Transactions of the **13th International Conference on Structural Mechanics in Reactor Technology** (SMiRT 13), Escola de Engenharia - Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, August 13-18, 1995

Preliminary assessment on the influence of distance between nuclear power buildings

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ABSTRACT: This paper summarizes an appropriate layout study of nuclear power buildings through the feasibility study of the deeply buried twin-type advanced BWR. Assessment has been carried out by analysis and dynamic experiment for understanding the behavior of reactor building (here after R/B) and turbine building (here after T/B). It is proposed that a twin R/B should be designed as a coupled system, if the distance of R/Bs is less than 1/4 of diameter (1/4D). We also reached the conclusion that the influence of distance between T/B and R/B depends on foundation type of T/B. Therefore, in the design stage of a T/B, we have to consider the dynamic interaction between R/B and T/B as well as surrounding soil.

1. INTRODUCTION

1.1 Background

From safety and economic points of view, multi-type nuclear power plants have generated larger electric power with smaller-scale reactor. In Japan, the limitation of site feasibility makes an R/B be buried about more than 40m for directly supported by bed rock. Fore more deeply buried R/B, it will be required to evaluate the dynamic behaviors of buildings and reciprocal stability of soil and buildings during strong earthquake, which will give us an appropriate design frame work.

1.2 Objectives and target

The objectives of this preliminary assessment through feasibility study are to propose the appropriate layout of nuclear power buildings, to establish the frame work of seismic design, and to obtain the important data for validation experiments. Preliminary analyses and experiments have been carried out to investigate the influence of the distance between R/Bs and the distance between the R/B and T/B.

1.4 Mkwh scale twin-type power plant has been investigated at the stage of preliminary assessment.

2. CONDITION

Geological condition of the potential construction site consists of about 65m Quaternary sediments with 10m soft sand, 40m-silt located from GL-19m to GL-61m, and 15m-sandy gravel. Water table is located near grand level (GL-6m). Soil properties for analysis are shown in Table 2.1-1.

Input motion for analysis and experiments are defined in Table 2.1-2 (JEA, 1987).

Plot plan of twin-type 1.4 Mkwh ABWR is shown in Fig. 2.1-1. In this study, R/B is designed as a cylindrical shape, based on the bed rock located 65m below grand level. Structural foundation (pile or slurry wall) is considered for T/B. R/B and T/B are connected with main steam tunnel supported by pile foundation. For construction of R/B, slurry wall is planned for bearing the earth pressure and keeping water tightness.

Table 2.1-1 Soil property

depth (m)	soil	γt	Vs	Go	νD	νS
-4.0	sand	1.9	170	5,600	0.35	0.33
-8.0	sand	1.8	170	5,300	0.45	0.33
-13.0	sand	1.8	310	18,000	0.45	0.33
-15.8	silt	1.7	160	4,400	0.49	0.49
-19.0	sand	1.9	270	14,000	0.46	0.33
-30.0	silt	1.7	170	5,000	0.49	0.49
-42.0	silt	1.6	210	7,200	0.49	0.49
-50.0	silt	1.6	220	7,900	0.49	0.49
-56.0	glavel	1.8	380	27,000	0.49	0.33
-61.0	silt	1.8	230	9,700	0.49	0.49
-65.0	glavel	2.0	400	33,000	0.47	0.33
-75.0	rock	1.7	400	28,000	0.47	0.47
-165.0	rock	1.7	440	33,000	0.47	0.47
-210.0	rock	1.8	470	41,000	0.47	0.47
-255.0	rock	1.8	530	56,000	0.47	0.47
-300.0	rock	1.8	630	73,000	0.47	0.47
	rock	2.3	1,200	338,000	0.47	0.47

νD; Dynamic Poisson's ratio
νs; Static Poisson's ratio
γt; unit weight (tf/m^3)
Vs; shear velocity (m/s)
Go; Shear modulus(tf/m^2)

Table 2.1-2 Imput motion

	Content
S1	Maximum design earthquake expected to be occured once at the site during the operation period of nuclear power plant
S2	Maximum extreme earthquake potential at the site

3. MODELS AND METHODS

3.1 Analytical models and methods

Cases of analysis model are shown in Fig. 3.1-1. Case S-1 to case S-6 are dynamically analyzed by pseudo 3-D FEM. Case S-7 is two dimensional plane strain model for static analysis based on ground response acceleration method.

3.2 Experimental models and methods

Corresponding to the analysis, the dynamic experiment has been carried out with the purpose of which evaluate the influence caused by the difference of T/B foundation systems. Experimental case and model are shown in Fig. 3.2-1. Experiments have been done by the following steps;
i) Evaluate the dynamic properties of dry sand (6m x 3m x 0.65m) which is the model of 65m depth soil,
ii) Realize the behavior of single building (R/B, T/B),
iii) Evaluate the dynamic interaction of R/B-T/B,
iv) Verify the 2-D equivalent linear analyses in comparison with experiment results.

4. RESULT AND EVALUATION

4.1 Analytical results

Analytical results of Case S-1 to S-7 are summarized as follows:
<u>1) Influence of the distance between R/Bs</u>
The distance of cylindrical R/Bs is set to a parameter normalized by the diameter (D) of R/B. The result of Case S-2 is shown in Fig. 4.1-1. In the figure, left earth pressure distribution indicates far side of neighboring R/B, and right side pressure indicates

another. 1 D is enough for neglecting the influence of neighboring R/B. Shorter the distance of R/B makes larger unbalanced earth pressure. Unbalanced pressure becomes 10% of the far side in the case of D/6.

2) Interaction between R/B and T/B

The result of acceleration, displacement and earth pressure of Case S-4 (R/B-T/B slurry wall with 20m, 40m distance) and Case S-5 (40m distance of R/B-T/B pile foundation) are shown in Fig. 4.1-2. The change of R/B-T/B distance from 40m to 20m makes acceleration increase and displacement decrease. Earth pressure is increased by about 15% comparing with single R/B. According to the influence analysis of T/B with slurry wall, acceleration is increased, displacement is decreased, and earth pressure is declined to 40% from T/B with pile foundation. Because the structural stiffness of slurry wall is stronger than one of pile foundation. R/B and T/B behave in the same phase, and the reciprocal displacements of R/B and T/B are 4.3cm and 3.4cm in case of pile foundation and slurry wall, respectively.

3)Analysis of plot plan (Case S-7)

The result of two dimensional plane strain model (Case S-7) simplified from plot plan is shown in Fig. 4.1-4. The displacement of surrounding soil is restrained by the R/B directly founded on the rock. The earth pressure around R/B is followed by own shape. The stress flow around R/B is more smooth than one around T/B, because of their different shapes. The ground behavior between the R/B and T/B is strongly restrained and its movement is extremely small.

4.2 Experimental results

Experimental results of Case E-1 to E-6 are summarized as follows:

1) Dynamic behavior of R/B

It is confirmed that R/B (Case E-2) is followed by the surrounded ground which behaves non-linearly during the earthquake motion. The influence of R/B on surrounding soil is negligible where the distance is more than one diameter from R/B. This trend is also found in the nonlinear analysis.

2) Interaction between R/B and T/B

The experimental results of Case E-4 (R/B-T/B with slurry wall) and Case E-6 (R/B-T/B with pile foundation) are shown in Fig. 4.2-1. The acceleration and displacement of soil between R/B and T/B are decreased from ones of single model. The rate of acceleration and displacement degradation of Case E-6 is lower than one of Case E-4. The relative displacement between Case E-6 is about 3 times larger than one of Case E-4 (see Fig. 4.2-2). These results are also simulated by the analysis of these models.

The result of ground motion shown in Fig. 4.2-3 indicates that the acceleration of experiment is smaller than one of two dimensional analysis, because the cylindrical shape of R/B in the experiment causes a stress flow more smooth (see Fig. 4.1-4).

5. CONCLUSIONS AND FUTURE PLAN

The conclusions of analyses and experiments are summarized as follows;

1) R/B which is deeply buried and directly founded on bed rock moves corresponding to ground motions.

2) When the distance between R/B and R/B is less than D/4, the evaluation of R/B-R/B interaction is required for designing R/B, because of significant unbalance force.

3)Interaction between R/B and T/B is strongly influenced by the location of different buildings in our case. It is suggested that R/B-T/B coupled model should be analyzed instead of standard single model, and the direction of earthquake motion and dynamic stiffness of soil should be considered at the design stage.

4)By simulating the soil model, sandy gravel layer located 10m under ground level causes most powerful earth pressure. Evaluation of dynamic properties of this layer and modeling are important for design stage of structures.

5)According to the analysis and experiment, we confirm that the dynamic behaviors of buildings are partially simulated by pseudo 3-D dynamic analysis and 2-D dynamic analysis with equivalent linear method. 3-D analysis will be required for evaluation of stability of soil surrounding the structures because of their different shapes (Cylinder and rectangular).

Through this assessment, the influence of distance between buildings is analytically evaluated, and fundamental behaviors are understood by experiments of simplified models. Such deep varied nuclear power plant has never constructed under the supposed geological condition which is more complicated than experiment model.

In the next step, experiments by precise model for validation and developments of analytical method are planned. We also consider to perform the synthetic research including establishment of design condition and seismic design frame work.

REFERENCE

Japan Electric Association: Technical Guidelines for a Seismic Design of Nuclear Power Plants, 1987.

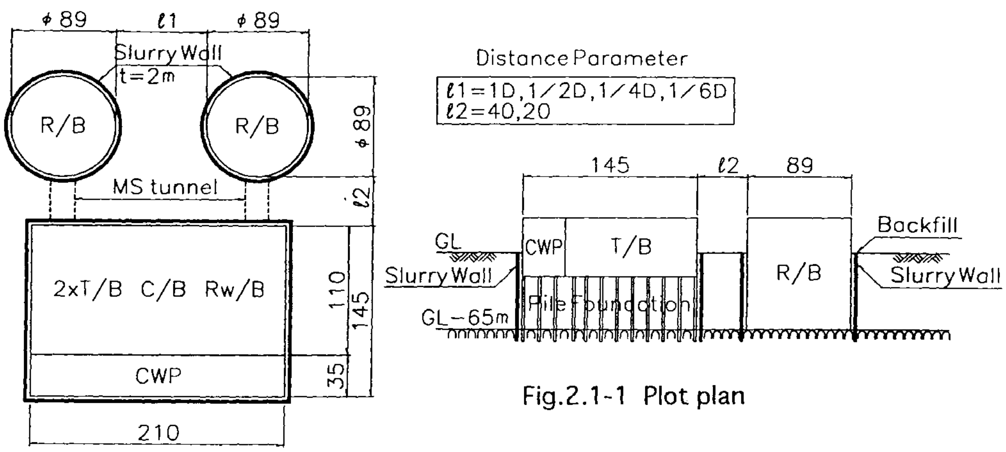


Fig.2.1-1 Plot plan

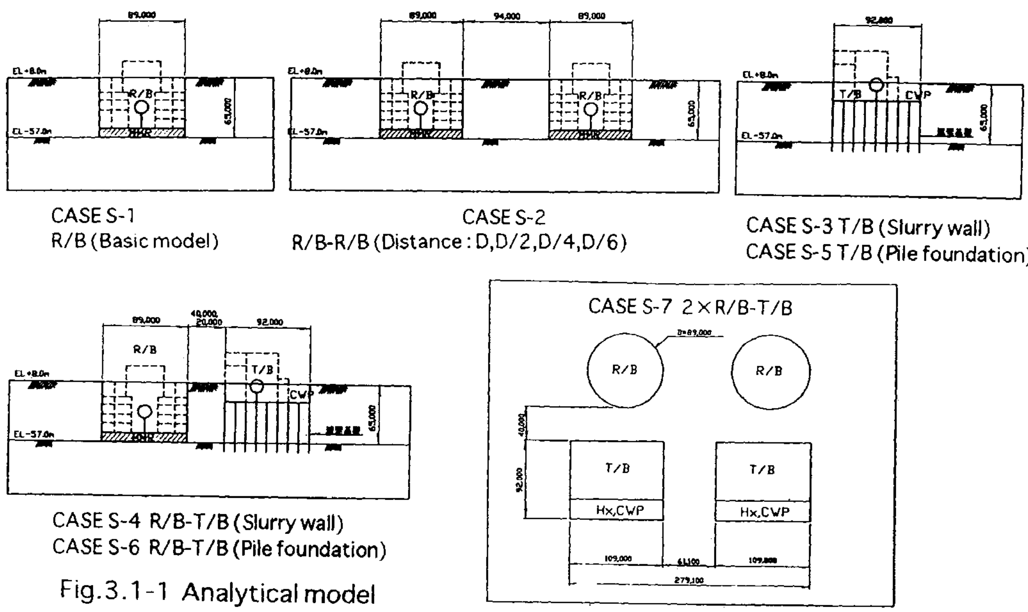


Fig.3.1-1 Analytical model

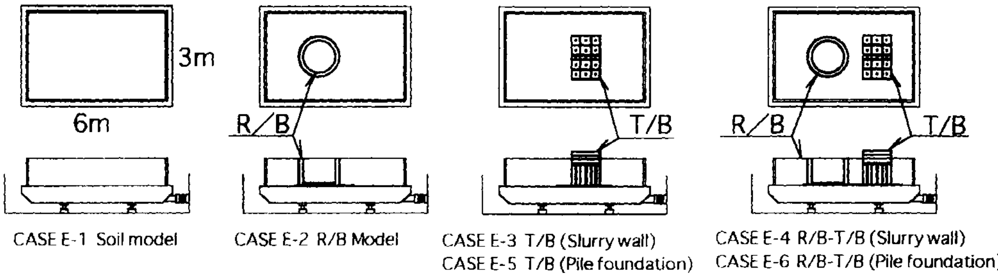
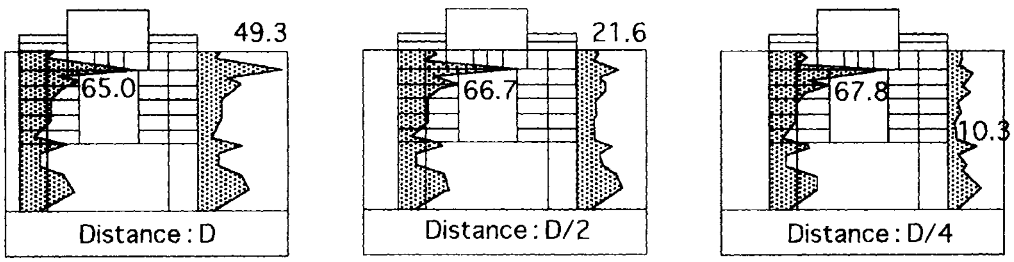


Fig.3.1-2 Experimental Model



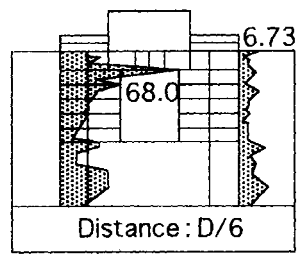
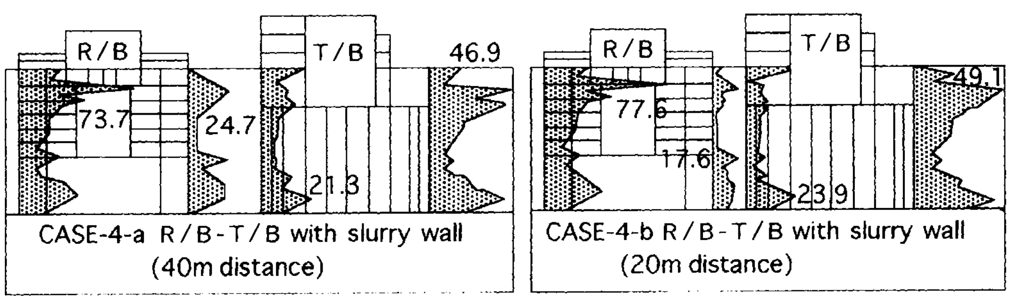


Fig.4.1-1 Parametric study of distance between R/Bs
(Maximum earth pressure : tf/m^2)



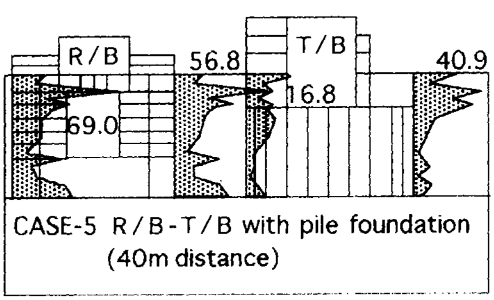
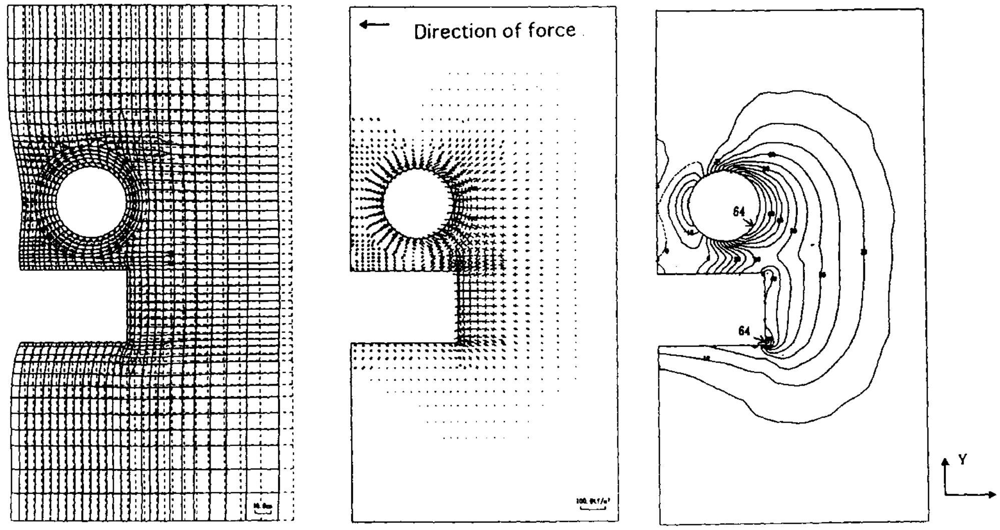
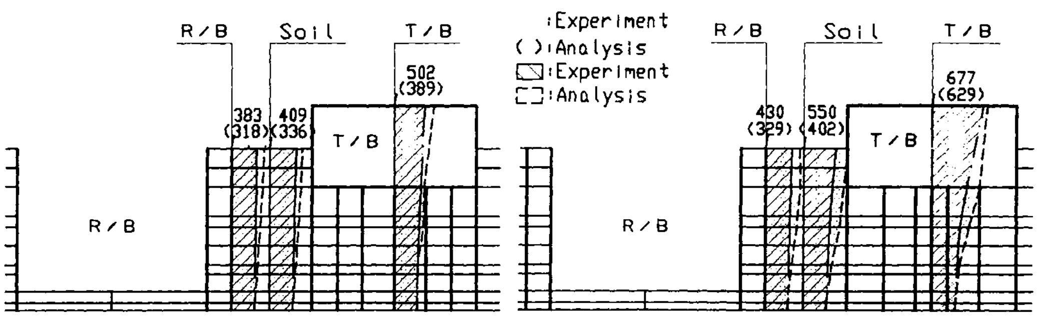


Fig.4.1-2 Earth pressure distribution influenced by the type of T/B foundation and distance between R/B-T/B



(a) Displacement (b) Principal stress (c) Contour of principal stress

Fig.4.1-3 Stress distribution in a horizontal plane (CASE S-7)
(unit : tf/m^2)



CASE E-4 CASE E-6

Fig.4.2-1 Maximum Acceleration with type of foundation
(unit : gal)

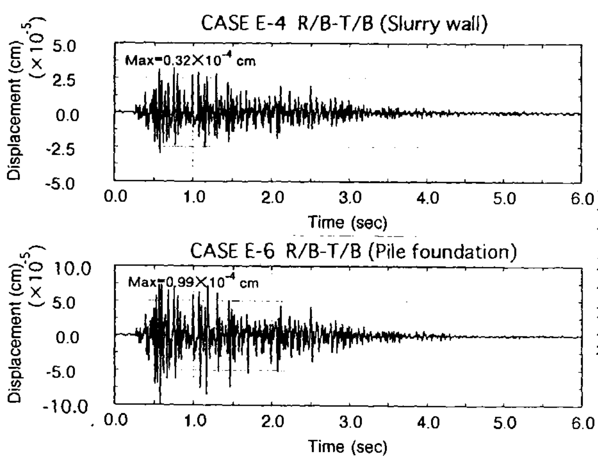
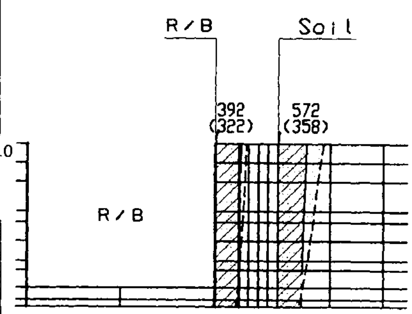


Fig.4.2-2 Relative displacement between R/B-T/B



CASE E-2

Fig.4.2-3 Maximum Acceleration of R/B (unit : gal)