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To cite this article: D X Wang *et al* 2016 *IOP Conf. Ser.: Earth Environ. Sci.* **39** 012026

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The model test of restoration project of the gravel beach of Chen Village fishing port

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Abstract. Gravel beach is a case in coastal landform by wave action. It is more and more crucial for the environment of coastal engineering in recent years. However, it is poorly studied for it in China. And this paper which is based on the model test of Restoration Project of the Gravel Beach of Chen Village Fishing Port, uses two dimensional normal physical models, aiming at exploring the movement of gravel beach under wave action and verifying the stability of the gravel beach section. The test depends on different water levels (designed high water level, designed low water level, and extreme high water level) and return periods (2, 5, 10, 25, 50 years once). Finally, two distinct experimental sections are got under the changed conditions and the movement law of gravels is obtained.

1. Introduction

Gravel beach is generally formed near the bedrock coast, and it is also a typical coastal landform effected by wave action. Because of the function of coastal protection and the great tourism resources [1], a large number of people are taking it accounts into the construction of artificial beach [2]. There have been some examples of the application of artificial gravel beach in shoreline protection [3], but in China things are different: only some scholars have made some surveys on the natural gravel beach [4, 5]. And even worse, the lack of information and attention leads to fewer physical model tests on gravel beach. The good news is the case that the coastal environment has gradually become a new hot spot in recent years along with the national attention to the environment. LaoTieShan, a famous tourist attraction in Dalian, is located at the border of the Yellow Sea and the Bohai Sea, and Chen Village Fishing Port is located at the foot of LaoTieShan. In recent years, due to wave erosion and man-made



influence, the south side of the port has been a certain degree of damaged. Withal, relevant departments take active measures, intending to fix the gravel beach. In order to achieve better engineering effect, a physical model test is needed in order to forecast the effect of the project and the stability of the gravels. Experiment was conducted in the wave flume of the Key Laboratory of Coastal Engineering of Dalian Ocean University, Liaoning Province. The representative section was extracted from the given terrain, and the gravity similarity criterion was adopted to this text. The goal is to reach a static equilibrium in the gravel beach of Chen Village Fishing Port such that erosion or sediment problems could be avoided or diminish. The initial wave conditions are got from the mathematical wave model test results, including different return periods (2, 5, 10, 25, 50 years once) and different water level (designed high water level, designed low water level, and extreme high water level).

2. Initial conditions

2.1. Water level

Extreme high water level: 2.91m

Designed low water level: 0.10m

Designed high water level: 2.27m

2.2. Wave conditions

Wave conditions could be seen in Table 1.

Table 1. Wave conditions.

Water level(m)	Return periods(year)	Significant wave height(m)	Wave period(s)
2.91	2	0.97	6.4
	5	1.50	8.3
	10	1.72	8.7
	25	1.95	9.1
2.27	2	0.94	6.4
	5	1.42	8.3
	10	1.65	8.7
	25	1.89	9.1
0.1	2	0.80	6.4
	5	1.24	8.3
	10	1.40	8.7
	25	1.62	9.1

2.3. The text terrain

In accordance with the relevant specifications [6, 7, 8], some research experience from scientific institutions [9, 10, 11] and measured topographic map, three typical sections in the project area were selected. On the basis of the representative of the section, the slope and the feasibility of putting in place in the actual wave tank, a typical section is chosen from those three (Figure 1). After the terrain construction is completed, the cement is used for getting a hard surface, which is convenient for the initial wave. After that, the screened gravel is putting on the original terrain as required, which

forming the sand fill surface of construction plan (Figure 2). Since then, terrain construction for the physical model test is completed.

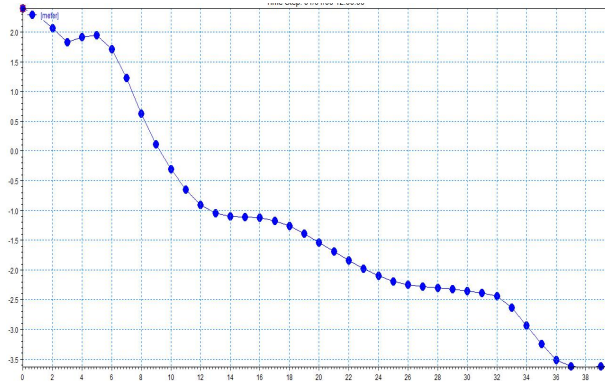


Figure 1. Typical section.

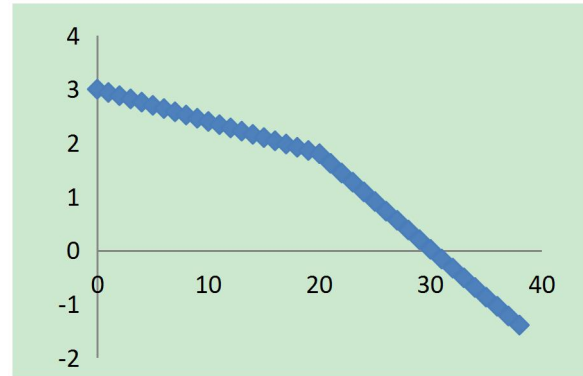


Figure 2. The designed sand fill surface(points 0-38, 1m per point).

3. Similarity criterion

In coastal engineering, the main external loads acting on the building are taken from the waves. Because the propagation of the wave is mainly dependent on gravity, it is usually called the sea wave as the gravity wave, so the wave simulation should follow the gravity similarity criterion. As a result, in coastal engineering, the gravity similarity criterion is the most commonly used criterion, especially in the experimental study of wave and its effect on engineering structures. When the system is under the action of gravity, gravity is:

$$G = mg = \rho Vg$$

The above 'm' is mass, 'g' is the acceleration due to gravity, ρ is density, V is the volume. The subscript P indicates the value of each physical quantity in the prototype. The subscript m indicates the values of each physical quantity in the model. Such as:

$$F_{gp} = m_p g_p = \rho_p V_p g_p$$

$$F_{gm} = m_m g_m = \rho_m V_m g_m$$

If λ refers to the ratio of prototype and model value:

$$\lambda_{F_g} = \lambda_m \lambda_g = \lambda_\rho \lambda_l^3 \lambda_g = \lambda_\rho \lambda_v^2 \lambda_l^2$$

$$\text{or: } \frac{\lambda_v^2}{\lambda_g \lambda_l} = 1$$

Also:

$$\left(\frac{v^2}{gl} \right)_p = \left(\frac{v^2}{gl} \right)_m = F_r$$

Here F_r is a dimensionless number called the gravity similarity criterion, or the Froude number.

Under the condition of gravity similarity criterion, as the result of $\lambda_g = 1$:

The ratio of velocity: $\lambda_v = \lambda_l^{1/2}$

The ratio of pressure: $\lambda_p = \lambda_l^2$

The ratio of time: $\lambda_t = \lambda_l^{1/2}$

The λ_l is the ratio of length.

The ratio of force and mass: $\lambda_F = \lambda_m = \lambda_l^3$

Taking into account the test equipment and relevant literature [6, 7, 8], as well as other factors such as technical requirements [12], determining the ratio of the length is between model and prototype is 1:10.

4. The text

4.1. Text materials

Because the test is based on the actual project, prototype stones used in the text should be selected from the quarry so that we could get the gradation of these prototype stones. After that, the stone is divided into three parts which are 'small', 'medium' and 'large' respectively. From those above working, in the light of the ratio of length, the parameter of the model gravel could be gotten: the ratio of that three parts is 3:4:3 and the average diameters of the model gravel are 2.2mm, 3.7mm and 4.27mm respectively. According to average diameters, three sieves diameter at 1.25mm, 2.5mm and 5mm are selected to get the model gravel. The parameters of model gravel are given in table 2.

Table 2. The parameters of model gravel.

	Major axis (mm)	Middle axle (mm)	Short axis (mm)	Quality (g)	Average diameter (mm)
Small	3.5	2.33	1.35	0.02	2.2
Medium	5.28	3.94	2.62	0.07	3.7
Large	6.1	4.51	2.92	0.11	4.27

4.2. The process

Because of different water levels and wave conditions, the text is done by this process:

First of all, water levels are used from low to high, it means that the order is designed low water level, designed high water level and extreme high water level. Secondly, waves are, under different water levels, from 2 years once to 50 years once which is to say that it is also following the small-to-large. At last, each wave simulates three times (two times under extreme high water level). After each simulation is completed, the terrain is not restored. And should not start next simulation before the water gets still.

5. Results

Owing to the limit of the experimental flume, the waves two years once and five years once under designed low water level cannot be reached. In fact, the influence under designed low water level, no matter which wave, is very little. Moreover, the terrain is not restored until the cycle over so the missing waves have little effect on the final results. The conclusive results under extreme high water

level are shown in Figure 3-6. (The red lines are the designed sand fill surfaces and blue lines the new profile)

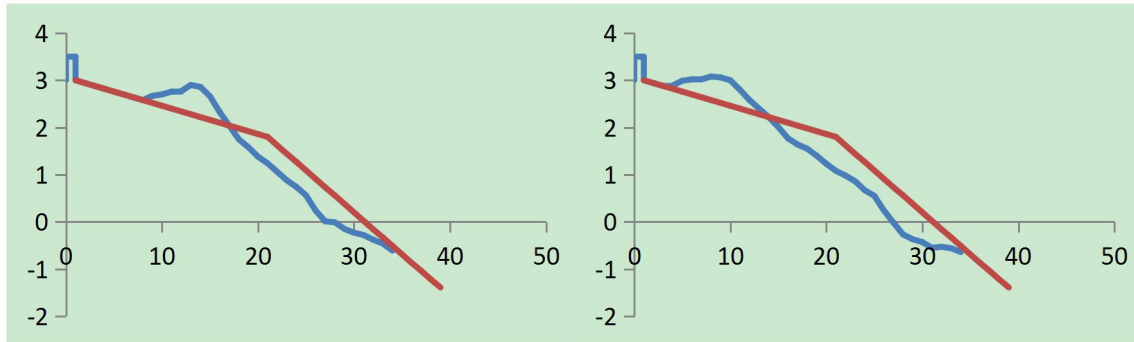


Figure 3. The result of 2-year-once wave.

Figure 4. The result of 5-year-once wave.

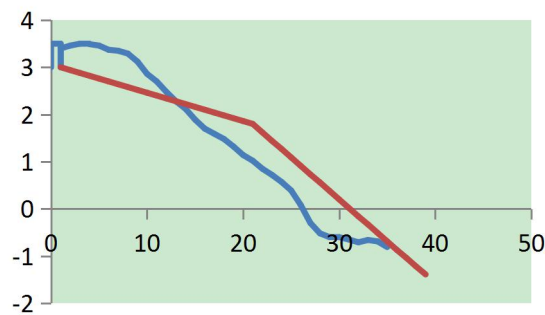


Figure 5. The result of 10-year-once wave.

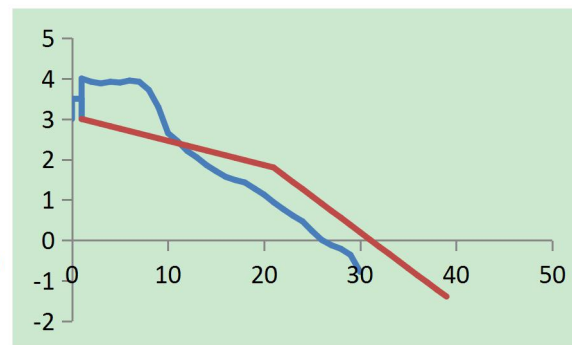


Figure 6. The result of 25-year-once wave.

6. Discussion

- Under the designed low water level, wave has little effect and cannot affect the beach, so this is not the point we follow closely.
- Under the designed high water level, the effects of wave increases slowly as time went by. With the action of wave, gravels at the wave breaking part are emptied. Some go downward with water. The other part goes upward and accumulates, forming a small beach berm. Due to the increasing of the wave and the passage of time, a 1:6 slope is established which roughly parallel to the designed filling surface.
- Under the extreme high water level, because of higher water level, the influence of the wave is not only similar as before but also more obvious than before. It is worth stressing that, at the measurement point 26-30 (that is, the distance from the wave wall 26-30m), a pit is formed. And with the increase of the wave, the bunker is inclined to increase as well.

7. Conclusion

- This text carries out a considerable number of simulations under various working conditions, but it actually do not get a real stable section. It is difficult to form a stable section on the beach, which can only form a relatively stable section. However, due to the consideration of this section test is to simulate the most unfavorable situation, and the actual situation in the

gravel beach cannot always be the most unfavorable situation, so this result can meet the requirements.

- Under the action of wave, gravels located at the measurement point 15-30 (i.e. Distance gear wave wall 15-30m) will be displaced away, and finally a slope which is parallel to the original design of filling sand surface could be formed. Even so, the height of the surface declines by about 1m. To avoid this, in actual construction, larger gravels should be utilized to ensure the stability of this wave breaking part. It is no doubt beneficial to the project and also numerous other adverse phenomena, such as erosion and the sediment load, will decrease.
- The joint point of the two slopes needs to move towards the seaward direction. It is to say that the length of the upper slope should be increased. Because we could see it from the results that gravel beach, under the waves washed, has the same law of motion in reference literature [13,14] : With the action of wave, the bunker is formed and this bunker continues 'climbing' and finally a platform emerges. The advantage of the movement towards seaward is that it can make the starting point of the bunker away from the beach so that the 'climbing' could be limited. At the same time, the extensions of the upper slope also could ease the accumulation of gravels so that the bunker behind the platform could be less steep and towering.

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