ON PREVENTIVE MAINTENANCE POLICY FOR WAVE DISSIPATING BLOCKS COVERING CAISSON BREAKWATER

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INTRODUCTION

The infrastructures are required to keep a certain level of performance during the duration of service. Because the performance of the infrastructures including harbor and coastal structures deteriorates due to aging and damage that is caused by the action of external forces, it is necessary to perform appropriate maintenance. Satow et al. (2009) proposed a mathematical model for the preventive maintenance of wave dissipating blocks based on the method of the reliability engineering. They also derived the expected maintenance cost over the in-service period and the optimal preventive maintenance policy. In this study, the optimal threshold for preventive maintenance to minimize the expected maintenance cost is determined for the wave dissipating blocks covering caisson breakwater by using the above model.

METHODOLOGY

The necessary condition to minimize the expected maintenance cost that Satow et al. (2009) derived is

$$\int_0^k [1 + M(x)]\, dG(K - x) = \frac{c_2}{c_1 - c_2} \qquad (1)$$

where k=cumulative damage of wave dissipating blocks where the preventive maintenance is performed, $M(x)$=renewal function that is given by using the convolution of $G(x)$, $G(x)$=probability distribution of damage caused by a storm, K=cumulative damage where the corrective maintenance is needed, c_1 and c_2 are the cost for corrective and preventive maintenance. The optimal threshold for preventive maintenance k^* is given so as to satisfy Eq. (1), however, it is necessary to determine the probability distribution $G(x)$. In this study, $G(x)$ is estimated on the basis of Monte Carlo simulation method using the stability formula for block proposed by Hanzawa et al. (1996). The relative damage level N_0 is

$$N_0 = \left[\frac{H_{1/3} / \{(S_r - 1) D_n\} - b}{a} \right]^5 N^{0.5} \qquad (2)$$

where $H_{1/3}$=significant wave height, D_n=nominal diameter of block, S_r=specific gravity of block, N=number of waves, a and b are the constants. The procedures to calculate the values of N_0 are as follows: 1) To set the specification of the intended wave dissipating block. 2) To calculate the offshore wave height in a storm by using an extreme distribution of offshore waves. 3) The wave height at the location of block is determined by the computation of wave transformation. 4) To calculate the value of N_0 in a storm using the wave height and the number of waves. 5) To repeat the procedure 2) to 4) many times

RESULTS

Figure 1 shows the frequency distribution of the relative damage level in a storm at a port in Japan. The design wave height and period are 10.9 m and 12.8 s respectively, and the mass of block is 80 t in this case. The abscissa axis is the number of displaced block related to the unit width (1 m). The solid line denotes the fitted Weibull distribution (two-parameter) whose parameters are given by the method of least squares and the dotted line is the exponential distribution for comparison. This result shows that the Weibull distribution can be used as $G(x)$.

The optimal threshold for preventive maintenance k^* is calculated by using the Weibull distribution and exponential distribution as $G(x)$. Table 1 shows the calculated result of k^*. It is necessary to lower k^* as c_1 becomes larger compared to c_2. Moreover, the values of k^* in the case of the Weibull distribution are small by comparison with the exponential distribution. The reason is that the Weibull distribution has wider skirt and the occurrence probability of damage of blocks caused by large wave is higher.

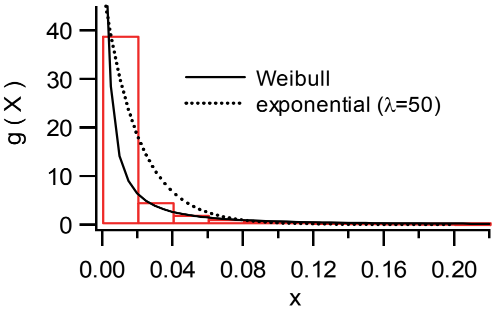
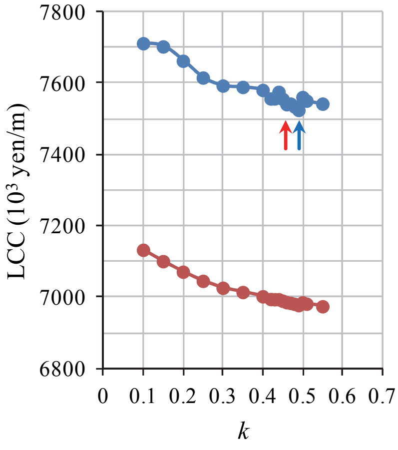


Figure 1 Frequency distribution of relative damage level

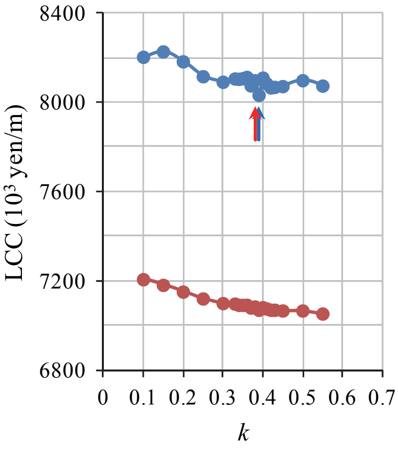
Table 1 Optimal threshold for preventive maintenance

Weibull distribution			exponential distribution			
K	$c_2/(c_1-c_2)$	k^*	K	$c_2/(c_1-c_2)$	k^*	
					λ=50	λ=100
0.5	0.2	0.285	0.5	0.2	0.407	0.445
	0.1	0.229		0.1	0.394	0.438
	0.05	0.177		0.05	0.381	0.432
	0.01	0.082		0.01	0.350	0.416
0.75	0.2	0.459	0.75	0.2	0.648	0.691
	0.1	0.382		0.1	0.635	0.684
	0.05	0.307		0.05	0.621	0.677
	0.01	0.158		0.01	0.590	0.661
1.0	0.2	0.644	1.0	0.2	0.891	0.938
	0.1	0.549		0.1	0.878	0.931
	0.05	0.454		0.05	0.864	0.924
	0.01	0.253		0.01	0.833	0.908

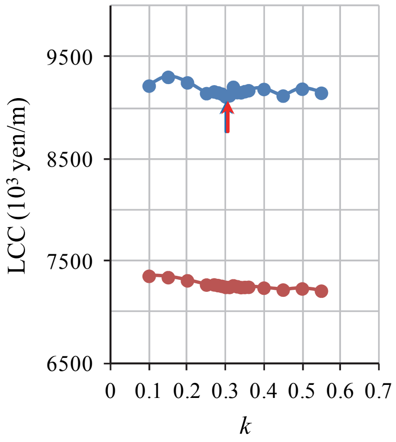
The method of Takayama et al. (2006) based on the Monte Carlo simulation by Hanzawa et al. (1996) is applied to the computation of the expected repair cost and the standard deviation of repair cost. The life cycle cost (LCC) is given by the sum of the initial cost and expected repair cost for the wave dissipating blocks. When the cumulative damage of blocks exceeds the threshold value k or K, the cost of preventive or corrective maintenance is allocated. The value of LCC is computed varying k within the range of [0.01, K]. Figure 2 shows the relation between k and LCC (red circle) in the case of K=0.75. Miyata et al. (2009) showed a criterion for repair of wave dissipating blocks to minimize the sum of the expected repair cost and standard deviation of repair cost to evaluate the risk of corrective maintenance whose cost remarkably increases. The values of the sum of LCC and standard deviation of repair cost (blue circle) are also shown in Figure 2 following Miyata et al. The blue and red arrows show the preventive maintenance level to minimize [LCC+standard deviation of repair cost] and k^* that are listed in Table 1 respectively. The values of k^* agree well with the simulated results and it shows the validity of the theoretical model.



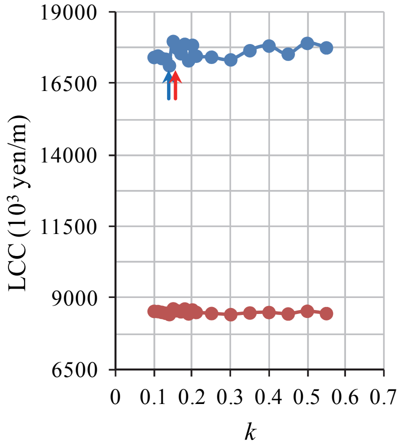
(a) $c_2/(c_1-c_2)$=0.2



(b) $c_2/(c_1-c_2)$=0.1



(c) $c_2/(c_1-c_2)$=0.05



(d) $c_2/(c_1-c_2)$=0.01

Figure 2 Relation between k and LCC (K=0.75)

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