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Influence on seismic response of base-isolated building by different phase spectrum of input wave

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ABSTRACT: In a seismic response analysis for nuclear facilities such as reactor building, simulated earthquake motion has been used as input ground motion. It is made using site-specific response spectrum and phase spectrum. There are two methods to determine the phase spectrum, one is using a phase spectrum of actual major earthquake and another is produce it by random process.

Under design level input, the ordinary seismic-resistant building responds almost linearly, though the response of base-isolated building shows a non-linear tendency based on the combination of isolator and damper. It is supposed for base-isolated building that the uncertainty of response under design level input would be increased compared with seismic-resistant building owing to its non-linear characteristics.

This paper examines the influence of the phase spectrum of input ground motion on the response of base-isolated building.

1 GENERATION OF SIMULATED EARTHQUAKE MOTION

In generating the simulated earthquake of the design basis earthquake S_2, the target spectrum which had the velocity level of 200 cm/s for slightly long-period domain and the acceleration level of 2,000 cm/s^2 for short-period domain in a response spectrum of 5% damping was employed(Kato,M.,1991).

For the phase spectrum of the simulated earthquake, phase spectra of following eight recorded earthquake motions are used

(1)La Union records on Mexico Earthquake(1985) NS, EW
(2) Taft records(1952) NS, EW
(3) Records at Hachinohe harbor on Tokachi-oki earthquake(1968) NS, EW
(4) El Centro records(1940) NS, EW

In addition, three motions with random phases and time dependent amplitude envelopes corresponding to Magnitude (M_J) 8.0 are generated. The simulated motion can be generated by an iterative procedure using superposition of sinusoidal waves. The agreement between the target spectrum and the response spectrum of the simulated motion can be improved by modifying an amplitude of spectrum according to the ratio of a calculated spectrum to a target spectrum. Fig. 1 shows the time histories of generated eleven acceleration waves. Fig. 2 shows an example of the agreement between the target spectrum and the spectrum of the generated motion in a response spectrum of 5% damping .

2 ANALYSYS CONDITIONS AND MODEL

An analysis model for seismic response of a base-isolated FBR plant is shown in Fig. 3. A single-stick lumped mass model with bending and shear stiffness is used for the superstructure.

Stiffness of seismic-resistant walls of reinforced concrete are evaluated by beam elements with bending and shear deformation, and the relation between shear deformation and shear force is modeled by the maximum point oriented tri-linear model to consider non-linear characteristics. Both the upper and lower basements are assumed to be rigid for out-of-plane direction.

The isolation story of building is modeled by a combination of laminated rubber bearings and steel dampers. Laminated rubber bearings are represented by a horizontal spring and vertical springs. Horizontal spring is concentrated to the center of the basement and its hysteresis characteristics has a tri-linear skeleton considering hardening of stiffness and effect of repeated deformation. Vertical springs of laminated rubber bearings are substituted to 19 springs distributed horizontally on the basement. The hysteresis characteristics of a vertical spring is modeled by a tri-linear skeleton that shows softening in the tension region and its response doesn't describe any loops. (Kato,M.,1993) These springs represent rotation of the isolation story and can evaluate the shift of the neutral axis caused by rocking of building.

Steel dampers are represented by a horizontal spring gathered to the center of the basement. They have perfect elasto-plastic hysteresis characteristics

Horizontal and rotational soil springs represent soil-structure interaction. Geometric non-linearity due to uplift is assumed for the rotational spring. The damping coefficient, however, is constant even if the basement is uplifted.

Two input levels for the seismic response are considered. One is the design level equal to S_2 and another is the seismic safety margin level equal to S_2 amplified by 2.

3 ANALYSIS RESULTS AND EVALUATION

3.1 Maximum Response of Superstructure

Fig. 4 shows the maximum acceleration response of the superstructure. From this figure, it is found that the coefficient of variation(COV) in the response obtained by the eleven input motions is about 0.1 for S_2 and 0.2 for $2\times S_2$.

The maximum response of the lowest seismic resistant wall on shear force-shear strain relation is shown in Fig. 5. COV of the maximum shear force is 0.15 for S_2 and 0.24 for $2\times S_2$.

3.2 Maximum Response of isolation Story of Building

Fig. 6 shows the maximum response of the isolation story. From this figure, it is found that COV in the response is roughly 0.15 for S_2 .

For $2\times S_2$ COV of the maximum response displacement of the isolation story is 0.07 and COV of the maximum response shear force is 0.2. The variations of seismic response obtained by using phase property of the actual earthquake records are larger than those obtained by random phases.

The seismic safety margin of the isolation story of the building which is designed to have a low center of gravity can be generally assessed in terms of horizontal displacement. Since variation of response at the seismic safety margin level ($2\times S_2$) is roughly half of that of design level (S_2), it is found that the seismic safety margin of base-isolated building is hardly affected by the phase of the input ground motion.

3.3 Floor Response Spectra

The floor response spectra at the reactor vessel supporting floor under S2 input is shown in Fig. 7. This figure shows that the floor response spectrum around the isolation frequency (1-2 seconds) varies so widely that COV becomes from 0.3 to 0.4. On the contrary, the variation in the short period range less than 0.2 seconds that is influential for equipments is similar to that of the maximum acceleration response of the building.

3.4 Consideration

Since the agreement between the target spectrum and spectrum obtained by simulated motion is verified in the 5% damping spectrum (see Fig. 2), COV of 0.15 for response under S2 is seemed to be large. An equivalent coefficient of viscous damping which is evaluated by the horizontal hysteresis loop of the isolation story is about 17% as shown in Fig. 8. Fig. 9(a) shows the acceleration response spectrum of 5% damping. COV of the spectrum is approximately 0.05, indicating good agreement with the target spectrum. Fig. 9(b) shows the acceleration response spectrum with an equivalent coefficient of viscous damping of 17%. The target spectrum of 17% damping is modified by 5% damping target spectrum. COV of the ratio of a target spectrum to the spectrum obtained simulated motion is roughly 0.1 in 17% damping. Since COV of 17% damping spectrum is nearly twice as much as COV of 5% damping spectrum, it is considered that the variation of seismic response of isolated building is caused by the variation of a high damping spectrum of input motion which is significant for isolation.

4 CONCLUSION

From the analysis of non-linear seismic response obtained by simulated input ground motions generated using eleven different phases, the following results are obtained.

(1) COV of the response during design level input shows a roughly 0.15.
COV in input motions with a response spectrum of 5% damping is roughly 0.05. COV in input motions with a response spectrum of 17% damping, which is equivalent viscous damping of the isolation system, is approximately 0.1.

(2) The variations of seismic response by phases of actual earthquake records is larger than those by random phases.

(3) The variation of the response in isolation story for the seismic safety margin level is roughly half of that for the design level input.

5 ACKNOWLEDGMENT

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REFERENCE

Kato, M. et al. 1991. *STUDY ON THE SEISMIC BASE-ISOLATED REACTOR BUILDING FOR DEMONSTRATION FBR PLANT IN JAPAN*. 11th SMiRT, Vol.K2

Kato, M. Watanabe, Y.,et al. 1993. *STUDY ON ULTIMATE BEHAVIOR OF BASE ISOLATED REACTOR BUILDING. 12th SMiRT*, Vol.K2

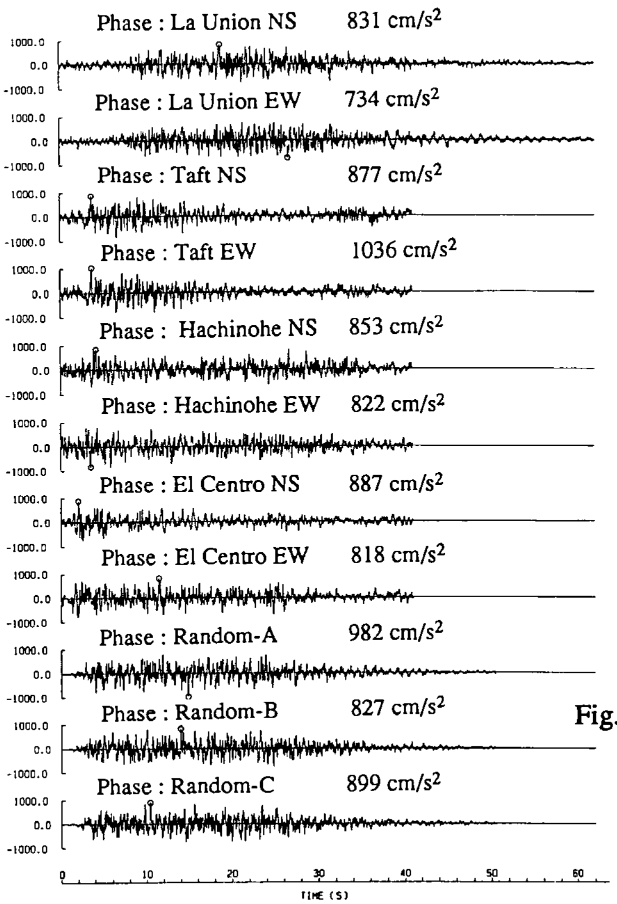


Fig. 1 Time Histories of generated eleven acceleration waves

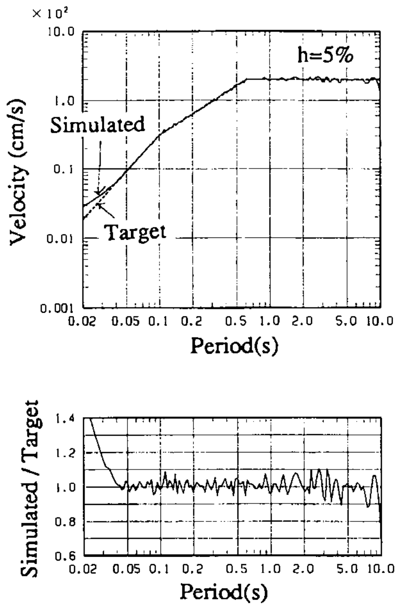


Fig. 2 Target Spectrum and Spectrum of Generated Motionin in 5% damping Response Spectrum(Taft NS)

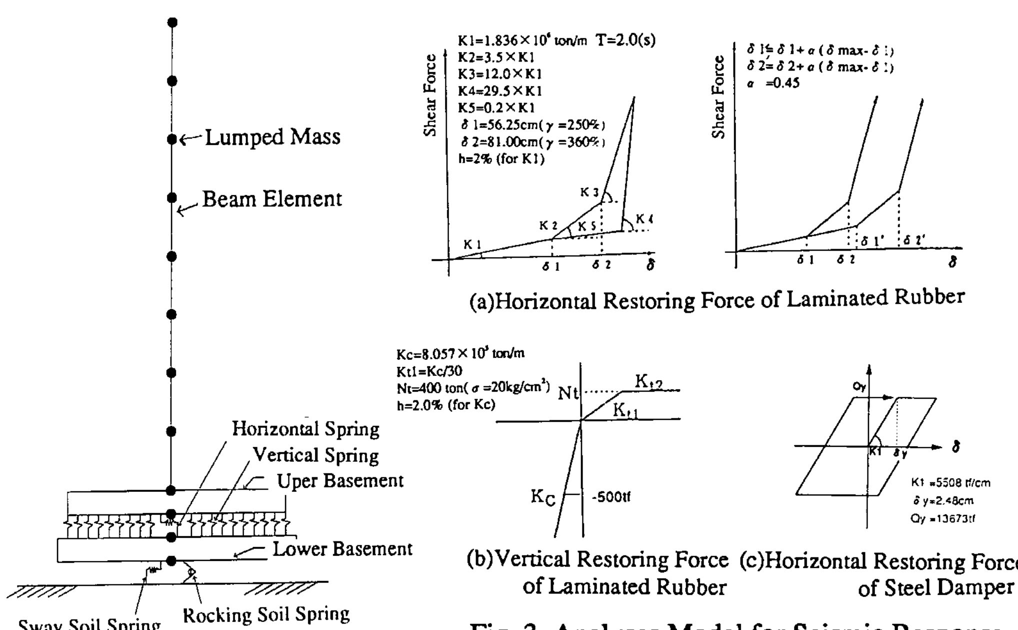
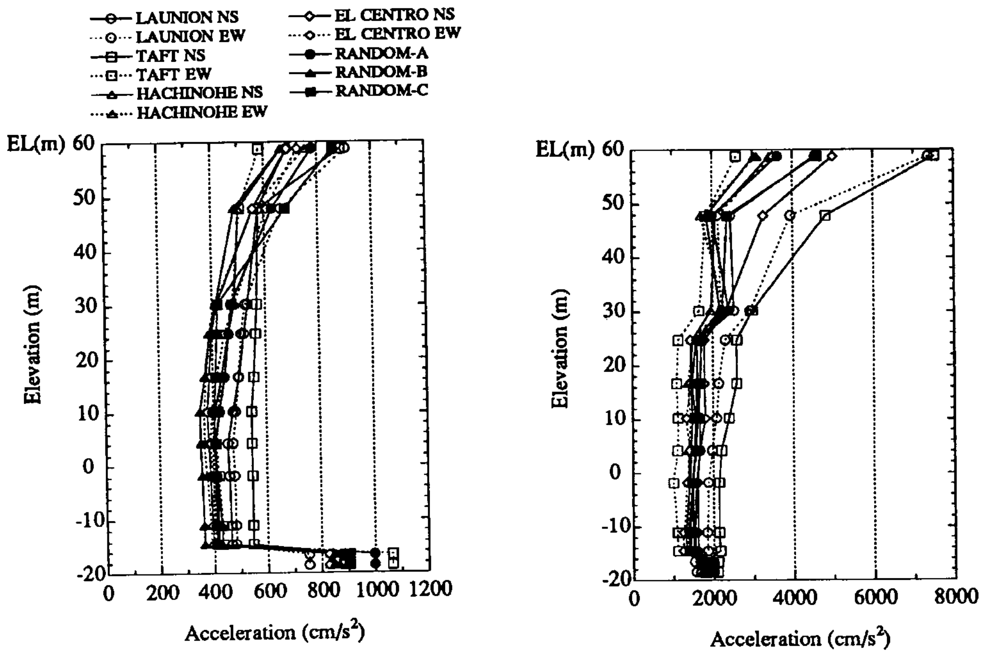


Fig. 3 Analyses Model for Seismic Response



(a) Response for S2

(b) Response for 2xS2

Fig. 4 Maximum Acceleration Response of Superstructure

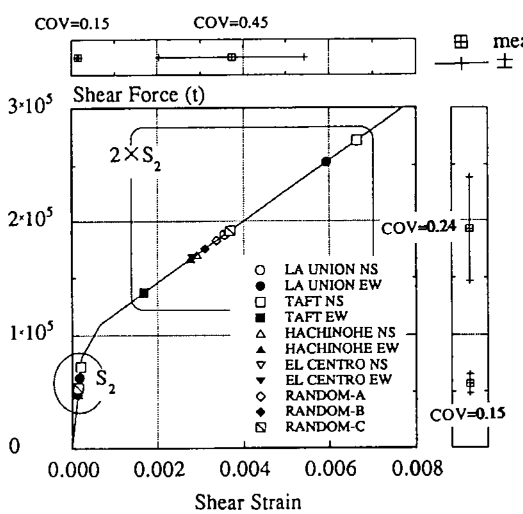


Fig. 5 Maximum Response of Superstructure

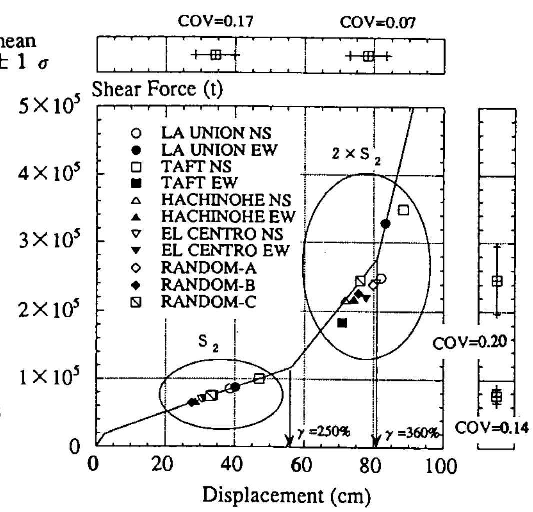
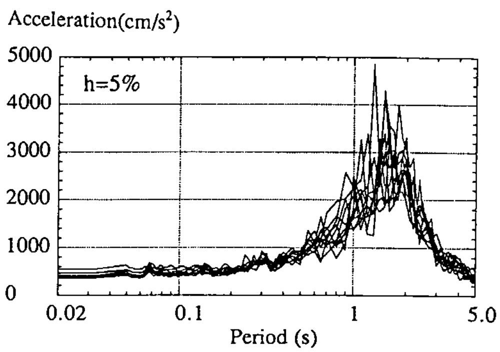
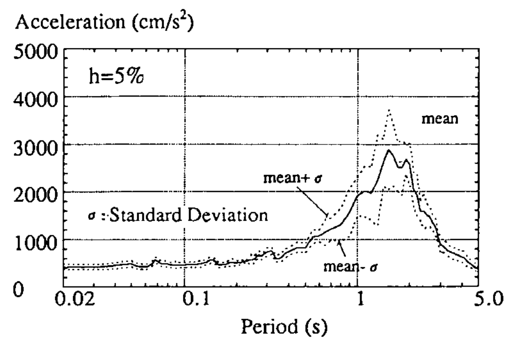


Fig. 6 Maximum Response of Isolation Story



(a) FRS of 11 input motions



(b) Variation of FRS

Fig. 7 Floor Response Spectra at Reactor Vessel Supporting Floor for S2

$$h_{eq} = \frac{\Delta W}{2\pi W} + \frac{h_0\sqrt{K1}}{\sqrt{K_{eq}}} \fallingdotseq 17\%$$

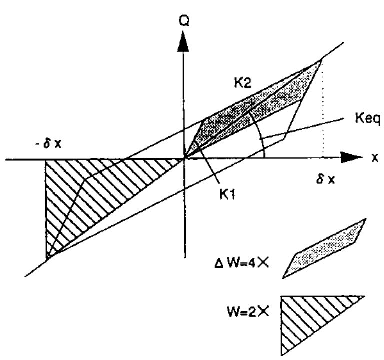
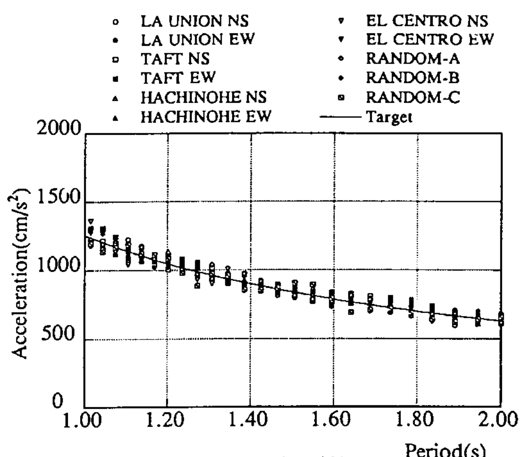
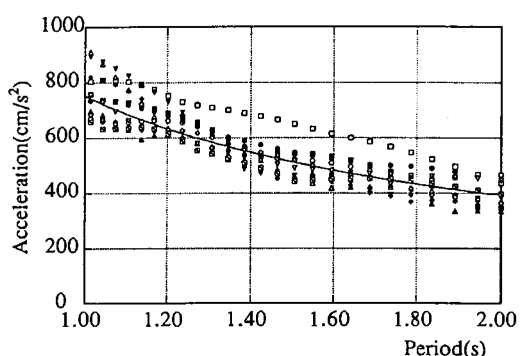


Fig. 8 Evaluation of Equivalent Damping Ratio



(a) h=5%



(b) h=17%

Fig. 9 Response Spectra for Slightly Long Periods