Assessment of typhoon prevention level at fishing port

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Abstract: Due to the need of typhoon grade evaluation in the construction plan of fishing port, the wave height distribution in the fishing port of typhoon 10 and typhoon 12 under adverse path was calculated, and the berthing area of the fishing port was counted. According to the theoretical formula, the wind force and anchor-holding force of the fishing boat are calculated, and the anti-typhoon grade of the anchorage is analyzed, which provides technical support for the construction of the port area.

1. Introduction
Fishing port is a very important infrastructure in coastal areas, a distribution center and comprehensive processing base of Marine aquatic products, and an important foundation for economic and social development in fishing areas. The southeast coastal area is affected by the tropical cyclone more seriously. The fishing port is an important place for fishing boats to avoid the wind safely. Therefore, it is necessary to build a good Marine fishery safety environment guarantee system and provide strong technical support for fishery production safety management.

2. Project area and overall design scheme
The Fishing Port located in the sea area to the west of Liantou Ridge at the mouth of Bohe Bay, and the geographical position is 111°14’33.18”, 21°25’44.58”. The design unit of this project provides two layout schemes. The layout of each scheme is shown in Figure 1 and Figure 2 respectively.

Scheme1: south breakwater 1410m, west breakwater total length 1770m; The south embankment, the west embankment and the north embankment form an enclosed entrance gate. The entrance gate is located in the south of the port, facing 15° West to the north, and its width is about 215m. The vertical wharf is 400m long, located inside the harbor basin and inside the south breakwater. Two high pile wharves, respectively 300m in length, are located on the shore of the fish pond. The approach channel and fishing boat berthing area in the port should be excavated to -3.2m, and the slope of the channel is 1:6.

Scheme2: South breakwater 1000m, northwest breakwater total length 2176m; The entrance gate is located in the south of the port, facing south and 205m wide. The internal construction layout of the harbor basin is the same as scheme 1.
3. Calculation of berthing area of fishing harbor under hypothetical typhoon

3.1. The design of typhoon
The sea area of the project is mainly SE to S direction according to the historical typhoon wave data. The door of fishing port is S to W direction in the schemes but the wave in SE direction is sheltered by the island on the east side of the fishing port, so the most disadvantageous typhoon path determined is S direction.

The average moving speed of typhoons, which have great influence on fishing ports since 2005 (shown in Table 1), is chosen as the moving speed of the designed typhoon. The average moving speed is 20.6 km/h.

According to the technical specification for assessment of typhoon protection grade in fishing ports (draft for soliciting opinions), the distance between the imaginary path and the edge of the fishing port is Radius of maximum wind. The $R_{\text{max}}$ can be obtained by using the formula (2) and the result are shown in Table 2. According to the intensity of tropical cyclones and the historical typhoon data in the vicinity of fishing ports, the corresponding central pressure and central wind speed of typhoons of different grades are shown in Table 2.

In order to ensure the accuracy of the calculation, assuming that the typhoon time is set to 25 hours and the time interval is 1 hour, and the moving speed of each stage typhoon is 20.6 km/h, then assuming the total length of the path is 515 km. Typhoon scenario parameters are shown in Table 2.
Table 1  Statistics of typhoon velocity

| typhoon number | Movement speed (km/h) |
|----------------|-----------------------|
| 0518           | 12                    |
| 0606           | 15                    |
| 0812           | 25                    |
| 1002           | 20                    |
| 1115           | 15                    |
| 1311           | 25                    |
| 1319           | 20                    |
| 1409           | 21                    |
| 1415           | 30                    |
| 1522           | 20                    |
| 1621           | 15                    |
| 1604           | 25                    |
| 1713           | 19                    |
| 1714           | 30                    |
| 1720           | 13                    |
| 1822           | 25                    |

Table 2  Hypothetical typhoon parameters

| Wind scale | Central pressure | Average wind velocity | Moving speed | Rmax |
|------------|------------------|-----------------------|--------------|------|
| 10         | 980hpa           | 26.5 (m/s)            | 20.6km/h     | 72.4km|
| 12         | 965hpa           | 34.8 (m/s)            | 20.6km/h     | 52.2km|

3.2. Verification and calculation of mathematical model

The third generation wave model WAVEWATCHIII will be used for the simulation of offshore waves, which provides wave boundary elements for the middle model mike21-SW at the boundary-20m isobaths, then the in-port wave conditions will be calculated by Mike21-BW.

The calculation range of the large model is 103°E~125°E, 13°N~33°N. Typhoon 1104, 1409 and 1604 are simulated and validated by Measured data from Buoys and ocean stations. The measured and simulated wave process curves are shown in Fig4. According to the wave height process curve, the measured wave height is in good agreement with the simulated wave height, and the model can accurately reflect the changing trend of wave. The wave model can be used to calculate the sea area near the fishing port.

Figure 3  The Location of fishing port and model range
Figure 4: The comparison of the measured and calculated significant wave height during typhoons

3.3. Input wind field

The characteristic distribution of typhoon wave is directly related to typhoon wind field, and the accuracy of typhoon wind field determines the simulation accuracy of the model to a great extent.

Holland Wind Field Model:

\[ w(r) = \alpha \rho \left[ \frac{B}{r} \frac{R_{max}}{r} \frac{(P_r - P_0)}{r} \exp \left[ -\left( \frac{R_{max}}{r} \right)^2 + \left( \frac{r}{r_f} \right)^2 \right] \right]^{-0.5} - \frac{rf}{2} \]

\[ r = \sqrt{(x-x_c)^2 + (y-y_c)^2} \]

\[ B = 1.5 \times (980 - P_0) / 120 \]  \hspace{1cm} (1)

B is Holland fitting parameter (given by Hubbert, 1991); \( \rho \) is air density and the value is 1.2 kg/m\(^3\); \( P_0 \) is the central pressure of typhoon, \( P_r \) is the peripheral pressure of typhoon and the value is 1013.3 hpa; \( r \) is the distance from the calculated point to the typhoon center, where \( x_c \) and \( y_c \) represent the position of the typhoon center. \( f \) is Coriolis parameter.

\( R_{max} \) is the Radius of maximum wind. The formula is based on a statistical analysis of central pressure and Radius of maximum wind data from the yearbooks of tropical cyclones.

\[ R_{max} = 1.119 \times 1000 \times (P_r - P_0)^{-0.805} \]  \hspace{1cm} (2)
3.4. Calculation results and area of berthed waters

Based on the numerical simulation of typhoon wave with imaginary unfavorable typhoon track, the typhoon wave elements at -20m isobath are obtained as follows: The wave $H_{13\%}$ is 9.05m under 10 grade typhoon and 9.88m under 12 grade typhoon, the period is selected according to table 4.3.2 of *Hydrologic Code for ports and waterways*. The results are shown in Table 3 and are the boundary of the middle model MIKE21-SW.

| Wind scale | $H_{13\%}$ (m) | $\bar{T}$ (s) | wind speed (m/s) |
|------------|----------------|---------------|------------------|
| 12         | 9.88           | 12.8          | 45.3             |
| 10         | 9.05           | 12.3          | 35               |

Fig5~6 shows the distribution of $H_{13\%}$ under the 10 grade typhoon in the adverse path of scheme 1 and scheme 2. Under 10 grade typhoon, the wave height of the berthing waters satisfies $H_{1\%}\leq1.0m$ in scheme 1; the water area of 46,400 m$^2$ in the berthing water area with $H_{1\%}\leq1.0m$ in scheme 2.

Fig7~8 shows the distribution of $H_{13\%}$ under the 12 grade typhoon in the adverse path of scheme 1 and scheme 2. Under 12 grade typhoon, the wave height of the berthing waters in scheme 1 satisfies $H_{1\%}\leq1.0m$; the water area of 37,000 m$^2$ in the berthing water area with $H_{1\%}\leq1.0m$ in scheme 2.

![Figure 5](image-url)
Figure 6  Distribution of $H_{13\%}$ of typhoon 10 grade under adverse path in scheme 2

Figure 7  Distribution of $H_{13\%}$ of typhoon 12 grade under adverse path in scheme 1
4. Grade evaluation of fishing port anchorage station

Assessment of Typhoon Prevention Level in Anchorage Area of Fishing Port is to calculate the anchor force of representative ship types in different areas of the port, and the maximum typhoon level of fishing vessels without anchor is used as the basis for analyzing typhoon prevention level in Anchorage Area. The main force of fishing boat during anchoring is anchor force and mooring force caused by wind and flow.

4.1. Ship Type Selection and Force Analysis

According to the field investigation and data collection, the 66 fishing boats in the vicinity of the project were counted, and the representative ship types were shown in Table 4 and Table 5.

| Total length | molded breadth | moulded depth | The draft | upperworks |
|--------------|----------------|---------------|-----------|------------|
| 38m          | 8m             | 3.3m          | 2.5m      | 0.8m       |

| Chain type   | weight | number | Chain length | Cable diameter |
|--------------|--------|--------|--------------|----------------|
| Stock anchor | 275kg  | 2      | 15m          | 22mm           |

4.2. Calculation results and analysis

The calculation formula of anchorage force:

\[ P = P_Z + P_c = \lambda_z W_z + \lambda_c W_c L \]  (3)

P is the total grip of the anchor; \( P_Z \) is the anchor holding power; \( P_c \) is Chain holding power; \( \lambda_z \) is Coefficient of anchor grasping force; \( \lambda_c \) is Coefficient of chain grip; \( W_z \) is The weight of the anchor in the air; \( W_c \) is The weight of the chain per meter in the air; L is The undercover chain length.
The value of anchor grip coefficient was 3.5, and the value of chain grip coefficient was 0.75. According to Formula (3), the single anchor grip was 10.54 kN when 275 kg anchor and 22 mm anchor chain with 15 m length were equipped.

The mooring force expressed as:

$$N = \frac{k}{n} \left[ \frac{\sum F_x}{\sin \alpha \cos \beta} + \frac{\sum F_y}{\cos \alpha \sin \beta} \right]$$

(4)

$N$ is the standard value of cable force (kN); $\Sigma F_x$ and $\Sigma F_y$ are the sum of transverse force and longitudinal force respectively, which are generated by the possible simultaneous occurrence of wind and water on ships. The calculation formula can be referred to Appendix E and F of JTS 144-1-2010 Load Code for Port Engineering; $K$ is the non-uniform coefficient of the force distribution of the mooring column; $n$ is the number of tethered columns to calculate the simultaneous force of the ship; $\alpha$ is the angle between the horizontal projection of mooring cable and the front line of wharf; $\beta$ is the angle between the mooring line and the horizontal plane.

Since the breakwater has no sheltering effect on the wind conditions of berthed ships in the harbor basin, therefore the wind load on fishing vessels in the harbor calculated without considering the shielding effect.

According to the calculation results of the flow velocity in the port of each scheme, the flow velocity in the port is relatively small, as shown in Fig9~10. The water area with the flow velocity < 0.2m/s takes up nearly 90%. Therefore, the flow force calculation velocity adopts 0.2m/s, and the water depth was 3.2m. The calculation result is that the current force of the fishing boat under ballast condition is 3.82kN. The result is shown in Tables 6.

It can be seen from the calculation results is that wind stress plays a dominant role in influencing the anchorage stability of fishing vessels. The transverse wind stress is much greater than the anchorage force, so the longitudinal berthing mode is adopted in typhoon period. The longitudinal wind stress of grade 10 and grade 12 typhoons is 9.26kN and 15.96kN respectively. After superposition of water flow force, the longitudinal wind stress of grade 10 typhoons is 10.01kN, which can meet the requirement of less than 10.54kN of anchoring force. The longitudinal wind stress of grade 12 typhoons is 16.41kN, which is larger than the requirement of 10.54kN of anchoring force.

Figure 9 Distribution diagram of maximum velocity in scheme1
Figure 10   Distribution diagram of maximum velocity in scheme2

Table 6  Fishing boats are subjected to wind and current forces at all levels of strong winds

| Wind scale | Wind stress on fishing vessels (kN) | ΣFy (kN) |
|------------|------------------------------------|----------|
|            | lateral force                      | Longitudinal force |
| 10         | 59.44                              | 9.26     | 10.01 |
| 12         | 102.50                             | 15.96    | 16.41 |

5. conclusion
The following conclusions are obtained through the calculation and analysis of the anchorage platform of fishing port: By assuming the S-direction of the unfavorable typhoon path and selecting the typhoons of 10 and 12 grade, the wave heights in the berthing waters of Scheme 1 meet \( H_{1%} \leq 1.0 \text{m} \), and the area of \( H_{1%} \leq 1.0 \text{m} \) in the berthing waters of Scheme 2 are 46400 m\(^2\) and 37000 m\(^2\) respectively, accounting for 4.6 % and 3.6 % of the total water area. Scheme 1 is recommended for design.

Through the calculation of wind stress, water flow force and anchor grasping force, the influence of wind stress on the anchorage stability of fishing boats is obtained. The transverse wind stress is much greater than the anchorage force, so the longitudinal berthing mode is adopted in typhoon period. The longitudinal combined stress of wind current under the action of grade 10 typhoon is 10.01kN, which can meet the requirement of less than the anchor grasping force of 10.54kN. The longitudinal combined stress of wind current under the action of grade 12 typhoon is 16.41kN, which is greater than the requirement of anchor grasping force of 10.54kN. Therefore, the maximum level of typhoon protection in the fishing port is 10 grade.

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