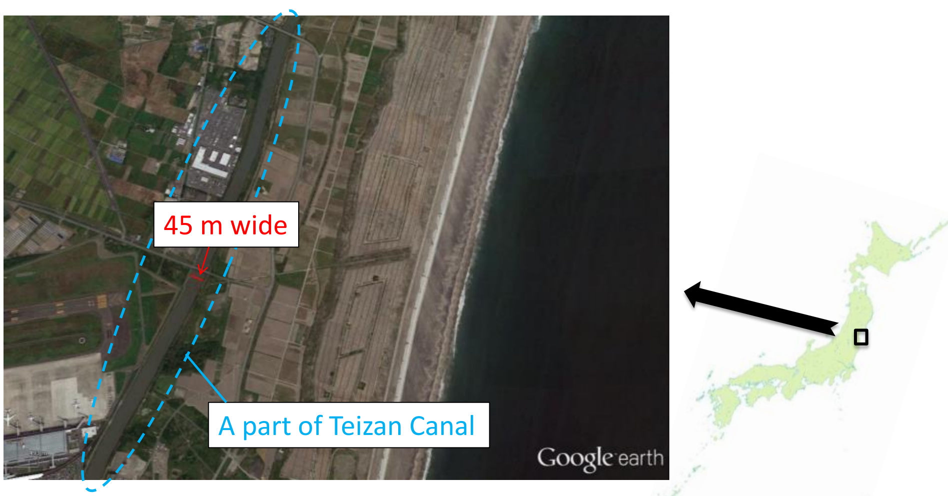

Figure 1. The part of Teizan Canal.

2 LABORATORY EXPERIMENT IN A TSUNAMI BASIN

2.1 Experimental Setup

Laboratory experiments were carried out in a tsunami basin at Waseda University, Japan (dimension: 4 m wide, 9 m long, and 0.5 m high). A chamber type wave generator (Oda *et al.*, 2012) is installed in the basin in order to produce tsunami-like waves. Wave heights and waveforms were controlled by the initial water level in the chambers and electrically controllable valves attached to the chambers.

Figure 2 shows the experimental layout. The offshore water depth was set to be 20 cm. An overflow measurement equipment and a canal model were put behind slopes as in Figure 3. The wave over the canal model was stored into the overflow measurement equipment, and then the amount of overflow was measured. The experiments were carried out with a scale of 1/100. The wave height, waveform, and water depth in the canal model were changed to test the sensitivity of the canal model on the amount of overflow. The wave heights at three different locations were measured using wave gauges (KENEK Co., LTD.) with a sampling frequency of 50 Hz. In order to make the condition without the canal model, the canal model was closed as shown in Figure 4. The three types of waves were generated as in Table 1. There are seven levels for controlling the opening if the valves (1: fully opened, 2-6: partially opened, and 7: completely closed). In this wave generator, it is noted that characteristic of wave is changed at boundary of valve opening level 4 and 5. The canal condition was changed for 0 cm, 2 cm, 4 cm canal depth and without canal condition for each type waves. The experiments were performed twice at least for each cases. The average values were recorded for results.

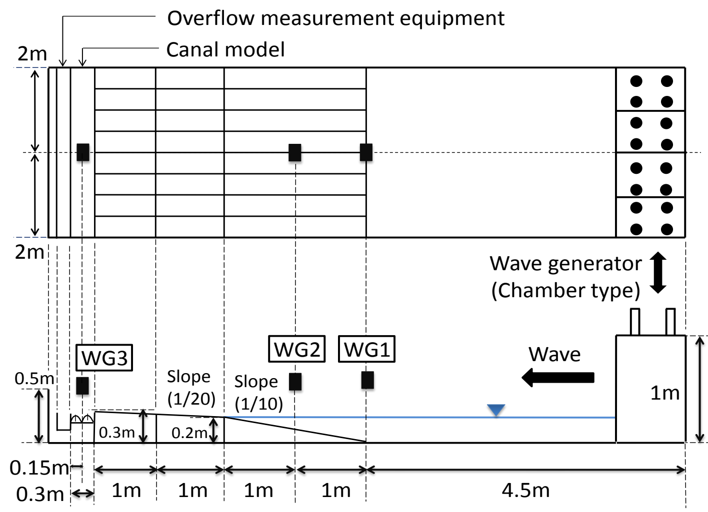

Figure 2. Experimental layout in a tsunami basin.

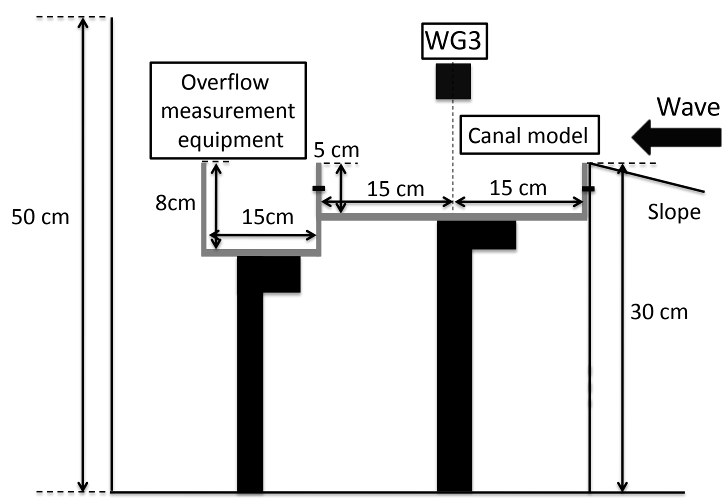

Figure 3. Canal model and overflow measurement equipment.

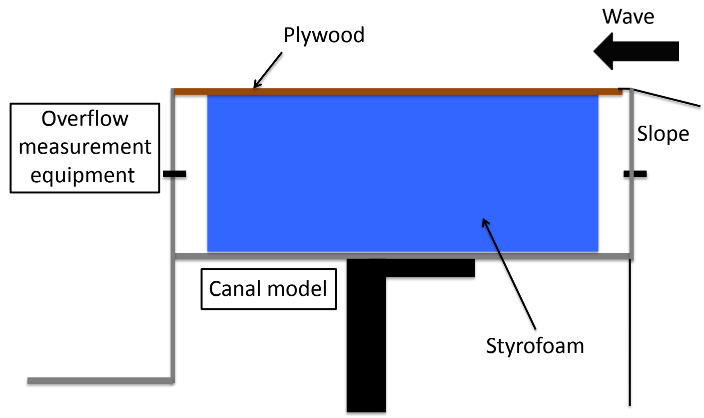

Figure 4. The experimental condition without canal.

Table 1. The characteristic of waveform.

	The duration time of water level	Wave height	Valve opening level	Initial water level in chambers (cm)
Type1	short	large	4	55
Type2	long	small	5	79
Type3	long	medium	4+6 (*)	80

(*) The half of the valves was set to 4, the others was set to 6

2.2 Experimental Results

Table 2 shows the summary of obtained data. Figure 5 shows the waveform of each wave type on 4 cm canal depth. Figure 6 shows the difference of the amount of overflow between with canal model and without canal model. This figure indicates that the amount of overflow with canal is less than without canal. The reduction rate of the amount of overflow is 35.7% in Type1, 59.2% in Type2 and 32.1% in Type3. This result shows that the reduction rate of the amount of overflow on Type2 is the largest in all types and the reduction rate of the amount of overflow becomes smaller when water level is low. Figure 7 means the difference of the amount of overflow for each water depth in canal. The amount of overflow gradually increases as water depth in canal becomes large. In addition to, the amount of overflow on Type1 and Type3 is almost the same in spite of difference of the maximum wave height. This result shows that the amount of overflow is determined not only the maximum wave height but also the duration time of water level.

Table 2. The experimental result.

	Canal condition	The amount of overflow (kg)	The maximum wave height in WG1 (cm)	The maximum wave height in WG2 (cm)	The maximum wave height in WG3 (cm)
Type1	Water depth in canal = 0 cm	1.27	7.30	7.99	2.55
	Water depth in canal = 2 cm	3.59	7.36	8.04	4.11
	Water depth in canal = 4 cm	22.05	7.35	8.06	2.73
	Without canal	34.29	7.30	7.98	
Type2	Water depth in canal = 0 cm	0.081	5.82	6.57	1.37
	Water depth in canal = 2 cm	0.030	5.74	6.41	2.30
	Water depth in canal = 4 cm	8.37	6.02	6.78	2.27
	Without canal	20.48	5.94	6.74	
Type3	Water depth in canal = 0 cm	0.45	6.27	7.07	2.87
	Water depth in canal = 2 cm	2.35	6.29	7.07	3.49
	Water depth in canal = 4 cm	20.48	6.27	7.07	2.85
	Without canal	32.56	6.29	7.03	

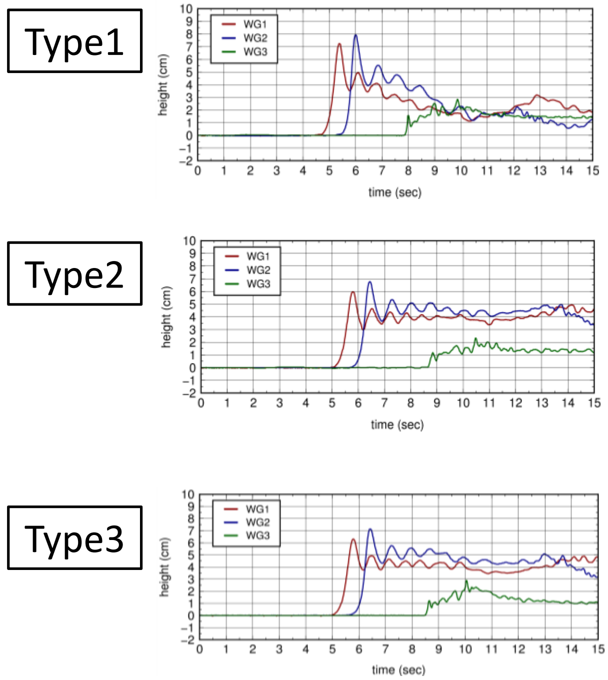

Figure 5. The waveform of Type1, 2 and 3.

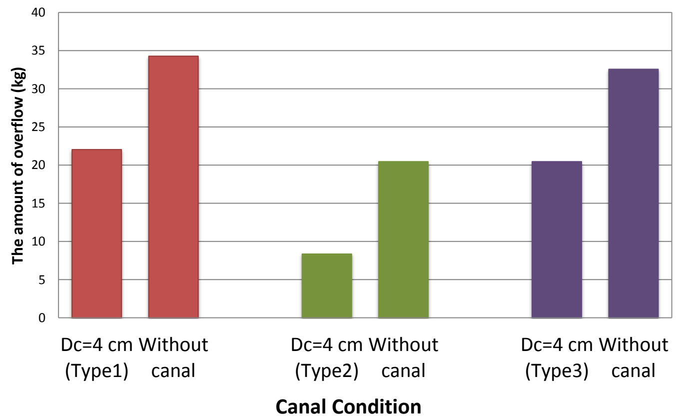

Figure 6. The difference of the amount of overflow between with canal and without canal.

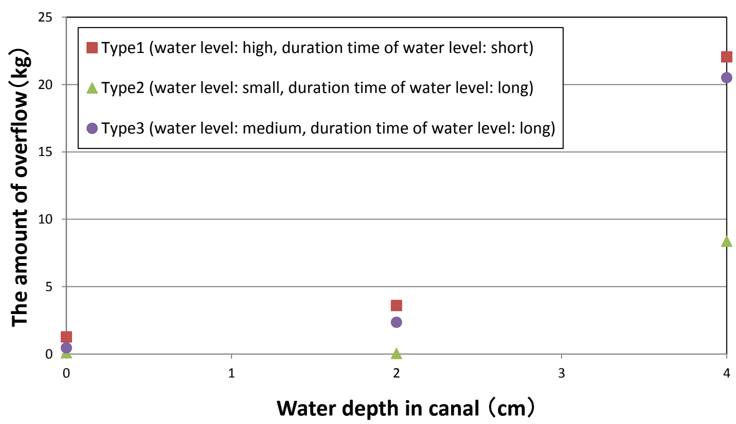

Figure 7. The difference between the amount of overflow and water depth in canal.

3 LABORATORY EXPERIMENRS IN A WAVE FLUME

3.1 Experimental Setup

In order to investigate the fluid motion of flow in a canal, the laboratory experiments were performed in a wave flume at Waseda University (dimension: 12 m long, 0.4 m wide, and 0.8 m high) with a scale of 1/50. Figure 7 shows the experimental layout. A pump is installed to produce overflow on a canal model. The flow rate can be changed by controlling a handle attached to the pump. The inflow part of the canal model was focused on and analyzed by PIV. The tracer (Diaion HP20SS, Mitsubishi Chemical Corp.) was used and the laser light (PIV Laser, KATOKOKEN CO., LTD) was used in order to visualize water flowing on focus area. The visualized flow image was captures by the high speed camera (High Speed Camera K4, KATOKOKEN CO., LTD) with high magnification zoom lens (Nikkor lens 50mm f/1.2, Nikon Corp.). Finally, the taken image was analyzed by fluid analysis software (FlowExpert2D2C, KATOKOKEN CO., LTD). The water level of inflow part of the canal model matched the actual Tohoku tsunami inundation height by changing the flow rate.

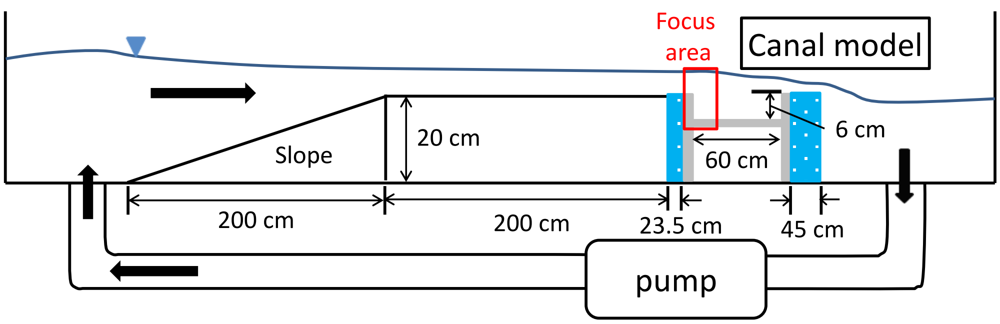

Figure 8. Experimental layout in a wave flume.

3.2 Experimental Results

Figure 9 shows the actual experimental condition. The water level of inflow part of the canal model was 6.4 cm. The water level in front of canal was higher than behind canal. Also, figure 10 shows the snapshots of the analyzed movie. The current characteristic was different between the inside of the canal model and upper side. In addition, some vortexes can be seen and an energy loss occurred due to the canal model.

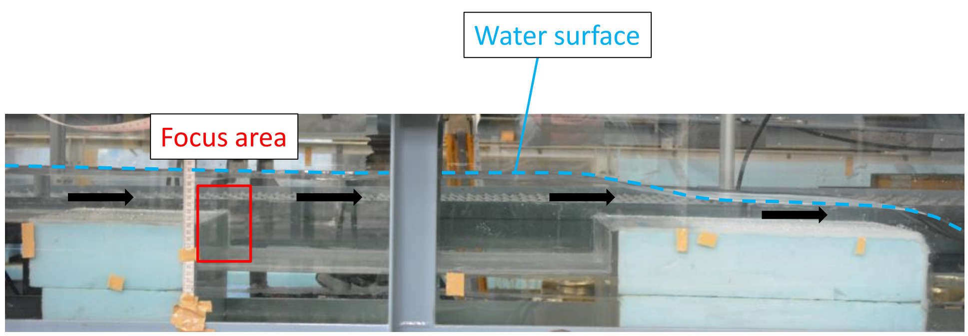

Figure 9. The actual experimental condition.

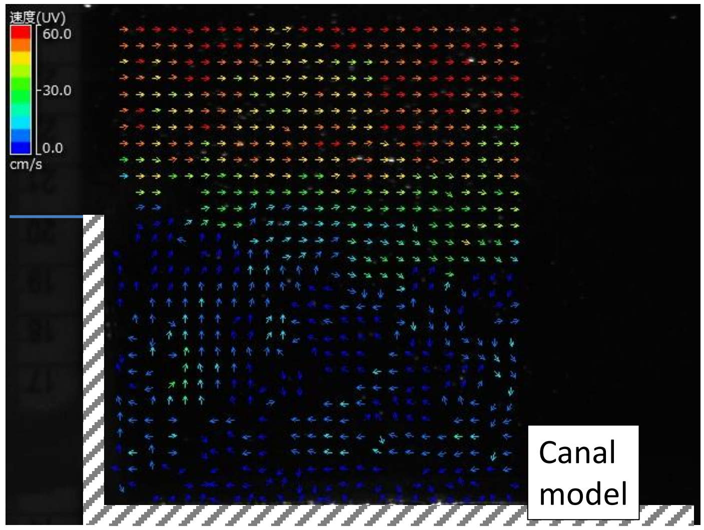

Figure 10. The snapshots of each analyzed image.

4 CONCLUSIONS

In this study, the authors focused on the tsunami reduction effect of a canal. The laboratory experiments in a tsunami basin showed that a canal reduced the amount of overflow, that the amount of overflow became larger as the water depth in a canal gradually increased, also that the amount of overflow was decided not only the wave height but also the waveform. The fluid motion of flow in a canal was investigated in a wave flume, especially inflow part of a canal. However, actual canal condition is more complex. Hence it is necessary to carry out more laboratory tests.

ACKNOWLEDGEMENT

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