# Seismic Analysis System of Bridge Pier with Pile Foundation in Ariake Soft Clay Region

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#### 1. INTRODUCTION

Design of bridge pier needs special attention such as consideration of ground displacement, soil-pile interaction effect etc., when foundation piles penetrate through soft clay layer. Ground displacement largely depends on soil shear wave velocity,  $V_s$  & strain dependence of  $G/G_0$ .

#### 2. ANALYSIS MODEL

Detailed dimension of the bridge pier and pile foundation are shown in Fig. 1. The pier is a reinforced concrete structure 4.0×2.0 m rectangular in plan supported by 9 (3×3), 1.00 m diameter circular RC piles. Corresponding analytical model is prepared and is as shown in Fig. 2 to be used in SESAS program. SESAS program was developed in Structural System Laboratory, Saga University.

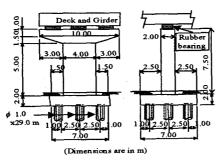


Fig. 1 Details of the bridge pier

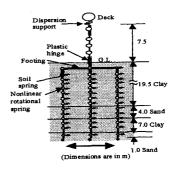


Fig. 2 FE model of the bridge

In this study, three cases of  $V_s$  value determination in the top clay layer were considered

Case I: Measured V, value

Case II:  $V_s = 50$  m/sec based on the Road Bridge Code Case III:  $V_s$  from The Railway Bridge Standard formula

For seismic analysis of structures in soft clay region, it is necessary to consider soil-pile interaction effect since large ground displacement occurs in such situation. In this study, analysis was carried out by both Penzien model and single input model concept. In Penzien model analysis pile-soil interaction effect is taken into account by the consideration of ground displacement input. In dynamic analysis, non-linear elasto-plastic material behavior was considered for piles. Linear pile behavior case was also performed for comparison purposes.

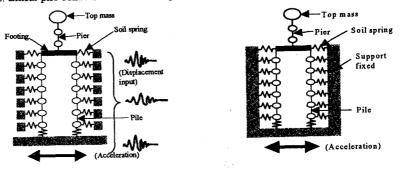


Fig. 3 Penzien model

Fig. 4 Single input model

## 3. RESULTS AND DISCUSSION

Maximum bending moment occurred in the pile by SESAS analysis for all cases of analysis are summarized in Table 1. It is observed that with pile nonlinear consideration, bending moments are reduced significantly. After exceeding cracking limit, non-linear histeretic behavior of the elements are considered in the non-linear case which cause histeretic damping and smaller bending moments are happened. Beyond cracking limit, linear behavior is not realistic for RC elements. In the seismic analysis of bridges in soft clay region, non-linearity in the piles should be considered.

Table 1 Maximum bending moment in the pile

Seismic	Model	Pile max bending moment (kN-m)												
record	MIOGEL	Pile linear							Pile nonlinear					
		Case I		Case II		Case III		Case I		Case II		Case III		
		Each	Avg.	Each	Avg.	Each	Avg.	Each	Avg.	Each	Avg.	Each	Avg.	
I-III-1	Penz.	7512		19117		4727	· · · · · · · · · · · · · · · · · · ·	4131		5250		2226		
I-III-2	Penz.	8537	7570	18539	19989	5460	4836	5182	4303	5250	5250	2733	2414	
I-III-3	Penz.	6661		22312		4322		3595		5250		2283		
II-III-1	Penz.	10339		17831		7723		5250		5250		4010		
II-III-2	Penz.	10870	10367	21607	19587	8993	7892	5250	5250	5250	5250	3805	3692	
II-III-3	Penz.	9893		19322	*	6961		5250		5250		3262		
I-III-1	Single	3107		2634		3086		1864		1675		1775		
I-III-2	Single	2688	2872	2982	2740	2692	2809	1816	1773	2069	1893	1762	1717	
I-III-3	Single	2820		2605		2648		1640		1934		1614		
II-III-1	Single	3708		3706		3904		2282		3331		2385		
II-III-2	Single	3822	3742	3923	3772	4034	3884	2116	2160	3068	3137	2224	2228	
II-III-3	Single	3697		3686		3713		2083		3012		2076		

Distribution of maximum bending moments throughout the pile are presented in Figs. 5, 6 and 7 for Type II -III-1 seismic record. In Penzien model analysis, maximum pile bending moment reached yield limit in Case I and Case II and approached to yield limit in Case III. However, in single input model analysis, maximum bending moment (Table 1) was much below yield limit. Penzien model analysis should be adopted in seismic analysis of bridge pier with pile foundation in soft clay region from safety point of view.

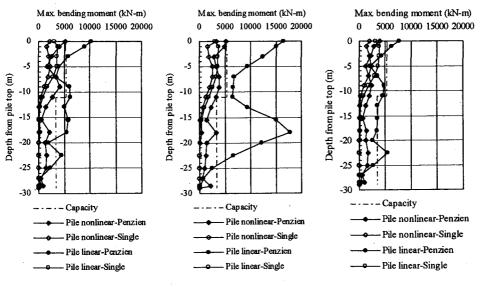


Fig. 5 Max. bending moment in pile in Case I

Fig. 6 Max. bending moment in pile in Case II

Fig. 7 Max. bending moment in pile in Case III

### 4. CONCLUSIONS

We propose Penzien model analysis method with non-linear pile behavior consideration for seismic analysis of all bridge structures with pile foundation in soft clay region such as Ariake soft clay region.