Experimental Management Study on Physical Influence Model of Wave Nearshore Mutational Terrain

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Abstract: The influence of nearshore mutational terrain on wave was experimentally studied via local-global physical wave model. It was discovered that the influence of submarine topography on wave was mainly manifested by the change in wave height, which was especially apparent when the submarine slope gradient changed greatly and presented approximate mutation. Moreover, the differences of different wave directions and different wave elements in influencing the wave heights with different accumulative frequencies were presented. Therefore, the influence of nearshore mutational terrain on wave should arouse high attention in the engineering construction.

1. Introduction
Islands and reefs are widely distributed in the South China sea, with quite complicated terrains, and the topographical changes are especially apparent in regions nearby islands and reefs. Mutational submarine terrains may exist in the outside regions of islands and reefs, the terrain difference may exceed one hundred meters, and the waves spread from open sea will experience a series of complex nonlinear changes under the influence of water depth change in regions nearby islands and reefs. During the wave propagation process at the seabed with gradually varied water depths, various phenomena like deformation, refraction, reflection, diffraction and crushing of shallow water will take place under the actions of currents, water depth and terrain. Therefore, the linear program gradually develops into a nonlinear problem, which will generate a major impact on coastal works. The main factors influencing the generation of reverse traveling waves in the changes of wave height with water depth and flow velocity are water flow velocity and water depth. When intense reverse traveling waves are generated on the free water surface during the model test process, the energy is continuously transferred upstream in the form of reverse travelling free surface waves, while the energy stimulating the wave surface fluctuation is provided and maintained by the currents with specific water depth and flow velocity through the sinusoidal terrain. As the generation of reverse traveling waves is very sensitive to the changes in flow conditions, the intensity of water surface fluctuation varies with the water depth and flow velocity, which is quantitatively manifested by the height change of reverse traveling waves, so the intensity of interaction between water current and periodic continuous sinusoidal terrain is embodied by the distribution of reverse traveling wave height under the varying water depth and flow velocity.

During the design of armor block or major structure in breakwater engineering, the selection of design wave elements is greatly associated with the stable weigh of armor block or structural safety, and
the general numerical simulation study of wave and experimental study of global physical model can provide macroscopic wave fields in engineering sea areas. However, as the boundary condition processing studied by the global wave model is based on macroscale, it is difficult for such wave fields to accurately consider the local terrain at the root of breakwater, not to mention the influence of mutational terrain with great submarine slope changes on the wave changes in local regions. Although the deformation of nearshore wave is calculated in standard [1] and related literature [2], this is based on the uniform submarine slope gradient. With the gradually deepened understanding of wave and continuous progress of model experimental techniques, in the wave fields investigated via global wave model, the reference waves are selected in sea areas relatively distant from the shore with relatively greater water depth and unobvious deformation of wave and shallow water, followed by the local-global physical wave model test. Nearshore waves are specially explored, and these special research projects can more accurately discover the changes in nearshore waves, especially the increase in wave height on the nearshore mutational terrain, and recheck the structural safety of breakwater in more detail, so as to optimize the design scheme and cost-benefit ratio of engineering investment and more reasonably control the engineering investment. This will play a guiding role in the engineering construction and facilitate the subsequent management and maintenance work of proprietors for key parts like breakwater foundation and armor block.

2. Nearshore Terrain and Test Water Level
In this local-global physical wave model test, the protrusion of local nearshore terrain was assumed, with a slope gradient of about 1:7, and the substrate was reef. The submarine topographic slope at 200 m nearshore was about 1:160, the natural water depth was greater than 20 m, and the substrate was mud. The test water level was 2.53 m.

3. Test Wave Elements
The reference wave point in the model test was about 600 m away from the nearshore mutational terrain, where the natural water depth was about 23.70 m, and the water depth beneath the test water level was 26.23 m. The test wave directions were S+5° and SSE+18°, and the wave elements in different groups are listed in Table 1.

| Wave direction | Group No. | H1% (m) | H3% (m) | Tmean (s) | Wave direction | Group No. | H1% (m) | H3% (m) | Tmean (s) |
|----------------|-----------|---------|---------|-----------|----------------|-----------|---------|---------|-----------|
| S+5°           | 1         | 5.59    | 3.87    | 8.20      | SSE+18°        | 1         | 5.47    | 3.78    | 9.01      |
|                | 2         | 6.32    | 4.40    | 8.67      |                | 2         | 6.20    | 4.31    | 9.57      |

4. Model Test
The model scale was λ=50, the model design was implemented according to the criterion of gravity similarity, and the model test was performed in accordance with national regulations [3].

In order to figure out the propagation laws of waves from the reference wave point to the offshore areas with protruding and mutational terrains, the S+5°-directional waves in group 1 were selected to carry out the test under two circumstances: wave absorption (reference waves) on quay wall and original terrain (water absorption on quay wall not done), and the wave height was measured. The wave height on the original terrain was measured in the other group, too, and the water depth, terrain and wave height measuring points in the sea area were arranged as shown in Figure 1.
Under the action of S+5°-directional waves in group 1, the wave absorption (reference wave) results of quay wall and measured wave height values of the original terrain (wave absorption of quay wall not done) are as seen in Table 2.

Table 2: Wave Heights at Measuring Points under S+5°-Directional Waves in Group 1 (m)

| Measuring point | Wave absorption on quay wall | Original terrain | Measuring point | Wave absorption on quay wall | Original terrain |
|-----------------|------------------------------|------------------|-----------------|------------------------------|------------------|
| N0              | H1% 5.84                      | H13% 3.94        | H1% 5.70        | H13% 3.93                    |
| A1              | 5.60                         | 3.89             | 5.64            | 4.04                         |
| A2              | 5.52                         | 3.83             | 5.45            | 3.92                         |
| A3              | 5.60                         | 3.90             | 5.67            | 4.01                         |
| A4              | 5.57                         | 3.76             | 6.31            | 3.71                         |
| A5              | 5.51                         | 3.92             | 6.27            | 4.11                         |
| A6              | —                            | —                | 6.09            | 3.87                         |
| A7              | —                            | —                | 6.31            | 4.42                         |
| B1              | 5.79                         | 3.92             | 5.91            | 4.09                         |
| B2              | 5.97                         | 4.13             | 5.69            | 4.03                         |
| B3              | 5.82                         | 4.05             | 6.30            | 3.83                         |
| B4              | 5.80                         | 3.91             | 5.82            | 3.75                         |
| B5              | 5.58                         | 3.99             | 5.01            | 3.79                         |
| B6              | —                            | —                | 4.83            | 3.45                         |
| B7              | —                            | —                | 6.61            | 4.07                         |

It could be seen from Table 2 that when the wave absorption treatment was made for the quay wall, namely, the influence of nearshore mutational terrain was not considered, the wave height at each measuring point was not obviously changed in comparison with that at the reference wave point, the maximum value of H1% appeared at the measuring point B2, being about 1.022 times that at the reference wave point, and the minimum value was reached at the measuring point A4, being 0.797 of that at the reference wave point. When the wave absorption treatment was saved, namely, there was original terrain under the effect of nearshore mutation, the wave height at the measuring points in the first row (A1-A7) was almost unchanged from the reference wave point to A4, but it experienced sudden changes from A4 to A7, and the wave height was remarkably increased. The H1% wave height was 1.068-1.107 times that at the reference wave point, and the H13% wave height at A7 was 1.122 times that at the reference wave point, this was because the offshore seabed was flat with a very gentle slope, while the nearshore seabed presented great topographic changes, with the slope reaching as high as 1:7.
so it was a topographic mutation region. After arrival, the waves experienced obvious reflection, so the wave height was increased within a certain range in the nearshore segment during the wave propagation process from the reference wave point in the deep-water zone to the shoal water zone. In the original terrain test of wave height at measuring points in the second row (B1-B7), the wave heights at B3 and B7 were increased, the H1% wave heights were 1.105 and 1.160 times that at the reference wave point, while the H13% wave heights showed no significant changes.

The measured wave height values in other wave directions and different wave groups on the original terrain are as seen in Table 3.

Table 3: Wave Heights at Measuring Points in Different Wave Directions and Different Wave Groups on the Original Terrain (m)

| Measuring point | S+5° | SSE+18° |
|-----------------|------|---------|
|                 | H1%  | H13%   | H1%  | H13% |
| N0              | 5.70 | 6.63   | 3.93 | 4.34 |
|                 | 5.53 | 6.12   | 3.76 | 4.15 |
| C1              | 5.79 | 5.79   | 4.16 | 4.28 |
|                 | 4.98 | 5.45   | 3.40 | 4.21 |
| A1              | 5.64 | 6.30   | 4.04 | 4.37 |
|                 | 4.82 | 5.03   | 3.51 | 4.04 |
| A2              | 5.45 | 6.48   | 3.92 | 4.40 |
|                 | 4.95 | 5.34   | 2.91 | 3.91 |
| A3              | 5.67 | 6.30   | 4.01 | 4.72 |
|                 | 5.00 | 5.52   | 3.10 | 3.47 |
| A4              | 6.31 | 6.72   | 3.71 | 4.66 |
|                 | 4.56 | 5.53   | 3.35 | 3.75 |
| A5              | 6.27 | 6.37   | 4.11 | 4.56 |
|                 | 4.33 | 5.51   | 3.28 | 3.92 |
| A6              | 6.09 | 6.10   | 3.87 | 4.49 |
|                 | 4.70 | 5.70   | 3.35 | 4.06 |
| A7              | 6.31 | 7.11   | 4.42 | 4.74 |
|                 | 5.63 | 7.10   | 4.07 | 4.85 |
| B1              | 5.91 | 6.12   | 4.09 | 4.64 |
|                 | 5.06 | 6.18   | 3.91 | 4.42 |
| B2              | 5.69 | 6.50   | 4.03 | 4.45 |
|                 | 6.12 | 6.05   | 3.62 | 4.31 |
| B3              | 6.30 | 6.42   | 3.83 | 4.23 |
|                 | 5.08 | 5.87   | 3.71 | 4.25 |
| B4              | 5.82 | 6.43   | 3.75 | 4.46 |
|                 | 4.86 | 5.48   | 3.56 | 4.36 |
| B5              | 5.01 | 6.10   | 3.79 | 4.38 |
|                 | 4.61 | 5.83   | 3.33 | 4.26 |
| B6              | 4.83 | 6.05   | 3.45 | 4.57 |
|                 | 4.13 | 5.62   | 3.46 | 3.95 |
| B7              | 6.61 | 8.57   | 4.07 | 5.10 |
|                 | 5.47 | 7.13   | 4.36 | 5.10 |

As seen in Table 3, affected by the nearshore topographic mutation, the wave heights at measuring points, no matter in the first row (A1-A7) or second row (B1-B7), away from the sea shore were approximate to that at the reference wave point, the wave heights at nearshore measuring points A7 and B7 were mostly larger than that at the reference wave point, the H1% wave height was increased by 29.3% at most, and the H13% wave height was increased by 22.9% at most. For the waves at the same measuring point but in different directions, the wave heights with different accumulative frequencies were influenced by the nearshore mutational terrain following not completely identical laws. For the waves at the measuring point A7 in the same wave group, the ratios of H13% wave height in two directions to the wave height at the reference wave point were both greater than the those of H1% wave height in two directions to the wave height at the reference wave point, but for S+5°-directional waves at the measuring point B7, the ratio of H13% wave height to the wave height at the reference wave point was smaller than that of H1% wave height to the wave height at the reference wave point. For the SSE+18°-directional waves at the measuring point B7, the ratio of H13% wave height to the wave height at the
reference wave point was greater than that of $H_{1/3}$ wave height to the wave height at the reference wave point. For the S+5°-directional waves at the measuring point A7 in the wave group 2, the ratio of measured wave height to the wave height at the reference wave point was lower than that in group 1, while the ratio of measured height of SSE+18°-directional wave at the measuring point A7 in the wave group to the wave height at the reference wave height was higher than that in the group 1. At the measuring point B7, the ratios of measured heights of both S+5°-directional and SSE+18°-directional waves in the wave group 2 to the wave height at the reference wave point were both greater than those in the wave group 1, indicating that the influence degree of nearshore mutational terrain on waves in different directions varied from zone to zone. Table 3 also showed that the ratio of wave height at measuring points in the group 2 to that at the reference wave point was greater than that in the group 1, manifesting that the greater the wave height, the longer the wave period, and the greater the influence degree.

5. Conclusion
It is found through the model experiment that waves are propagated from the deep-water zone to the shoal water zone, and meanwhile, they may also be spread from the shoal water zone to the deep-water zone, the variation trends are consistent, and the main influencing factors are wind direction and terrain.

5.1 The local-global physical wave model experiment indicates that the waves in the nearshore sea area are obviously affected by the nearshore mutational terrain, and the wave height is obviously increased. When the waves pass through the mutational terrain, the wave steepness is firstly abruptly increased and then drastically decreased in the shoal water zone with the topographic mutations, and the front wave steepness is equivalent to the rear wave steepness, and the wave steepness changes little during the propagation process in the shoal water zone.

5.2 The nearshore mutational terrain influences the wave heights with different accumulative frequencies in the nearshore sea area to different extents.

5.3 The influence of nearshore mutational terrain on the waves in the nearshore sea area varies with the wave direction.

5.4 Different waves are influenced differently by the nearshore mutational terrain. To be more specific, the greater the wave height, the longer the wave period, and the greater the influence degree.

References:
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