

Embedment Effect Test on Soil-Structure Interaction

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1 INTRODUCTION

A project consisting of laboratory test and field test has been conducted to clarify the embedment effects on soil-structure interaction. The objective of this project is to obtain data to improve and prepare seismic analysis codes regarding the behavior of embedded reactor buildings during earthquakes.

Few studies[1,2,3] using large scale models have been reported focusing on soil-structure interaction. This project was planned to study the effect of soil-structure interaction using small size soil-structure models as well as large scale models.

This project is carried out under the sponsorship of the Ministry of International Trade and Industry.

2 OUTLINE OF TEST

2.1 Schedule

The project started in April 1986 and will end in March 1994(See Fig.1). It consists of laboratory test with shaking table and field test with exciter. Some embedment conditions are applied to test models used in laboratory and field tests to discuss the embedment effects on soil-structure interaction.

Figure 2 shows laboratory test schedule. Laboratory test was planned to obtain the data under well known test conditions. Figure 3 shows field test schedule. Field test was planned to measure the response of large scale models.

2.2 Test Models

(a)Laboratory Test Models

Figure 4 shows the configuration of soil models used in laboratory test. Two soil models made of silicone rubber are used. The soil models have different stiffness each other. Their cylindrical configuration is 3m in diameter and 70cm in height. They have brass bars around their circumferential edges to restrict vertical deformation of soil models during shaking table test. Figure 5 shows the structure model made of

aluminum. It simulates dynamic characteristics of reactor buildings.

(b) Field Test Models

Field test is carried out on three sites. Two sites are used for dynamic test with four test models in dimensions of 8×8m in plane and 10m in height. The rest was used for static test with one concrete block as a test specimen. Figure 6 shows the configuration of Model A and Model B. These two test models used in dynamic test simulate dynamic characteristics of BWR type reactor buildings and are built on the soft rock site. The other two specimens, Model C and D, for dynamic test have dynamic characteristics of PWR type reactor buildings(See Fig. 7). Model C is built on the same site as BWR type models are built on. Model D is built on the hard rock site to discuss the embedment effect under different soil conditions.

2.3 Measurement

Many accelerometers are installed on the test models as well as in the ground around test models in both laboratory test and field test. Earth pressure is also measured on the underneath and side of base of structure models in laboratory test and Models A, B, C and D in field test.

Earthquake observation is also carried out in the two sites for dynamic test of field test. The observation started from October 1989 in the soft rock site and from June 1990 in the hard rock site. There are some arrays in the sites as well as many accelerometers installed on and around test models. Figure 8 shows the array in the soft rock site.

3 INTERIM RESULTS

3.1 Embedment Effects

As an interim result, the embedment effects are confirmed from tests. Natural frequencies and damping factors of the embedded test models increased and amplitude of them decreased compared with non-embedded conditions(See Table 1).

3.2 Recorded Earthquakes

Some earthquakes are also recorded in the soft rock site. Figure 9 shows the epicenter of earthquakes occurred in 1989. These earthquake records are listed in Table 2.

REFERENCES

- [1] M.Iguchi et al., "Model tests on interaction of reactor building and soil" Structure Mechanics in Reactor Technology, Vol.K1, 1987
- [2] M.Iguchi et al., "LARGR-SCALE MODEL TESTS ON SOIL-REACTOR BUILDING INTERACTION" 9th World Conference on Earthquake Engineering, 1988
- [3] A.H.Hadjian et al., "Soil-Structure Interaction Lotung Experiment :Prediction Evaluation Basis", Structure Mechanics in Reactor Technology, Vol.K1, 1989

Item	Fiscal Year	1986	1987	1988	1989	1990	1991	1992	1993
LABORATORY TEST		=====							
FIELD TEST		=====							
EARTHQUAKE OBS.					=====				
OVERALL EVALUATION							=====		

Figure 1 Schedule

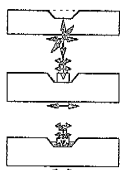
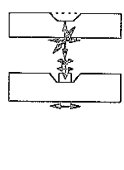
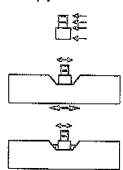
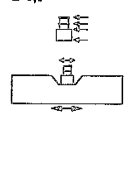
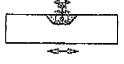

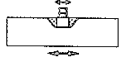
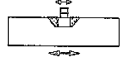



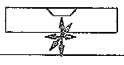

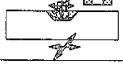
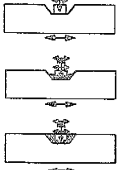
Title of test	Basic characteristics test		Building characteristics test		Variation tests		
Name of model	A	B	C	D	E	F	G
Feature	· Embedment depth · Ground stiffness	· Embedment depth · Ground stiffness	· Embedment depth · Building vibration characteristic	· Embedment depth · Building vibration characteristic	· Vibration characteristics adjacent building · Embedment depth · Soft	· Irregularity to back fill	· Non-linearity of back fill
Ground	Soft	Hard	Soft	Hard	Soft	Hard	Soft
Building	Rigid base	Rigid base	Rigid base + Superstructure	Rigid base + Superstructure	Rigid base × 2	Rigid base	Rigid base
87	Fabrication of test model						Material test for selection of non-linear material
88	A-0,1,2 	B-0,1 	C-0,1,2 	D-0,1 			
89	A-3 	B-3 	C-3 	D-3 	E-1 	F-1 	Material test for selection of non-linear material
90	A-0' 	B-0' 			E-3 	F-2 	Material test for selection of non-linear material
91							G-1,2,3 

Figure 2 Laboratory test schedule

Soft Rock A Point			Hard Rock B Point	Hard Rock C Point
MODEL-A	MODEL-B	MODEL-C	MODEL-D	MODEL-E
1987 A 1	1988 B 1	1989 C 1	1988 D 1	1987 E 1, 2
1987 A 2	1989 B 2	1990 C 2	1989 D 2	1987 E 3
1987 A 3	1989 B 3	1990 C 3		1988 E 4
1988 A 4	1992 B 4	1991 C 4		
1990 A 5		1993 C 5		
1992 A 6				

Figure 3 Field test schedule

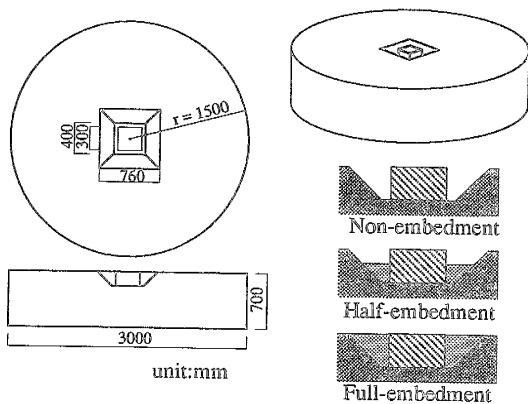


Figure 4 Soil model for laboratory test

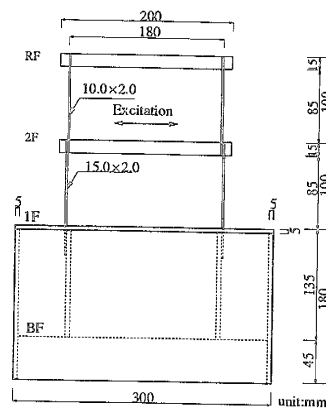


Figure 5 Structure model for laboratory test

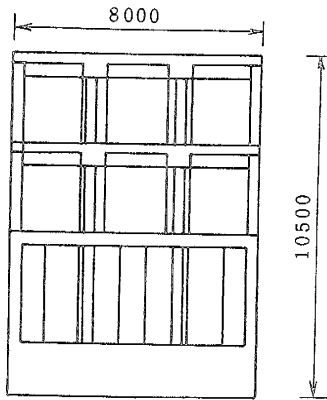


Figure 6 Model A and B for field test

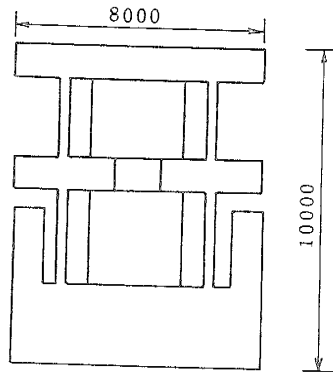
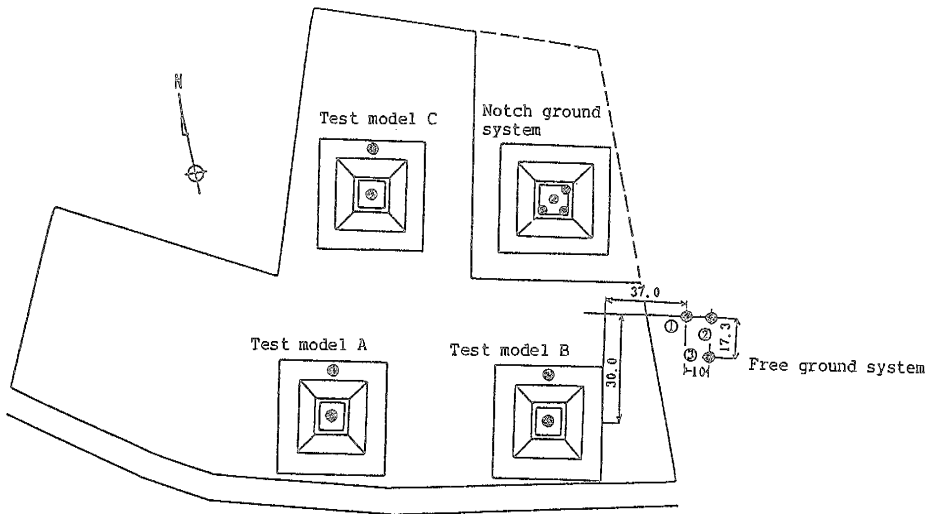


Figure 7 Model C and D for field test



Plane arrangement

Unit (m)

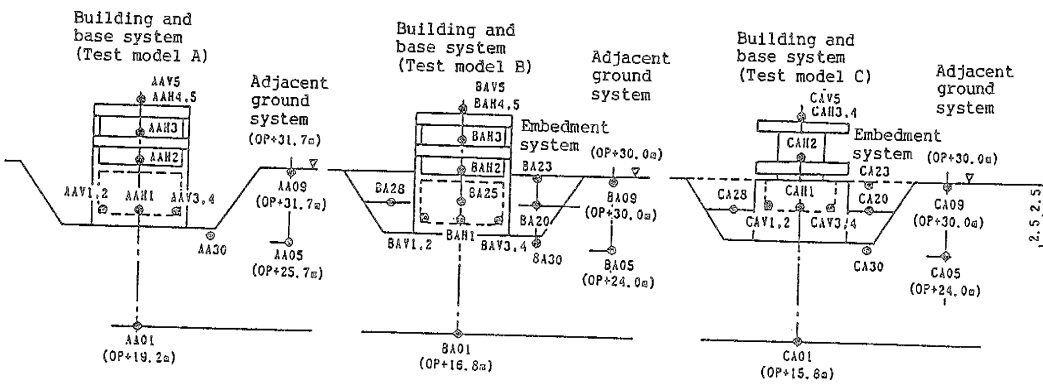
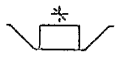
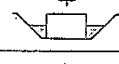



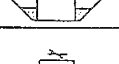



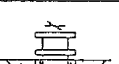


Figure 8 Array in the soft rock site

Table 1 Result of field test

		Test	Excitation point	Excitation direction	Natural frequency (Hz)	Damping factor (%)	Sway (%)	Rocking (%)	Upper structural elastic deformation(%)
Test model A		A 1	1 F	NS	10.1	7.6	37	63	—
				EW	10.1	8.3	38	62	—
				UD	15.8	6.2	—	—	—
		A 2	1 F	NS	11.7	9.5	41	59	—
				UD	15.4	9.3	—	—	—
		A 3	1 F	NS	14.3	41.7	38	62	—
				UD	17.2	33.9	—	—	—
		A 4	RF	NS	8.9	14.7	14	76	10
EW				8.8	17.0	19	69	12	
Test model B		B 1	RF	NS	6.9	4.5	15	75	10
				EW	6.2	4.2	15	79	6
				1 F	NS	6.9	4.5	16	79
		B 2	RF	NS	8.2	5.0	15	73	12
				1 F	NS	8.2	5.0	14	71
		B 3	RF	NS	9.2	13.5	14	72	14
				EW	9.0	14.7	16	77	7
				1 F	NS	9.0	12.0	17	68
Test model C		C 1	RF	NS	5.9	5.1	17	74	9
				EW	5.5	4.2	11	54	35
		BF	NS	5.9	5.1	17	74	9	
Test model D		D 1	RF	NS	11.0	1.9	9	41	50
				EW	8.4	1.1	5	25	70
			BF	NS	11.0	1.9	9	41	50
		D 2	RF	NS	11.3	4.4	10	38	52
				EW	8.7	1.5	5	21	74
			BF	NS	11.3	4.5	10	39	51

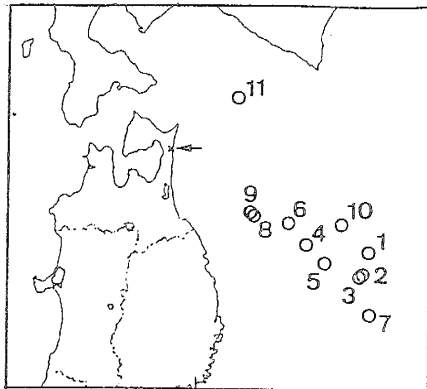


Figure 9 Epicenter of earthquakes

Table 2 Earthquake records in 1989

No	TIME				M	Max. Acc (GAL)		
	M	D	h	m		NS	EW	UD
1	10	27	02	07	6.2	0.65	0.90	0.33
2	10	29	12	09	6.0	1.00	1.03	0.52
3	10	29	14	26	6.5	1.84	2.27	0.83
4	11	02	03	26	7.1	26.2	22.9	13.5
5	11	02	03	36	—	1.65	1.72	0.67
6	11	02	05	20	5.4	0.50	0.56	0.51
7	11	05	05	12	5.9	0.60	0.60	0.40
8	11	06	17	56	5.4	8.00	7.60	3.00
9	11	21	13	47	5.9	3.20	3.30	1.40
10	12	17	08	25	5.8	1.10	0.80	0.50
11	12	21	01	12	4.7	6.60	8.70	2.60