Damping Factor for Pseudo-Static Method on Seismic Design of Pile Supported Wharves

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SUMMARY
Seismic design of pile-supported wharves against the level-one earthquake ground motion is carried out by pseudo-statics using the seismic coefficient calculated with the natural period of piled wharf and the acceleration response spectrum at vertual fixed point of the piles. Meanwhile dynamic analysis is also employed, taking into consideration for the dynamic interaction of piles and ground.
The response behaviors of pile-supported wharves with the pseudo-static and dynamic analyses are compared in this paper. As the result, it is clarified that discrepancy in of subgrade reaction and the damping factor in the pseudo-static and dynamic analyses causes the difference in the response behaviors of the piled wharf.

Keywords:Pile-supported wharves, subgrade reaction, level-one earthquake ground motion, pseudo-statics and dynamic analyses

Seismic design of pile-supported wharves against the level-one earthquake ground motion is carried out by pseudo-statics using the seismic coefficient calculated with the natural period of piled wharf and the acceleration response spectrum at vertual fixed point of the piles(response spectrum analysis). Meanwhile dynamic analysis is also employed, taking into consideration for the dynamic interaction of piles and ground.
In response spectrum analysis, the damping factor is generally used 20% at the time of calculating an acceleration response spectrum. According to Kuwabatra・Nagao (2010), it is supposed that the reasonable value of the damping factor of the response spectrum analysis is 5% considering the dynamic interaction of piles and ground, while there are few examples which is examined the damping factor of pile-supported wharves.
This study aims at discussing the response behaviors of pile-supported wharves with the pseudo-static and dynamic analyses. Calculation of the damping factor of pile-supported wharves is tried by measuring of the displacement of the free oscillation of the superstructure using two-dimensional dynamic analyses. Furthermore, the coefficient of the subgrade reaction which is used by calculating the natural period of pile-supported wharves and vertual fixed point of the piles in response spectrum analysis is taken as the value equivalent to dynamic analysis, and the maximum acceleration of the superstructure is obtained by using calculated the damping factor. the maximum acceleration is compared with the two-dimensional dynamic analyses.

2. EXAMINATION CONDITIONS

In this study, it is aimed at the model pile-supported wharf as shown in **Figure 2.1**, it is used FLIP (Finite element analysis of Liquefaction Program) for two-dimensional analysis. Soil conditions are as shown in **Table 2.1**, and set up as the loose sands in consideration of the past results of the soil conditions as which a pile-supported wharf is employed. Moreover, it set to the conditions which liquefaction doesn't occur since it is aimed at level-one earthquake ground motion. The soil modulus is set up in accordance with the setting method normally used in FLIP by Morita et al. (1997). In two-dimensional analysis, in order to deal with the dynamic interaction of piles and ground, the nonlinear spring for pile-ground interaction which modelled the load displacement relation of the spring combined piles with ground is used.

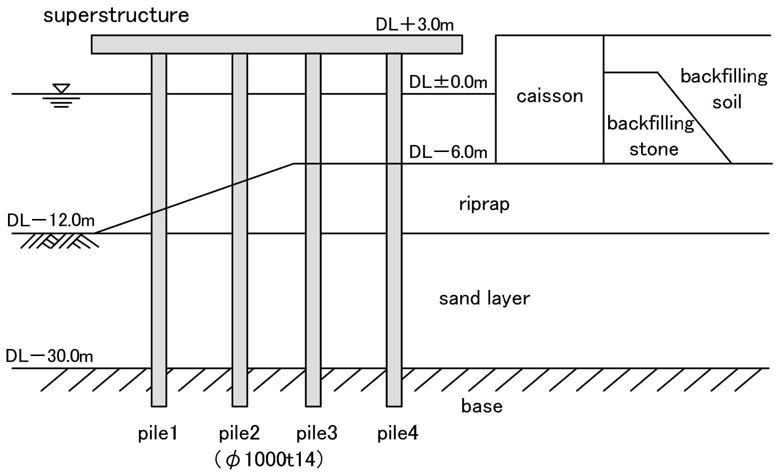

Figure 2.1. Model pile-supported wharf

Table 2.1. soil condition

soil layer	γ_t (kN/m^3)	γ' (kN/m^3)	N-value	σma' (kN/m^2)	Gma (kN/m^2)	Kma' (kN/m^2)	constraint pressure dependency	ϕ (°)
backfiling soil	18.00	8.00	11.0	98.00	79270	206700	0.50	39.50
backfiling stone	20.00	10.00	—	98.00	180000	469400	0.50	35.00
riprap	20.00	10.00	—	98.00	180000	469400	0.50	35.00
sand layer	20.00	10.00	10.0	98.00	75210	196100	0.50	39.30
base	20.00	10.00	50.0	98.00	188500	491600	0.50	43.27

Calculation of the damping factor of pile-supported wharves is tried by measuring of the displacement of the free oscillation of the superstructure by giving the one wave of the sine wave to the base using two-dimensional dynamic analyses for the model wharf shown in **Figure 2.1**. Then, using the calculated damping factor, the maximum acceleration of the superstructure is obtained in response spectrum analysis, and it compared with the two-dimensional analysis results. At this time, the coefficient of the subgrade reaction which is used by calculating the natural period of pile-supported wharves and vertual fixed point of the piles in response spectrum analysis is taken as the value equivalent to dynamic analysis which can be obtained the secant stiffness of the nonlinear spring for pile-ground interaction, shown in **Figure 2.2**. Calculation of the maximum acceleration of the superstructure is intended for 10 waves of the level-one earthquake ground motion which maximum accelerations and predominant periods are different shown in **Table 2.2**.

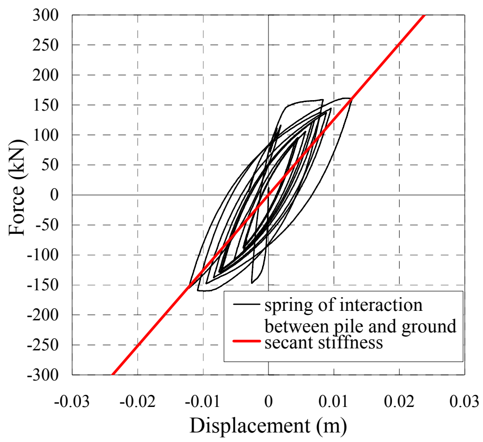

Figure 2.1. Model pile-supported wharf

Table 2.2. level-one waveform of earthquake ground motion used for exmamination

earthquake wave	maximum acceleration (Gal)	predominant period (s)
Hitatinaka	159.2	1.04
Shimizu	132.0	1.59
Hakata	166.1	0.48
Hatinohe	214.2	1.16
Ishinomaki	247.6	1.00
Iwakuni	312.3	0.24
Yokkaichi	108.1	1.38
Tiba	95.0	1.34
Mizuru	380.5	0.22
Kobe	274.1	0.36

3. RESULT OF STUDY AND DISCUSSION

Figure 3.1 shows the time serried of displacement of the superstructure at the time of by giving the one wave of the sine wave. As seen in **Figure 3.1**, the free oscillation of the superstructure is carried out and it is confirmed that the damping factor can be obtained.

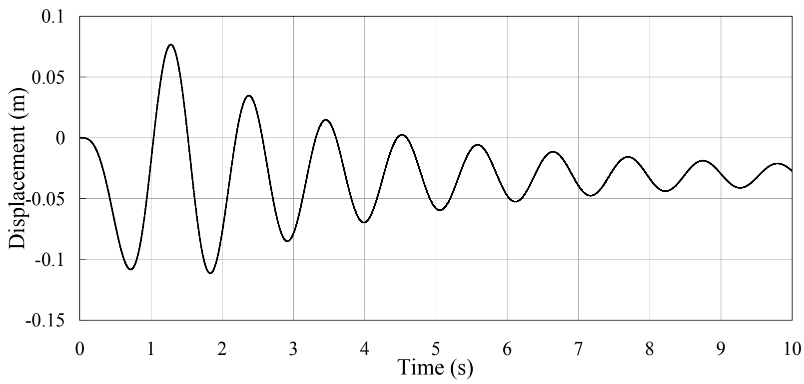

Figure 3.1. the time series of the displacement of the superstructure

The amplitude is computed from the displacement of the place shown in figure **Figure 3.1**, the natural logarithm of the ratio of the adjacent amplitude is taken, and the damping factor is obtained by calculating logarithmic decrement. The result of obtained the damping factor by having changed into from 0.7Hz to 4.5Hz of the frequency of the sine wave which input into the base are depicted in **Figure 3.2**. the figure shows the damping factor are calculated about 3~8% smaller than 20% which are usually used by the design of pile-supported wharves. Moreover, the tendency for the damping factor to become large is confirmed as the displacement of the wharves becomes large. It is considered that the big damping where displacement is larger showed according to the damping effect by the strain of the ground.

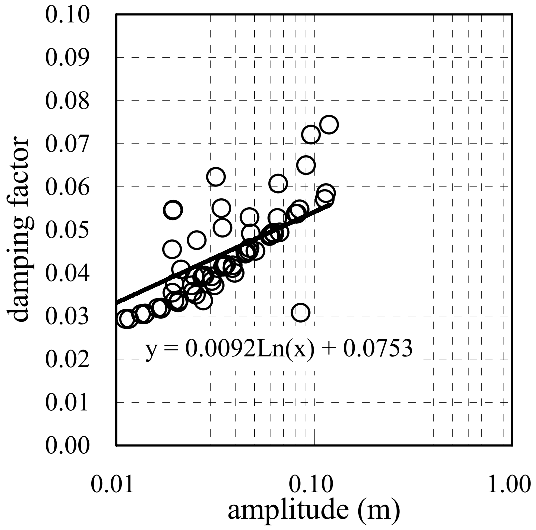

Figure 3.2. the results of damping factor of the superstructure

when the level-one waveform of earthquake ground motion which is intended the examination is given to the model pile-supported wharf, the displacement of the superstructures are calculated as 0.01~0.19m. Therefore, according to the displacement of the superstructure, the damping factor of the wharves is set to 3~6% from the logarithm approximated curve of **Figure 3.2**.

Figure 3.3 shows the results of calculated the acceleration in the superstructure in each waveform by the response spectrum analysis using the configured damping factor. In addition, the results at the time of being referred to as h=0.20 are also shown for comparison. As previously indicated, the coefficient of the subgrade reaction is equivalent to two-dimensional analysis in both cases. In the case of h=0.20, the figure shows the acceleration in superstructure is 30~75% of two-dimensional analysis, and the acceleration which is corrected to the damping factor is 60~115%. Thus, it is clear by correcting the damping factor to get up close the acceleration of the superstructure obtained in two-dimensional analysis.

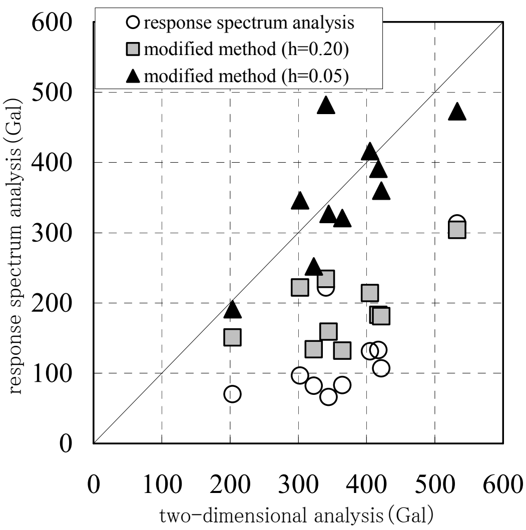

Figure 3.2. the comparison of the acceleration of the superstructure

4. CONCLUDING REMARKS

In this study, calculation of the damping factor of pile-supported wharves is tried by measuring of the displacement of the free oscillation of the superstructure using two-dimensional dynamic analyses. As the result, the damping factor are calculated about 3~8% smaller than 20% which are usually used by the design of pile-supported wharves. Furthermore, the tendency for the damping factor to become large is confirmed as the displacement of the wharves becomes large. It is clear that the acceleration of the superstructure calculated from the response spectrum analysis is agreement with two-dimensional analysis by correcting the damping factor.

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