Study on Tsunami Forces Acting on Cylindrical Structures Surrounded by Weir

University of Miyazaki Student Member Indradi WIJATMIKO
University of Miyazaki Member Keisuke MURAKAMI

1. Introduction

Many infrastructures can be seen on a vulnerable area against tsunamis, and they are under the risk of suffering from many types of severe damages caused by tsunami inundation. Especially, when tsunami damages on structures that contain hazardous materials such as petroleum which may cause an expansion of disaster over a wide coastal area (Cruz *et al*. 2009). Meanwhile, the building code regulation of oil storage tanks requires an oil weir to restrain the spread of oil spilled from the tank. The inundated flow overtopping this weir produces a complex flow around the storage tank as well as round the weir. Furthermore, the overtopped flow may also produce an additional wave pressure on the structure. This study carried out a series of hydraulic experiments concerning tsunami inundation in order to investigate the characteristic of wave pressures and forces acting on the cylindrical structure which is surrounded by a wall that suppose an oil weir.

2. Experimental Setup

As seen in Figure-1, two dimensional open channel, 12m in length, 0.4m in width and 0.4m in height, was used to generate bore type tsunami. The water level at the impounded region, h_1 in Figure-1, was changed in the range from 20cm to 30cm to generate various height of tsunami by instantly pulling up the division gate installed at 5.8m upstream of the channel. The quiescent water level, h_2, was set as 4.5cm. On the downstream area, a cylindrical structure with 15cm height was set on the dike with 11cm height. The cylindrical structure, its diameter was D=4cm, 8cm and 11cm respectively, was set 30cm from the tip of the dike. Five pressure gauges were attached vertically on the front face of the cylinder with 2.75cm interval from the bottom. The tsunami force was also measured with using four strain-stress gauges attached at the upper end of the beam, which supports the cylindrical structure.

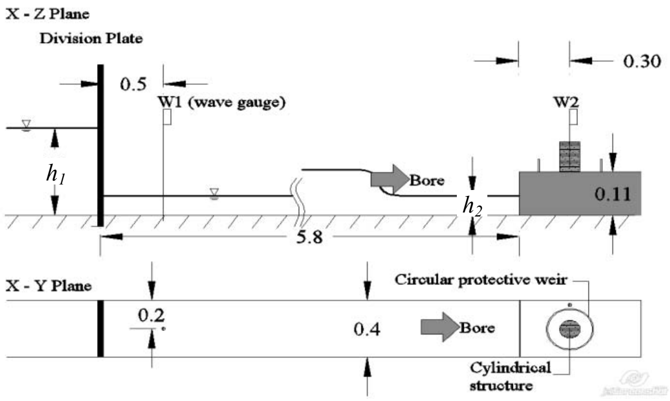


Figure 1. Experiment Setup (units in m)

Circular wall, that suppose an oil weir, was set to surround the cylindrical structure as shown in Figure-1. The building code regulation of oil weir requires a space more than 100% of tank volume (DGSM, 2003). Regarding this, three cases of circular wall, D'=26cm diameter with h'=4cm height (weir type A), D'=26cm with h'=6cm (weir type B) and D'=22cm with h'=6cm (weir type C), were chosen in this study. In order to compare the effect of circular wall on the wave pressures and forces characteristic, we conducted some experiments of setting a straight wall, its height was 5cm, on the tip of the dike. Wave gauges were used to measure water surface elevation both on the offshore at W1 and on the dike at W2.

3. Research and Discussions

Bore type tsunami propagates in the channel just after pulling up the division plate on the upstream side. Figure-2 shows some water surface profiles at W2, beside the structures on the dike. The water surface profiles in the case of setting weir are similar to those in the case of no weir, though the inundation depth beside the weir seems slightly larger. In the case of h_1=20cm, only a small amount of water overtopped the weir. The volume of water over the weir becomes larger with increase of inundation depth as seen in the case of h_1=25cm and h_1=30cm, and flow around the structures becomes significantly complex.

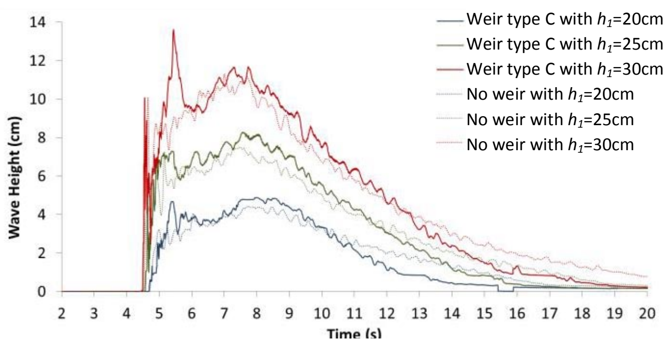
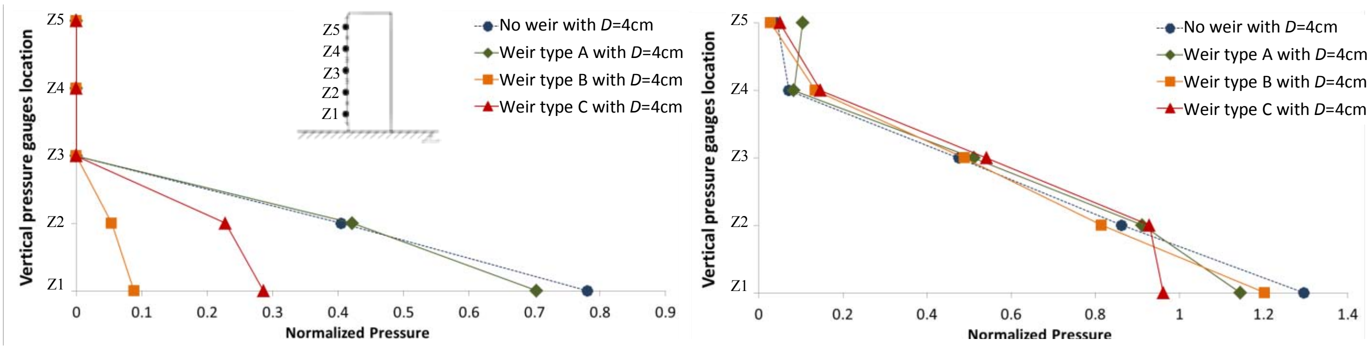


Figure 2. Water surface profiles at W2

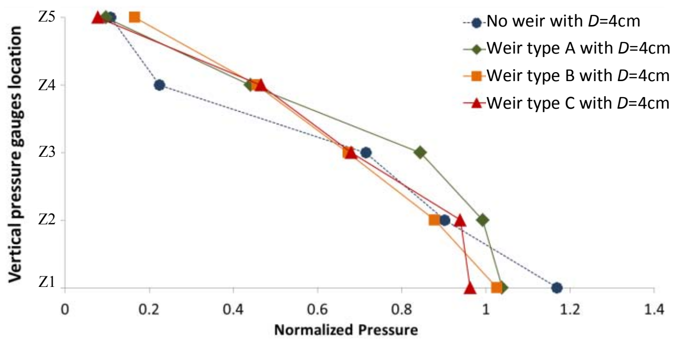
Figure-3 shows the distributions of maximum sustain wave pressure on the front face of cylindrical structures. As shown in this figure, the vertical axis is the location of the pressure gauges from the bottom to the top, while the horizontal axis is the normalized pressure by the wave surface elevation at the W1.In the case of smaller wave overtopping condition as shown in Figure-3(a), the weir height play an important role on effectively in reducing pressures at each location and the maximum wave pressure shows much smaller values than the case of no weir. Weir type A, lower weir case, did not significantly reduce pressure due to there were some flow stream down to the cylinder with increasing velocity. While the higher weir, type B and C, only allowed small amount of overtopped water to flow inside and hit the structure. Further, wider diameter of weir causes significant reduces pressure as the water surface elevation inside weir become shallower due to increased weir area.



(a) h_I=20cm (b) h_I=25cm

While in the case of larger wave overtopping condition as shown in Figure-3(b) and 3(c), the weir diameter play an important role in reducing the sustain pressure at the bottom of cylindrical structure. The weir with smaller diameter, that means the cases of smaller space between weir and cylinder, tends to lower the pressure at the bottom section. The sustain pressure at the bottom section also smaller than the pressure measured in the cases of straight wall existence at the tip on the dike (Wijatmiko and Murakami, 2010), because in the case of straight wall, velocity increases as wave overtopped wall and stream directly to the dump area without any obstacles. On the other hand, from observation, the existence of weir tended to increase pressure at the higher location (Z3 and Z4). It occurred because after the wave overtopped the weir, the weir act as container for the initial wave, while the sustain wave continuously flow above the trapped initial water inside weir with significant velocity. As a result, water surface elevation increased and it generated more pressure at the top section of structure.

Figure-4 shows the maximum sustain wave forces acting on the cylinders due to sustain wave in all cases. It is obvious that the weir reduces the wave forces approximately a half of that acting on the cylinder without weir even in the case of significant wave overtopping condition. The inundated water behind cylindrical structure tends to create hydrostatic force, which reduced the drag force from the tsunami wave.



(c) h_I=30cm

Figure 3. Distribution of maximum sustain wave pressure on the front of cylindrical structures

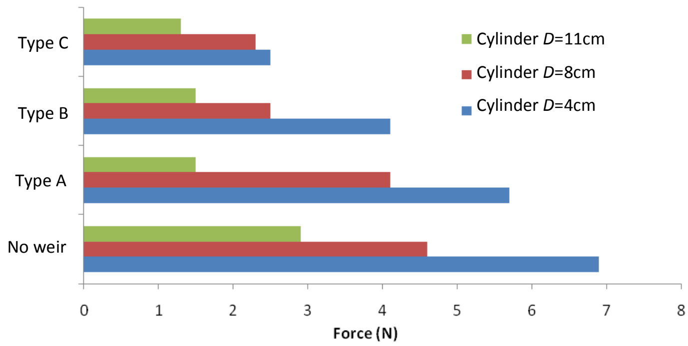


Figure 4. Maximum sustain wave force (h_I=30cm)

4. Conclusions

This study investigates the characteristic of wave pressures and forces acting on the cylindrical structure with surrounding wall that suppose an oil weir. The weir tends to reduce wave sustain pressures on the bottom section of the cylinder even when the inundated flow largely overtops the weir. On the contrary, sustain pressure at higher section of cylinder increased as the water surface elevation became higher. The magnitude of this local pressure closely relates to the configurations of flow over the weir. The weir also reduces maximum sustain wave forces and has close relations with specifications of the weir as well as the inundation depth.

References

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