PHYSICAL MODEL ON WAVE DISSIPATION EFFECT OF PERFORATED CAISSON

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Perforated caisson structure was usually adopted by harbor engineering design to reduce wave height and wave forces on the structure. Through wave physical model test, wave height distribution in front of non-perforated and perforated caisson with different directions was studied respectively with the layout of a project in China. And then dissipation effect of wave height of perforated caisson was obtained from comparison of the two cases. It was indicated from the results that reduction effect of wave height had great relation with the position of perforation on the caisson when dimension of caisson and perforation, perforation rate were fixed. The perforated caisson had a remarkable wave-dissipation effect when the perforation was between once the wave height above or below the still water level, which proved the rationality of the recommendation of Code for Design and Construction of Breakwaters. It was suggested for this project that design of perforation should be consistent with the code as possible and near the design high water level.

Keywords: wave physical model; perforated caisson; wave dissipation effect

1 Introduction

Perforated caisson was proposed in 1960's by Jarlan (Canada) and then the newly designed structure was widely concerned around the world, which was adopted by many projects in Canada, Italy, Japan and South Korea. In 1975 perforated caisson was first applied into breakwater of Qinhuangdao port in China, in following years similar structure was observed in Dalian port and Qingdao Port. Also many articles were published on the research of perforated caisson. According to the existing results, wave-dissipation effect is relevant to exterior condition and interior condition. The exterior condition includes wave height, wave period and water level, etc. and the interior condition includes perforated ratio, width of perforated chamber and the design of upper structure of caisson, etc..

In this paper the perforated caisson was designed for a new project with two cases, non-perforated caisson and perforated caisson. The layout of the project was shown in Figure.1, in which the length of berth was 1552m, including four areas, I, II, III and IV. Wave entered the harbor basin mainly from E and ENE direction. Wave height in front of berth was measured by a physical model and then wave dissipation effect was compared. Finally some suggestions for the structure design were obtained for reference of similar projects.

2 Wave condition

Wave condition of the physical model was shown in Table.1.

Table.1 Wave parameters of -13m isobaths of model test

Water level	Return period	Wave hiehgt H13% (m)	Wave period $\overline{T}$ (s)
EHWL:+5.82m Extreme highest water level	50a	5.36	8.9
DHWL:+4.73m Design highest water level	50a	5.24	8.9
	10a	3.96	7.8
	2a	2.44	6.3
DLWL:+0.59m Design lowest water level	50a	4.63	8.9

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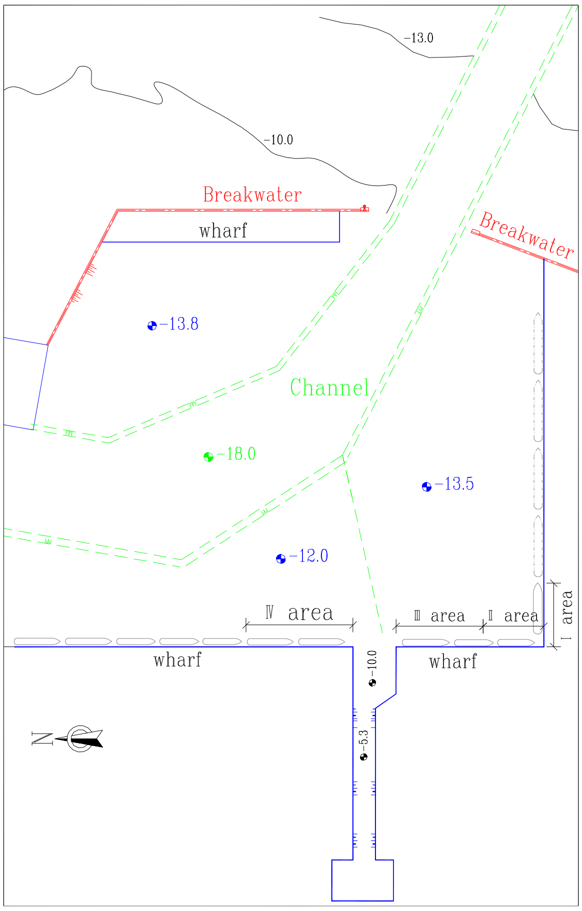
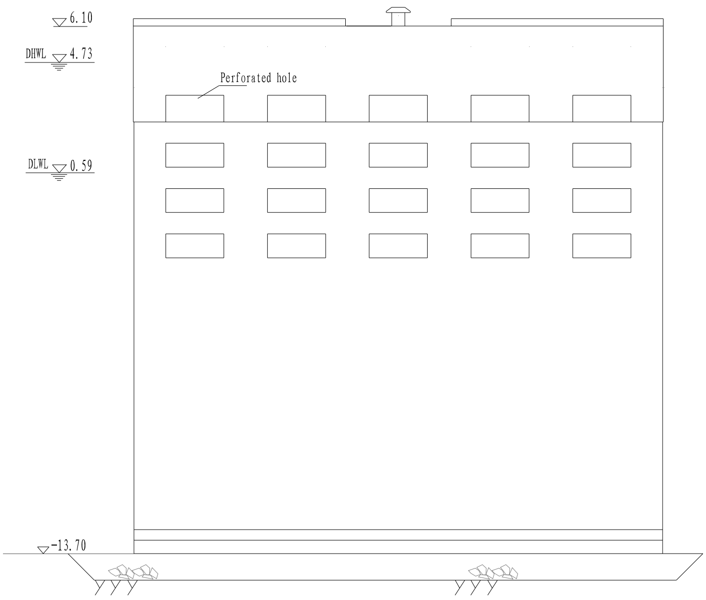


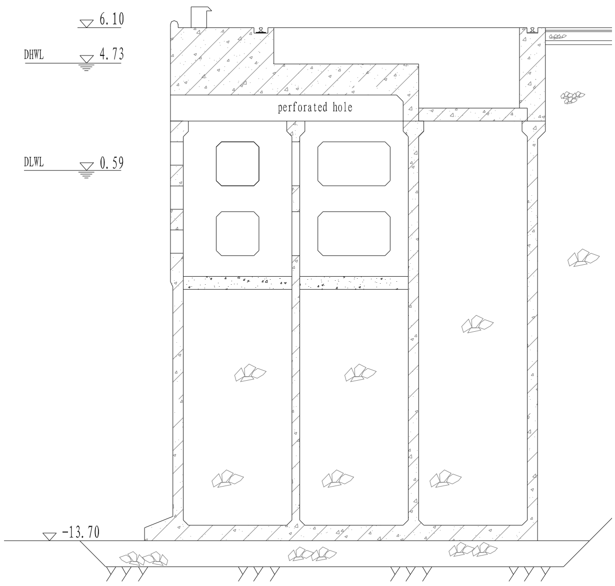
Figure.1 Layout of project (Unit:m)

3 Design of perforated caisson

Vertical caisson was designed for the project, including non-perforated caisson and perforated caisson. The length of caisson was 20m and the width was 15.2m. Three rows of perforated holes (2.2m*0.9m) were designed on the face wall and one row (2.2m*1.0m) was on the upper structure. The sketch of perforated caisson was shown in Figure.2.



2-a front view



2-b side view

Figure.2 Front view and side view of section of perforated caisson

3 Model design

The physical model accords with Test Regulation of Wave Model and designed by gravity principle. The relationship of scale was as following:

$$\lambda = \frac{l_p}{l_m} = 80 \qquad (1)$$

$$\lambda_t = \lambda^{1/2} = 8.94 \qquad (2)$$

In which, λ was length scale, l_p was length of prototype, l_m was length of physical model, λ_t was time scale. The eleven wave measurement position was shown in Figure.3.

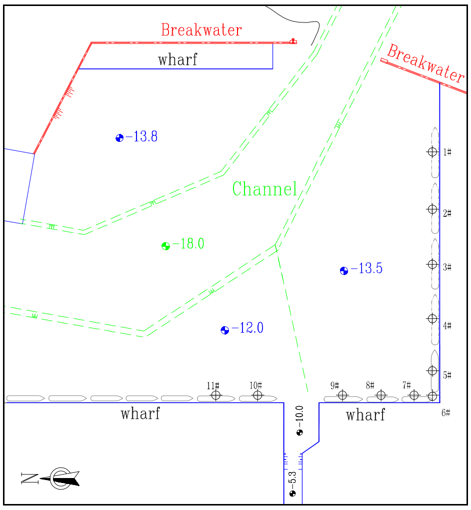


Figure.3 Sketch of measurement points of physical model

4 Test results of wave height of two design cases

4.1 non-perforated caisson

Wave entered the harbor basin from the breakwater entrance, which was consisted of wave action diffraction and reflection. The wave height of different direction of non-perforated caisson was shown in Table.2.

Table.2 Results of wave height of non-perforated caisson with different direction (Unit:m)

Test condition / Meas. points	E direction				ENE direction			
	50a ($H_{13\%}$)			2a($H_{4\%}$)	50a($H_{13\%}$)			2a($H_{4\%}$)
	EHWL	DHWL	DLWL	DHWL	EHWL	DHWL	DLWL	DHWL
1#	1.74	2.05	1.92	0.90	2.14	2.31	2.45	1.54
2#	2.27	2.50	2.29	1.17	4.61	4.61	4.72	2.86
3#	2.41	2.75	2.48	1.23	4.72	4.90	4.86	2.98
4#	2.65	3.09	2.75	1.38	4.29	4.45	4.40	2.80
5#	3.11	3.41	3.06	1.66	4.02	4.09	3.89	2.65
6#	3.75	3.98	3.38	1.83	4.50	4.51	4.17	2.73
7#	3.54	3.67	3.15	1.78	4.61	4.66	4.26	2.77
8#	3.75	3.98	3.33	1.96	3.64	3.67	3.38	2.05
9#	4.56	4.87	4.07	2.41	3.00	3.09	2.69	1.72
10#	3.54	3.56	2.96	1.81	1.93	2.03	1.62	0.99
11#	3.22	3.25	2.69	1.69	1.82	1.73	1.30	0.96

4.2 perforated caisson

Wave reflection effect of perforated caisson was lower than non-perforated caisson. Under EHWL and DHWL, the perforated area of the caisson was below still water level and the wave dissipation effect was little. While under DLWL, the perforated area was around the still water level and wave dissipation effect was obvious. The wave height of different direction of perforated caisson was shown in Table.3.

Table.3 Results of wave height of non-perforated caisson with different direction (Unit:m)

Test condition / Meas. points	E direction				ENE direction			
	50a ($H_{13\%}$)			2a($H_{4\%}$)	50a($H_{13\%}$)			2a($H_{4\%}$)
	EHWL	DHWL	DLWL	DHWL	EHWL	DHWL	DLWL	DHWL
1#	1.72	1.99	1.85	0.86	1.88	1.99	2.13	1.35
2#	2.19	2.46	2.11	1.14	4.56	4.42	4.34	2.74
3#	2.34	2.61	2.30	1.23	4.66	4.72	4.44	2.80
4#	2.57	2.83	2.55	1.35	4.23	4.30	4.07	2.56
5#	3.00	3.25	2.45	1.61	3.91	3.93	2.78	2.47
6#	3.59	3.62	2.55	1.70	4.29	4.24	3.10	2.55
7#	3.38	3.46	2.41	1.61	4.40	4.35	3.19	2.65
8#	3.54	3.72	2.69	1.82	3.54	3.56	2.73	2.02
9#	4.29	4.61	3.24	2.32	2.84	3.04	2.08	1.69
10#	3.38	3.41	2.22	1.70	1.82	1.89	1.20	0.96
11#	3.11	3.09	2.08	1.63	1.66	1.68	0.93	0.84

4.3 Analysis of wave dissipation effect

Based on wave height measured from the physical model, wave dissipation effect was obtained by comparison of the two design cases (see Figure.4). The wave dissipation effect was expressed by reduction percent of wave height of perforated caisson relative to non-perforated caisson (see Table.4).

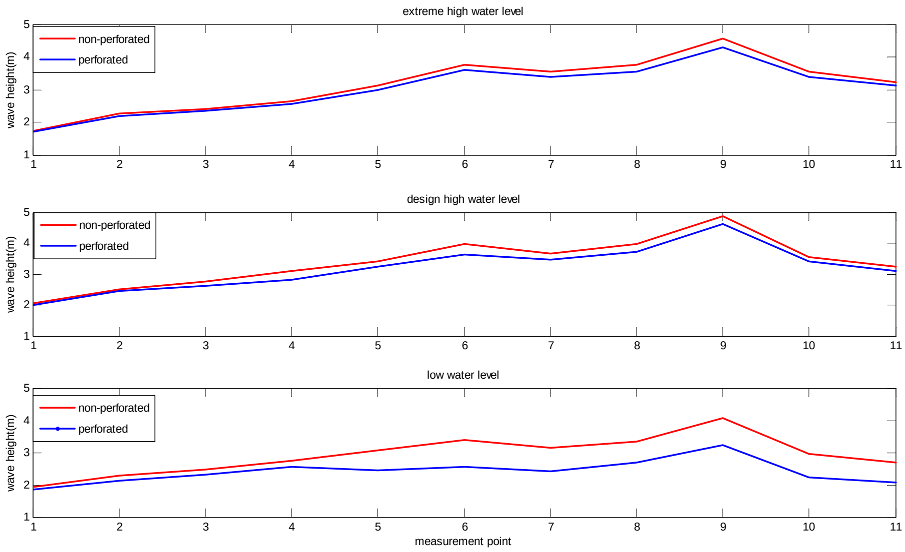


Figure.4 Wave height of non-perforated caisson (points 1#-4#) and perforated caisson (points 5#-11#)

Table.4 Reduction of wave height of perforated caisson relative to non-perforated caisson

Measurement position	E direction		ENE direction	
	HWL	DLWL	HWL	DLWL
I, II area	5.3	22.7	4.8	26.4
III area	5.8	19.8	3.2	21.0
IV area	4.3	23.8	6.1	27.2

Note: HWL means EHWL and DHWL.

It was indicated from Figure.2 and Table.4 that wave dissipation effect of perforated caisson under EHWL and DHWL was mostly below 6% because the perforated area was below still water level. While under DLWL the perforated area was around the still water level and there was a time difference between incident wave and reflect wave, the wave dissipation effect was 19%~27%.

4.4 Influence of perforated caisson on green water and berth condition

Green water height on berth with 10 year wave under DHWL was shown in Table.5, from which it can be found that green water height of perforated caisson was relatively smaller than non-perforated caisson.

Table.5 Experimental results of green water height for non-perforated and perforated caisson (Unit:m)

Measurement position \ Wave direction		E direction		ENE direction	
		Non-perforated	perforated	Non-perforated	perforated
I area	5#	0.37	0.30	0.90	0.77
I, II area	6#	0.63	0.46	0.94	0.81
II area	7#	0.42	0.35	1.00	0.86
III area	8#	0.60	0.53	0.58	0.50
	9#	1.10	0.98	0.52	0.40
IV area	10#	0.46	0.40	-	-
	11#	0.34	0.27	-	-

Non-operation days of berth, on which the wave height was larger than 0.8m was also evaluated according to wave statistical results on grading and frequency. The results shown that non-operation days of non-perforated caisson was 10.5d/year and that of perforated caisson was 9.3d/year.

5 Suggestion for structure design

It is suggested by Code for Design and Construction of Breakwater that the perforation shall be between once the wave height above or below DHWL, which had better not to be twice design wave height below DHWL. In practice many projects in China accorded with the Code, which proved the rationality of the recommendation of Code. However the perforated area was not feasible under DHWL and the wave dissipation effect was not so good as well as the green water height and non-operation days. In addition, wave dissipation under DLWL was much better than DHWL. It was suggested for this project that design of perforation should be consistent with the Code as possible and near DHWL.

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