Numerical simulation of the seismic responses for JPDR subjected to actual earthquakes

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ABSTRACT

Soil-Structure Interaction(SSI)analyses have been performed by utilizing CRAS code(developed in CRIEPI),FLUSH code and the seismic data observed on JPDR(Japan Power Demonstration Reactor of Japan Atomic Energy Research Institute(JAERI))to validate the analytical methods and numerical models currently adopted for seismic design.

Parametric analyses have also been conducted to examine the effects of the foundation embedment.

From the comparison of the numerical results with the observed ones,the numerical methods and models for SSI have been verified and it may be clarified that the foundation embedment plays an important role to reduce the seismic responses of an embedded structure due to earthquake motions.

1. Introduction

SSI studies have been performed on JPDR containment building by using the actual recorded earthquake input motions,and by evaluating SSI modeling and analysis through the comparison of calculated seismic responses against actual recorded earthquake data.

This paper documents the results of the JPDR SSI analyses using the CRAS code and FLUSH code and their comparison against measured data from observed earthquake.

Parametric analysis was also conducted to examine the effect of the foundation embedment.

This earthquake observation was undertaken jointly by JAERI and CRIEPI, taking adnantage of decommissioning the JPDR.

2. Description of JPDR structure and the Surrounding Ground

The JPDR structure(Fig.2-1)is buried nearly 1/3 of its total height in sand and sandy gravel consists of a containment vessel made of steel and inner concrete structure.The foundation mat is a reinforced concrete cylindrical caison of 20m in diameter. The total weight of the structure is about 1,300 tons.

Fig.2-2 shows the soil profile of the surrounding ground of JPDR obtained from the standard penetration test and seismic wave test. The ground,from surface to GL-14m, consists of a sand layer which has the maximum N-value of about 20, and from GL-14m to GL-17m, consists of a gravel layer which has the N-value of about 50. Below GL-17m the ground consists of shale whose N-value is more than 50(Ref.1,2).

3. Simulation Analysis

3-1 Numerical Model

JPDR and the surrounding ground are made into axi-symmetric FEM model for CRAS(105 solid elements 4 shell elements),and are made into 2-D FEM model(107 elements)for FLUSH. The rigid base of the model is at -24.5m below grade at which level G_1 measuring point was set.

To examine the effect of the foundation embedment against horizontal earthquake motion, the embedment depth was variated.

3-2 Seismic Data observed on JPDR (Ref.1,3)

The earthquake observations were performed during the period from June 1982 to September 1982.There were four observation points to monitor the earthquake response: G_1(GL,-24.5m)and G_2(GL,0.0m)for ground measurement, S_1,(GL,-12.5m,on the foundation concrete)and S_2(GL,8.4m, operating floor)for the structure. The 3-component acceleration time trace(NS,EW,and UD)was recorded at each measuring point(shown in Fig.2-1).

The earthquake data employed in the study are shown in Fig.3-1. The observation accelerogram G_1-NS (for horizontal),was used as the input motion to the numerical model.

4. Results

4-1 Seismic Responses of JPDR and the Surrounding Gruond due to Horizontal Earthquake Motion (by CRAS)

The calculated maximum horizontal acceleration responses of JPDR and the surrounding ground by CRAS code are compared with the observed ones as shown in Fig.4-1.

The amplification factors of the maximum acceleration of JPDR between the foundation(S_1)and the operation floor(S_2)are about 3.6 for the observed results, 2.7 for calculated ones. Between the base rock(G_1)and the ground surface(G_2)the amplitication factor are about 4.1 for observed results, and 4.6 for calculated ones. The calculated seismic responses agree well with the measured data in soils and at JPDR foundation.
However, the calculated peak acceleration at operation floor under-predicted the measured response by 10%. This may be due to the higher frequency effect of the actual building which was not included in the CRAS simulation.Also it could be due to the coupling effect from vertical motions which was not included in the analysis.

The calculated transfer functions(G_2/G_1 and S_2/G_1)by CRAS code are compared with the ones derived from the earthquake observation (OBS) and the theoretical ones by Multiple Refection Theory (M.R.) by Sawada (Ref.3)as shown in Fig.4-2, 4-3.

From these results, it is clearly seen that the calculated results are in satisfactory agreement with ones from earthquake data except nearing 6.0 Hz.

4-2 Comparison between CRAS and FLUSH

Fig.4-4 shows the transfer function of G_2/G_1, calculated by FLUSH compared with ones by CRAS.

Fig.4-5 shows the calculated effective shear strain (γeff) of JPDR and the Ground by FLUSH compared with ones by CRAS. These results agree well with each other.

In these simulation analyses, it was ascertained that CRAS code and FLUSH code are useful to estimate the seismic responses of the embedded structure due to earthquake motions.

4-3 The Effect of the Foundation Embedment (calculated by CRAS)

The calculated maximum acceleration responses of JPDR and the surrounding soil with variation in the embedment depth are shown in Fig. 4-6. It is clearly seen that the acceleration responses of the ground increase scarcely,but those of JPDR structure increase remarkably with the decrease of the embedded depth.

The maximum stress distributions of JPDR with variation in the embedment depth are shown in Fig.4-7.

From these results, it is clearly seen that the acceleration responses and the stresses(bending stress)of JPDR decrease with the increase of the embedment.

5. Conclusion

The main results obtained from the comparison between the numerical results using FEM models(CRAS model and FLUSH model)and ones of the earthquake observations, are summarized as follows.

(1) Good correlation are obtained for predominant frequencies at 4.0 Hz for the soil and 8.0 Hz for the structure due to horizontal earthqake motion.

(2) The calculated seismic responses agree well with the measured data in soil and at building foundation.

(3) The foundation embedment has significant effect in reducing the seismic responses of the structure.

(4) Both codes(CRAS and FLUSH)are useful to estimate the soil-structure interaction of embedded structure due to horizontal earthquake motion.

6. Acknowledgements

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7. Reference

(1) Iwatate,T. et al “Soil-Structure Interaction of JPDR” CRIEPI Rep. 383008 July, 1985

(2) Yoshida,Y. et al “Soil-Structure Interaction of JPDR (1) In-situ Test for static and Dynamic Properties of the Ground(in Japanese)”, July, 1983 CRIEPI Rep. 383001

(3) Sawada,Y. et al “Soil-Structure Interaction of JPDR (3) Investigation of Dynamic Characteristics based on Earthquake Observation (in Japanese)”, November, 1983 CRIEPI Rep. 383029

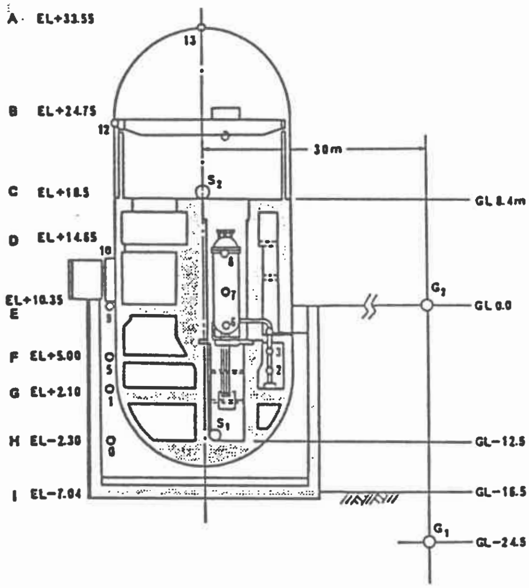

Fig.2-1 Facility Outline (Level Name)

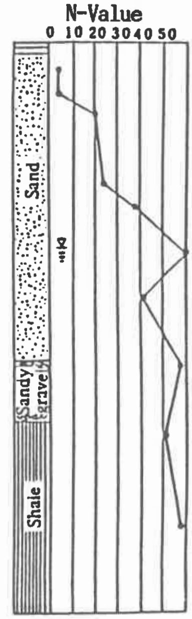

Fig.2-2
Standard Penetration Test Result
N-Value

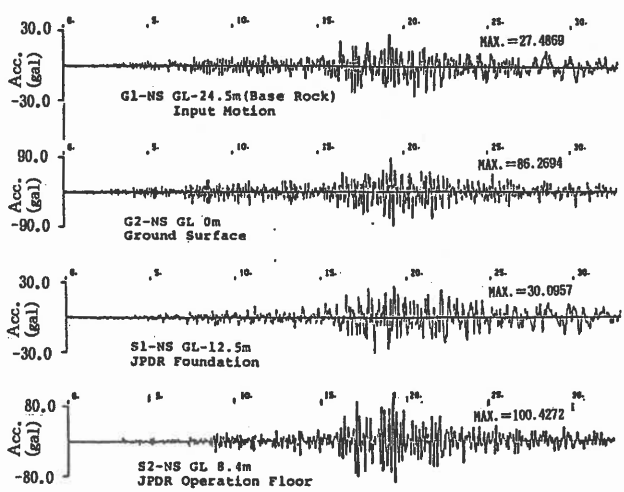

Fig.3-1 Observation Accelerogram

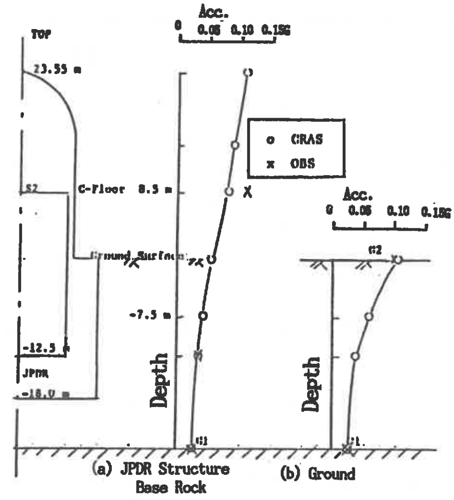

Fig.4-1 Maximum Horizontal Acceleration Responses of JPDR and The Surrounding Ground
(Comparison between Observed Results and Calculated Ones)

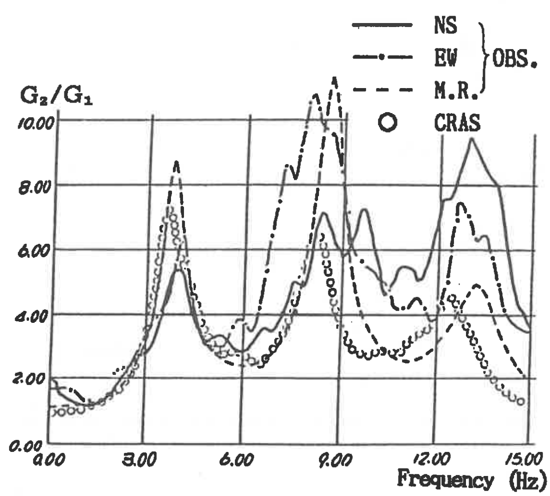

Fig.4-2 Comparison between Observed and Calculated Transfer Functions (G_2/G_1)

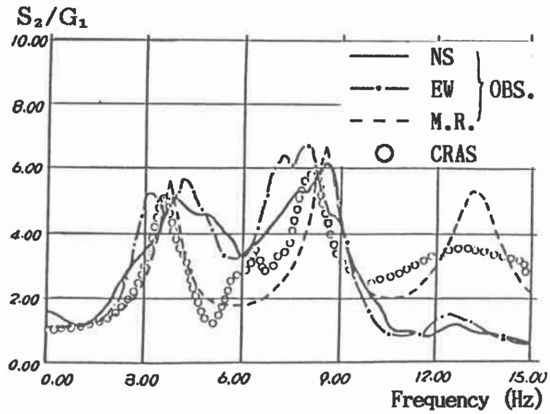

Fig.4-3 Comparison of Transfer Functions between Base Rock(G_1) and Operating Floor(S_2)

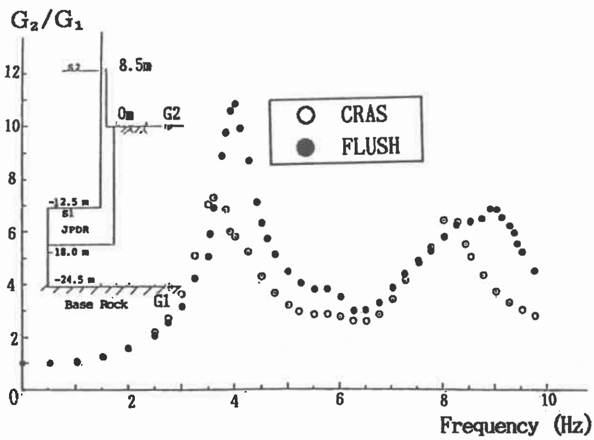

Fig.4-4 Transfer Functions between Base Rock and The Ground Surface(G_2/G_1) (Comparison between CRAS and FLUSH)

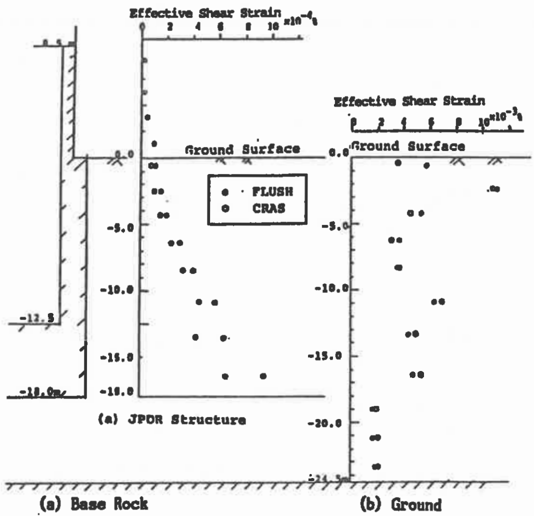

Fig.4-5 Shear Strain Distributions of JPDR Structure and The Ground (Comparison between CRAS and FLUSH)

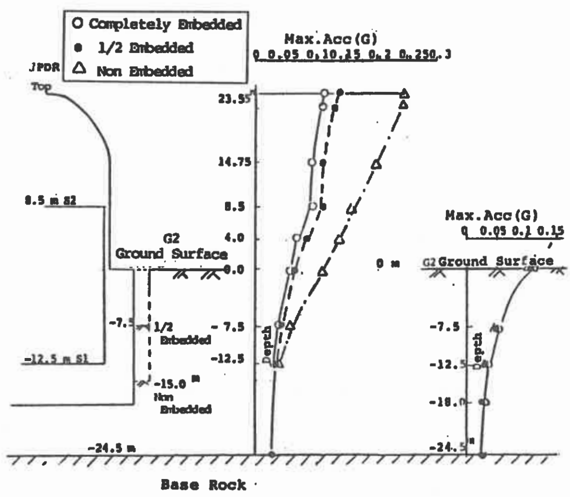

Fig.4-6 Calculated Maximum Acceleration Responses of JPDR and The Burounding Ground with Variation in The Embedment Depth(for Horizontal Motion)

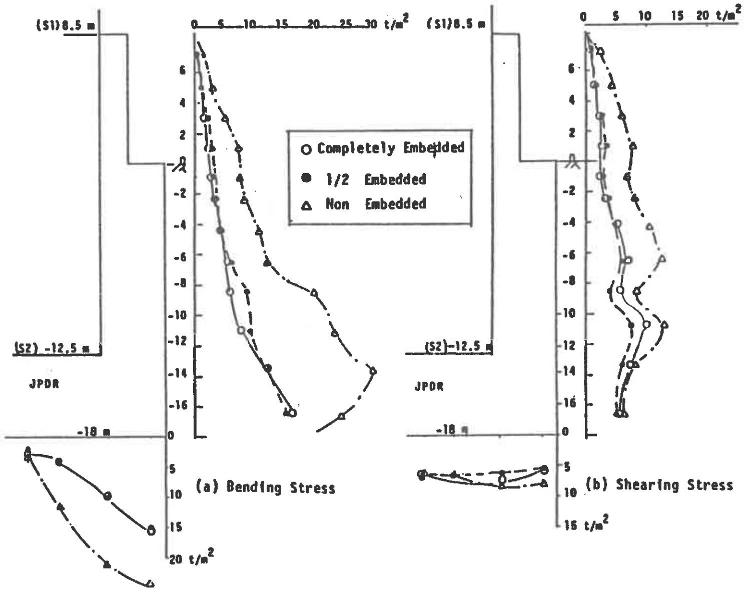

Fig.4-7 Maximum Stress Distributions of JPDR due to Horizontal Earthquake Motion with Variation in The Embedment Depth