CHAPTER 7 ANALYSIS OF TWO "STANDARD CASE" BREAKWATERS IN SERIES

7.1 INTRODUCTION TO USING MULTIPLE CYLINDERS

It is intended that the breakwater analyzed in Chapter 5 be used in series with other breakwaters to create a larger effective area and to model the long cylinder of Chapter 5, which was shown to be extremely effective for normal waves. Before presenting the effectiveness of multiple cylinders, several factors should be considered. First of all, each new cylinder adds six degrees of freedom to the system. Since the results of this chapter only consider two cylinders in series, the [6x6] matrices and {6x1} column vectors defined in Chapter 5 are now [12x12] matrices and {12x1} column vectors, respectively. The procedure for determining the added mass and damping coefficients for a single cylinder was discussed in Chapters 5 and 6. However, a new problem is introduced as additional breakwaters are added to the system. For the case of two breakwaters, the first breakwater is displaced in a mode (degree of freedom) at a given frequency and the aforementioned terms are computed. The procedure is repeated for all six degrees of freedom, while the second breakwater is kept fixed. Next, the first breakwater is kept fixed while the second breakwater displaces. It is found that the added mass and damping terms are coupled in the twelve equations of motion describing the structures' positions. This suggests that the breakwaters can model a longer (more effective) structure while maintaining practical considerations by being placed in series with one another. This also raises the question of breakwater spacing. How far can the breakwaters be spaced without losing effectiveness? This optimal design issue can be quite exhaustive. Therefore, two breakwater spacings are considered in this chapter, 1.22 m (4 ft) and 6.1 m (20 ft). Figure 7.1 shows the two breakwaters in series and includes the new location of the XYZ axes. The incident wave angle β is defined as before.

7.2 TRANSMISSION COEFFICIENT AND FREE SURFACE ELEVATION AMPLITUDES

Once the added mass, damping, and force matrices are found, the same procedure used to find the RAO values for one breakwater is used for two breakwaters. The resulting transmission coefficients are shown in Table 7.1 for ω=1.25 rad/s along with the appropriate single breakwater cases. Once again, this can be somewhat misleading as the values are found for the center of the breakwater, or in the case of multiple cylinders, at Y=0 (the midpoint between the two breakwaters or the center of the gap).

Table 7.1 - Transmission Coefficients for ω=1.25 rad/s.

Incident Angle, β	T for One Cylinder	T, Two Cylinders, 1.22 m Gap	T, Two Cylinders, 6.1 m Gap
0°	0.689	0.435	0.655
15°	0.580	0.341	0.477
30°	0.417	0.388	0.361

The free surface elevation amplitudes are shown for the 1.22 m gap and β values of 0°, 15°, and 30° in Figures 7.2, 7.3, and 7.4, respectively, and for the 6.1 m gap and β values of 0°, 15°, and 30° in Figures 7.5, 7.6, and 7.7, respectively. All plots are shown for the wave frequency equal to the first wet natural frequency of one breakwater. First we shall consider the small gap (1.22 m gap) case. Figure 7.2 shows the overall effectiveness of the two cylinders for normal waves and suggests a more effective system than the one cylinder of Figure 6.18. This point is augmented by the decreased transmission coefficient in Table 7.1. Figures 7.3 and 7.4 show contrasting viewpoints. Figure 7.3 suggests that for oblique angles the two cylinders can be very effective when close together. On the other hand, Figure 7.4 is ominous in that amplification can occur at some distance beyond the location where the structure is deemed effective. However, the two cylinders do help reduce this effect as discussed in the previous chapter. More cylinders should prove beneficial.

For the large gap (6.1 m) case, some interesting points are revealed. For normal waves (Figure 7.5), some of the effectiveness is lost as the waves seem to “pass through” the gap (see Table 7.1 also). This is due to the sharply reduced added mass and damping coupling terms that diminish as the gap is increased. As the gap is increased between the breakwaters, the two cylinders act more and more independently and less like one long cylinder. For the oblique waves of Figures 7.6 and 7.7, the structure is effective over a larger bandwidth (Y range) than for the smaller gap. The only situation that suggests using a larger gap for more effectiveness is in the 30° incident wave case where the transmission coefficient is actually reduced for the increased gap. However, it is apparent what happens here. Comparing Figures 7.4 and 7.7 shows that the waves that seem to go around the breakwater are blocked due to the large Y distance covered by the two breakwaters. Since the transmission coefficient is calculated for 50 m downstream, the larger gap reduces the probability of calculation in the "amplified" region.

7.3 FREE SURFACE ELEVATION PLOTS

The free surface elevation plots for β equal to 0°, 15°, and 30° along with a wave frequency of 1.25 rad/s and a breakwater spacing of 1.22 m are shown in Figures 7.8-7.10, respectively. As in Chapter 6, the figures all contain six parts (a)-(f) which are free surface elevation plots at a time t which is a fraction of the period T, and include t equal to 0, 0.2T, 0.4T, 0.6T, 0.8T, and T, respectively. Conclusions made for one breakwater with the wave frequency considered can likewise be made here as the two cylinders act as one longer cylinder. This is due to the small gap which yields large coupling terms of the added mass and damping matrices. Figure 7.8 shows that the waves do not simply pass between the structures as one would suspect to be the case (at very large gaps).

The free surface elevation plots for β equal to 0°,15°, and 30° along with a wave frequency of 1.25 rad/s and a breakwater spacing of 6.1 m are shown in Figures 7.11-7.13, respectively. With this larger gap, the breakwaters act more independently. As in Figure 7.11 (a), this can be seen by the dip in the wave amplitudes between the structures as the waves pass over the breakwaters.