Experimental study on wave force of anti-L-shaped parapet of inclined breakwater

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Abstract: The stability of the parapet of the inclined breakwater directly determines whether the project can run safely. In recent years, people have studied the wave force of L-shaped parapet of inclined breakwater. The distribution of wave force is clear and the calculation method is relatively mature. However, there is little research on the distribution and calculation method of wave force on the surface of anti-L-shaped parapet. Through the physical model test, the distribution law of the wave force of the anti-L-shaped parapet is explored, and the calculated value of the wave force is compared with the measured value. The stress mode of the parapet inclined breakwater in the actual project is summarized, which can provide reference for the engineering application.

1 Introduction

Breakwater is an important hydraulic building for artificial cover port engineering. Inclined breakwater has the advantages of weak wave reflection, good structural stability, low requirement of foundation bearing capacity and simple construction [1]. It is widely used in ocean, river and city revetment application. When the outer waves hit the inclined breakwater surface, the waves are broken, and continue to move up, if the inclined breakwater does not have enough elevation, there will be overtopping phenomenon. The more waves not only undermine the stability of the waters inside the harbor, but also poses a threat to the safety of the building. Usually in the top of the breakwater to set the parapet, not only can protect the port staff and property safety, and can reduce the cost of the project. Anti-L-shaped parapet and L-shaped parapet compared to the former has its unique advantages. First of all, the waves into the parapet toes, to go through the parapet surface of a distance, the waves can impact to the wall of the parapet, in the process of consumption of part of the wave of kinetic energy, making the wave on the parapet of the horizontal force significantly reduced; Wave impact to the parapet platform will produce a downward vertical wave pressure, as well as artificial block ballast effect, can offset part of the waves on the bottom of the parapet of the floating force [2], which is more conducive to the stability of the parapet. In the actual project, the inclined breakwater is often hollowed out of the base of the parapet, parapet displacement instability caused by damage [3]. Therefore, it is of great significance to ensure the safe operation of the inclined breakwater by exploring the distribution law of the wave force on the anti-L-shaped parapet and accurately calculating the wave force of the parapet.

In this paper, the physical model test, the anti-L-typed parapet surface pressure distribution, the total horizontal force and the total Floating force test results, comparative analysis with the “Harbor
Engineering Design Manual[4] in the calculation of the results of the difference and reasons. And make reasonable recommendations on the calculation methods proposed in the specification.

2 Test Survey
2.1 Test equipment
The experiment was carried out in the Key Laboratory of Coastal Engineering of Dalian Ocean University. The effective size of the tank was 40m long, 0.7m wide and 1m deep. One end of the water tank is equipped with motor generators irregular wave machine, can generate a regular cycle of 0.5~5s between the regular waves, irregular waves and other waves. Trough the end of the installation of vertical energy dissipation grid, so as not to wave reflection.

2.2 Test content
“Harbor Hydrologic Norms”[5] on the inclined breakwater wave force calculation formula for the parapet before the cover block without the case, in order to compare with this test parapet before the shelter is not placed.

The regular waves are used in the experiment. The water depth of the project is 14.25, 15 and 15.5m, and the incident wave height is 3.75, 4.5 and 5m, and the incident wave cycle is 10s. In order to measure the wave force acting on the parapet, a certain number of pressure sensors are arranged on the surfacing surface and the bottom surface. The specific measuring point is shown in Figure 1.

![Figure 1](image)

**Fig 1.** The actual project parapet pressure measuring point layout(Unit: mm)

3 According to the standard method to calculate the wave force on the parapet
Test wave using the incident wave height of 3.75m, wave period of 10s, in three different water depth conditions, according to “Harbor Hydrologic Norms” provides that under the action of the wave crest, the average pressure on the parapet calculated by the following formula: \( \bar{p} = 0.24 \gamma HK_p \). Where: \( \bar{p} \) is the average pressure strength (kPa); \( \frac{L}{H} \) for the dimensionless parameter \( \xi \) and Potain \( \frac{L}{H} \) on the average pressure coefficient.

According to the standard calculation of inclined breakwater parapet in three water depth under the conditions of the wave average pressure, the results shown in Table 1, parapet pressure distribution shown in Figure 2, the calculation of the wave force on parapet shown in Table 2.

| Water depth (m) | \( p \) (kPa) | \( 0.6 \bar{p} \) (kPa) |
|----------------|---------------|------------------------|
| 14.25          | 31.2          | 18.72                  |
| 15             | 36            | 21.6                   |
| 15.5           | 39.6          | 23.76                  |
Table 2. Calculation results of wave force on the parapet (kN/m)

| Water depth (m) | Horizontal force | Floating force | Vertical wave pressure |
|-----------------|------------------|----------------|-----------------------|
| 14.25           | 70.70            | 62.4           | 43.68                 |
| 15              | 93.67            | 72             | 50.4                  |
| 15.5            | 112.86           | 79.2           | 55.44                 |

![Diagram a) d=14.25m](image1.png)

![Diagram b) d=15m](image2.png)

![Diagram c) d=15.5m](image3.png)

Fig 2. Distribution of wave force of the parapet under three water depth conditions (unit: kPa)

4 The parapet of each measuring point measured results

4.1 The actual wave pressure distribution on parapet

In the actual project, the inclined breakwater parapet under the three kinds of water depth impact of the incident wave, the distribution of parapet surface wave pressure is shown in Figure 3.

![Diagram a) d=14.25m](image4.png)
![Diagram b) d=15m](image5.png)
Fig 3. Distribution of actual wave pressure on parapet under three water depth conditions (unit: kPa)

4.2 Calculate the results

According to the measured results of the each measuring point on the parapet, the wave force of per meter is calculated as shown in Table 3.

**Table 3.** the actual wave force calculation results of the parapet (kN/m)

| Water depth (m) | Horizontal force | Floating force | Vertical wave pressure |
|----------------|------------------|----------------|------------------------|
| 14.25          | 82.06            | 65.84          | 49.74                  |
| 15             | 115.80           | 83.99          | 59.06                  |
| 15.5           | 141.43           | 101.12         | 67.98                  |

5 Comparison of wave force results

According to the "Harbor Engineering Design Manual"[^4], Figure 2 shows that under the three water depth conditions, incident wave effect, the parapet surface pressure distribution is divided into two parts: the parapet platform surface below the rectangular distribution, above the platform surface was trapezoidal distribution. The distribution of the pressure distribution of the bottom of the parapet is triangular. Figure 3 shows that, according to the results of the physical model test, the wave surface and the bottom surface under the action of the trapezoidal distribution of the waves, the middle of the parapet is a wave of the main area, the area by the direct impact of the incident wave, will produce a maximum pressure. Above the main active area, the incident wave energy is converted into potential energy. As the height increases, the wave pressure decreases gradually. It can be seen that the distribution of the wave pressure given by the norm is quite different from the experimental results.

From the data in Table 2 and Table 3, it can be seen that the calculated value of the wave force of the parapet is smaller than that of the actual value.

In comparison with the difference between the calculated values of the horizontal wave force and the measured values, the calculated horizontal wave force is 70.7 kPa and the measured value is 82.06 kPa under the water depth of 14.25 m, the difference is 16%. The calculated value of horizontal force is 93.67kPa and the measured value is 115.80kPa, under the water depth of 15 m, the difference is 23.6%. Under the condition of water depth of 15.5m, the calculated value of horizontal force is 112.86kPa, the measured value is 141.43 kPa, the difference is 25.3%.

For the difference between the calculated value of the floating force and the measured value, the calculated value of the floating force is 62.4 kPa and the measured value is 65.84 kPa at the water depth of 14.25 m, the difference is 5.5%. Under the condition of water depth of 15m, the calculated value of the floating force is 72kPa and the measured value is 83.99kPa, the difference is 16.65%. Under the condition of water depth of 15.5m, the calculated value of the horizontal force is 79.2 KPa, the measured value of 101.12kPa, the difference between the two reached 27.68%.

It can be seen that the difference between the calculated value and the measured value of the horizontal wave force and the floating force of the parapet increases with the increase of the water depth. This is mainly due to the calculation of the wave surface on the surface of the waves on the wave height is less than the actual wave height, resulting in the horizontal wave force specification.
calculation value is too small. For the bottom of the parapet, the standard will be inside the bottom of the parapet pressure as 0, and the actual project, the most inside the parapet there is pressure, which led to the calculation of the floating force is less than the actual value.

6 Conclusion

(1) The results of the comparative analysis show that the size of the total horizontal force and the total floating force, the distribution of the pressure and the height of the waves calculated by the formula in the current standard are quite different from the measured results. With the increase of water depth, the maximum difference between the calculated value and the measured value of the horizontal wave force is 25.3%. The main reason is that the wave height calculated by the method is smaller than the actual effect of the wave.

(2) anti-L-shaped parapet surface by the incident wave of gravity, resulting in a downward vertical wave pressure, to offset part of the wave float force, is conducive to the stability of the structure of the parapet, in the practical application of the broad prospects.

(3) It is suggested that in some related engineering designs, specification method to calculate the total horizontal force and the float force multiplied by a certain of the safety factor, more conducive to the stability of the project and safe operation, if necessary, through the physical model test to be verified.

References

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