Experimental Study on the Function of Green Buffer Zone for Disaster Reduction

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Abstract: along with climate change, the rising of sea level, the enhancement of storm surge, the increasing of extreme waves, the revetment and the land area behind it are facing more and more risk. Under the action of strong typhoon, some revetments were damaged. In the process of restoration, revetment elevation shouldn't increase due to the limitation of land area which already built, how to achieve the protection effect under the condition of wave enhancement in a limited height has become the problem and it is researched in this paper. Overtopping is the main form of damage to revetment and land area caused by strong waves. By building green buffer zone, the water flow speed of overtopping water body can be reduced, and the drainage time of strong waves can be prolonged, so as to reduce overtopping. Combined with the actual project, the green buffer zone is simulated by physical model test of cross section, and compared with the traditional revetment without green buffer zone, the results show that its efficiency is obvious.

1. Introduction

In 2018, the typhoon “mangkhut” hit the coast of south china, caused a lot of coastal engineering damage. See figure 1, the typhoon moving path and the characteristic wave height of the open sea. Due to the large typhoon radius, the moving speed of the typhoon before landing slows down, resulting in a long-term strong wave process and storm surge in a large coastal area. After the assessment, the water level and wave of some damaged coasts increased and beyond design condition.

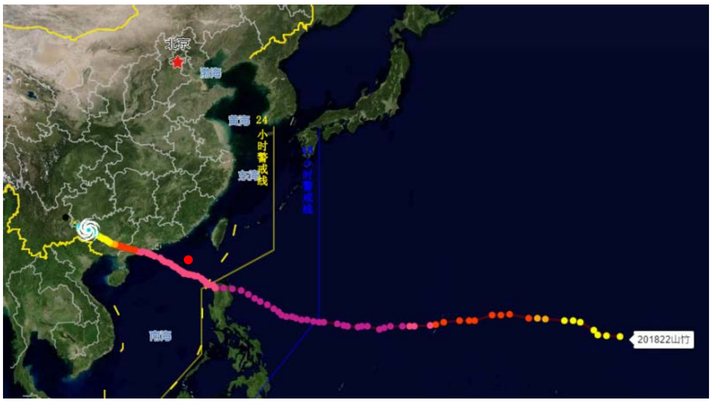

Fig.1 Sketch Map of Landing Path of Typhoon “Mangkhut”

For the existed project, although the water level and design wave are increased, in order to meet the requirements of production and landscape, the top elevation of revetment should not be increased under the condition of constant protection standard, and at the same time, the sea side cannot be expanded due to the limitation of sea use. Under limited conditions, it is proposed to use

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green plants to build buffer zones [1] [2] [3].

2. Methodology

2.1 Equipment and Instrument

The experiments described here were conducted at the Research center for disaster prevention and mitigation of water transport engineering,Tianjin Research Institute of water transport engineering, Ministry of transport [4] [5] [6],Tianjin,China. In a wave flume 68m long, 1.5m deep, 1.0m wide, on which the semi-circular structural closed-cover is set. At one end of the flume, it was equipped with wind generating device,and different wind speed can be generated in the closed flume by means of changing the rotational frequency of wind fan. At the other end, the wave generator is set, which is electromotor servo driving and absorption-type wave generator, and the regular and irregular waves can be generated. This device is composed of wave generating machinery, electro servo control system and absorption module. The maximum simulated wind speed is 14m/s, regular wave and irregular wave can be generated, and the maximum wave height is 0.35m, shown in Fig.2.

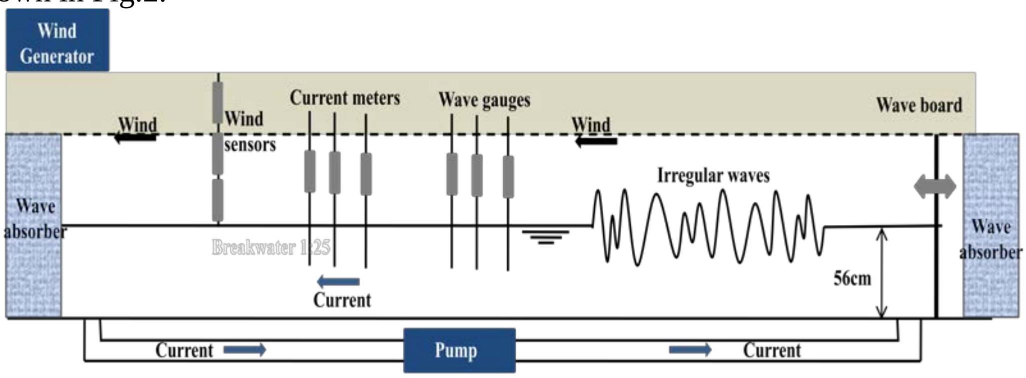

Fig.2 Schematic of the Flume for Experiment

2.2 Model Design and Scale

2.2.1 The Physical Model Must Satisfy Gravitational Similarity and Geometry Similarity.

In BS6349, PIANC Designer's Handbook, and Physical Models and Laboratory Techniques in Coastal Engineering,the recommendations on the range of the model scales for 2D Physical model is 1:10 to 1:50. And The scale of the model should also consider the following factors:1) The capability and accuracy of test equipment and apparatus, especially the range of wave height capable of being generated in the laboratory; In general, the significant wave height (Hs) should not be less than 0.02m, and the spectrum peak period should not be less than 0.8s. With consideration of the above, geometric scale for simulation test of revetment section choose 1:23.5, the mass scale is 1:12978, and the time scale is 1:4.85.

2.2.2 Model Construction

The model construction had involved two stages. The first one was the construction of the physical model based on the detail of structure design of cross-section including armor blocks fabrication, rock selection and etc. The second one will involve arrangement of model, installation of wave gauge and etc.

The deviation in geometric dimension of model building and its constructional elements should be controlled within ±1% and not exceeding ±5mm. The Amour block, four foot hollow block and barrier board are made up of atomic ash and iron powder. The weight deviation and geometric dimension error meet the requirements of the test procedures. All types of block stones in the section model are selected according to the gravity scale, and the quality deviation is controlled within ± 5%. Because the model test uses fresh water, but the actual project is sea water, affected by the density difference between fresh water and sea water, the model considers 1.025, that is, the influence is considered in the block making.

2.3 Waves and Water Levels

Irregular waves are test in experiment and JONSWAP spectrum simulation is used for irregular waves. Water level +3.455m, significant wave height of 100yrs return period Hs=2.87m, and average period $\bar{T}$=12.32s. Water level +3.255m, significant wave height of 200yrs return period Hs=4.09m, and average period $\bar{T}$=13.53s. The water level and wave conditions were used to simulate wave overtopping.

2.4 Measurement Methodology of Overtopping

The measurement of wave overtopping volume is to collect the overtopping water body with the water collection device after the wave retaining wall on the top of the dike, and to obtain the overtopping volume of the model by measuring the volume of the water body. The total overtopping water body of a complete wave train is taken as the total overtopping amount of corresponding duration by irregular waves, and then the average overtopping amount of single width is calculated. According to the similarity criterion, the model overtopping is converted to the original overtopping. The average overtopping of a single width is calculated as follows:

$$q = \frac{V}{bt} \tag{1}$$

Where q is average wave overtopping per unit width ($m^3/(m\cdot s)$),V is total volume of overtopping water under the action of one wave series(m^3),b is the width of the overtopping container, t is duration of one wave series(s).

2.5 Model Section

The tested revetment section is shown in Fig. 3. A row of C25 plain concrete blocks are set in front of the Accropode at the slope toe of the revetment, which are connected with 1t four-foot-hollow-block, and then 300-500kg bottom protection block stone with a thickness of 700mm is set in the four-foot-hollow-block. The size of C25 plain concrete block is 0.8m × 1.0m × 1.8m (height × thickness × length), the top elevation is the same as that of four-foot-hollow-block, both of which are -1.40m, and the top elevation of Accropode at the slope toe is -0.90m.The top elevation of wave wall is +6.85m.

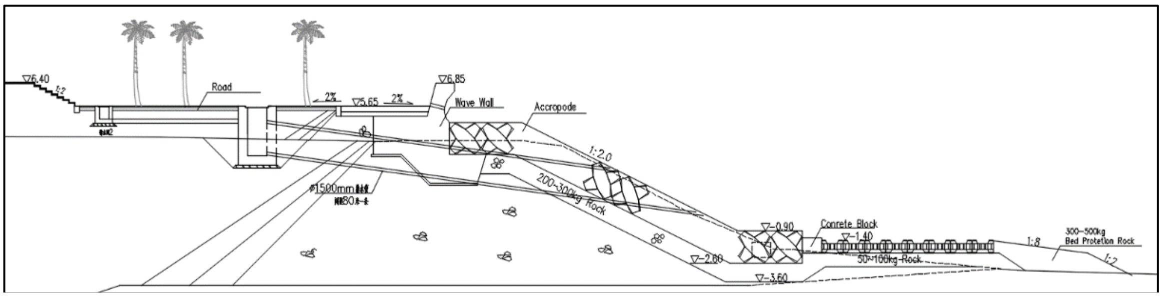

Fig.3 The Structure of Test Section

3. Results

3.1 Simulation Results without Green Buffer

When the top elevation of the wave wall is +6.85m and +7.00m, the overtopping of the wave wall top under different water levels and different wave conditions is measured(shown in Fig.4), and the results are shown in Table 1.

Measure the overtopping on the top of the second wall behind the wave wall, The elevation were raised to 6.64m and 6.85m to measure the wave overtopping volume of Overtopping volume results were shown in Table2.

Table.1 Overtopping Results on the Top of Wave Wall

Elevation of wave wall(m)	Water Level (m)	Return Period of Wave	Wave Overtopping($m^3/(m\cdot s)$)
+6.85	3.255	200yrs	0.132
	3.455	100yrs	0.135
+7.00	3.255	200yrs	0.129
	3.455	100yrs	0.133

Table.2 Overtopping Results of Second Wall Behind the Wave Wall

Elevation of wave wall(m)	Elevation of second wall(m)	Water Level (m)	Return Period of Wave	Wave Overtopping ($m^3/(m\cdot s)$)
+6.85m	+6.40m	3.255	200yrs	0.062
		3.455	100yrs	0.065
	+6.64m	3.255	200yrs	0.059
		3.455	100yrs	0.062
	+6.85m	3.255	200yrs	0.042
		3.455	100yrs	0.044

Fig.4 Measurement of Wave Overtopping volume on the top of wave wall

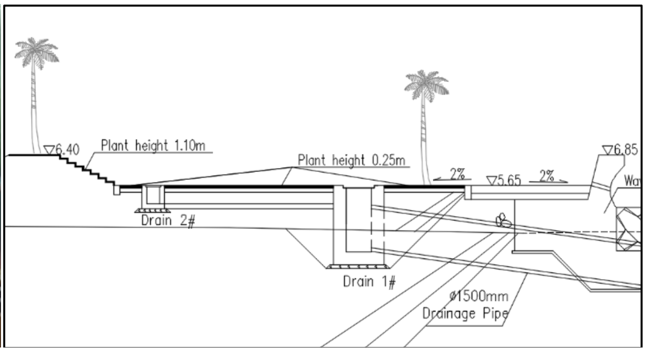

Fig.5 Planting Range and Height Behind Wave wall in test

3.2 Simulation Results with Green Buffer [7][8][9]

In order to further optimize the overtopping of the second wall behind wave wall of the test section, the tests under 5 combinations were carried out, and the plant planting range and selected plant height during the test are shown in Table 3 and Fig.5. Among them, in case3,case4, and case5, plants with height of 0.25m are planted intermittently behind the wave wall, the number of plants planted per square meter is about 146 strains, and 1.1m shrubs are planted from the bottom of the second wall to the top, the number of plants planted per square meter is about 54 strains.

The results of wave overtopping on the top of second wall with water level +3.255m, significant wave height of 200yrs return period Hs=4.09m were shown in Table 3.

However, the effect of the height, density and width of the green buffer zone on the reduction of overtopping is obvious, and the higher the plant is, the greater the density is, the wider the width is, and the more obvious the effect of reducing overtopping is.

Table 3 Test Cases And Results

Cases	Planting Range	Plant height (m)	Top elevation of second wall (m)	overtopping ($m^3/m\cdot s$)
Case1	Drain 1# to the top of second wall	0.25	6.40	0.027
Case2	Drain 1# to the top of second wall	1.1	6.40	0.0125
Case3	Shown in Fig.5	0.25 and 1.1	6.40	0.0195
Case4			6.64	0.0136
Case5			6.85	0.0120

4. Conclusion

(1) Due to climate change, coastal engineering is facing a great risk. Ecological coast is one of the measures to reduce disasters.

(2) Green buffer zone can effectively reduce the amount of overtopping, and its effect is related to plant height, density and width.

(3) The relationship between plant strength and wave overtopping reduction should be further studied.

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