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Comprehensive evaluation of verification tests for seismic analysis codes. Part 5 : applicability of proposed evaluation method of restoring force characteristics

Kambayashi A.[(1)], **Yamamoto M.**[(2)], **Kitada Y.**[(3)], **Akino K.**[(3)], **Takiguchi K.**[(4)]

(1) Takenaka Corporation, Japan

(2) Obayashi Corporation, Japan

(3) Nuclear Power Engineering Corporation, Japan

(4) Tokyo Institute of Technology, Japan

ABSTRACT: In this paper, the applicability of three methods to the actual plant was verified. The detailed method and the simplified method were introduced in PART 4 and these method consider the dynamic effect in the skeleton curve for the seismic response analysis. Another method is conventional design method. As the analytical results, it was found that there was no difference in the analytical results of the first two methods. The results of the conventional method were larger than the others. In conclusion, the simplified method was recommended.

1. INTRODUCTION

NUPEC(Nuclear Power Engineering Center) conducted 'Tests on Dynamic Restoring Force' and 'Elasto-plastic Tests of Reactor Buildings'. These tests included the cyclic loading tests of a typical reinforced concrete shear wall of the reactor building. Based on these test results, the dynamic effect of restoring force characteristics were evaluated. In Part 4, the method of skeleton curve and hysteresis characteristics were evaluated. Based on the analytical result with these method for a simplified reactor building model and the simulation of the specimen of shaking table test, the skeleton simplified method which considered the influence of the strain rate was proposed. As a hysteresis characteristics, conventional method of the maximum point-oriented method was proposed.

This paper reports the applicability of the proposed method to the actual nuclear reactor buildings. The seismic response analyses were performed for two types of reactor building. The results were compared with the results obtained from the skeleton detail method and conventional design method.

2. ANALYTICAL MODEL

2.1 Proposed method of skeleton curve considering dynamic effect

In PART 4, the evaluation method of skeleton curve and hysteresis characteristics were proposed. The formula of proportional increase rate of skeleton curve was established regarding the relationships of the average shear strain rate. The formula is shown below.

$$\alpha = \left(\frac{\bar{\dot{\gamma}}}{\dot{\gamma}_0} \right)^{0.02} \quad \text{.............(1)}$$

where α : increase rate of skeleton, $\dot{\gamma}$:average shear strain rate, $\dot{\gamma}_0$:average shear strain rate equal to static test.

The maximum point-oriented hysteresis is used for the hysteresis loop, which is used in the design of actual nuclear plant.

2.2 Skeleton detailed method, skeleton simplified method and conventional design method

In PART 4, two types of the seismic response analysis method are studied. One is the skeleton detailed method in which the skeleton curve is changed with the maximum value of shear strain rate at each half loop. The other one is the skeleton simplified method in which the skeleton curve is changed when the response analysis is finished. And the calculation is repeated until the skeleton curve is converged. Although the skeleton curve is changed considering dynamic effect in these method, that is not changed due to shear strain rate in the conventional design method.

2.3 Analytical model and parameters

The actual BWR and PWR types reactor buildings were analyzed. Fig.1 and Fig.2 shows the configurations. Shear wave velocity of the ground(Vs) is 1000m/sec for the BWR-type building, and 1500m/sec for the PWR-type building . Fig.3 and Fig.4 show the analytical model for BWR and PWR.

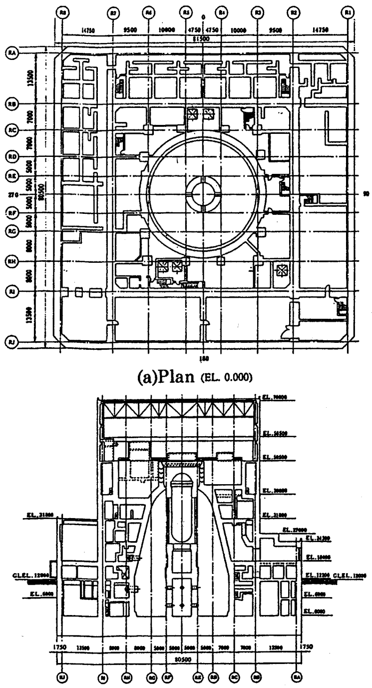
Artificial seismic motion of S2 for designing nuclear power plants in Japan was used as input motion. The time history and response spectra of input seismic motion are shown in Fig. 5 and Fig. 6. Two levels of input motion, 1.0 time and 1.5 time of the maximum acceleration of the original wave were studied. The analysis cases are shown in Table 1.

3. CALCULATION RESULTS

The increase rate of skeleton curve α in the skeleton simplified method was about 1.2 in case of the large response(case-5,11). In the skeleton simplified method, α was adjusted only twice in the case 5, while in another case, it was adjusted once.

The comparison of the maximum response acceleration, shear force and shear strain, for the BWR type reactor building are shown in Figs. 7 and 8 in the input levels of 1.0×S2 and 1.5×S2, and for the PWR type reactor building, in Figs 9 in the input levels of 1.5×S2. There was no difference on the results with the proposed methods (case-1,2,4,5,7,8) and with the conventional design method (case-3,6,9) in the maximum response of accelerations and the maximum response of shear stress.

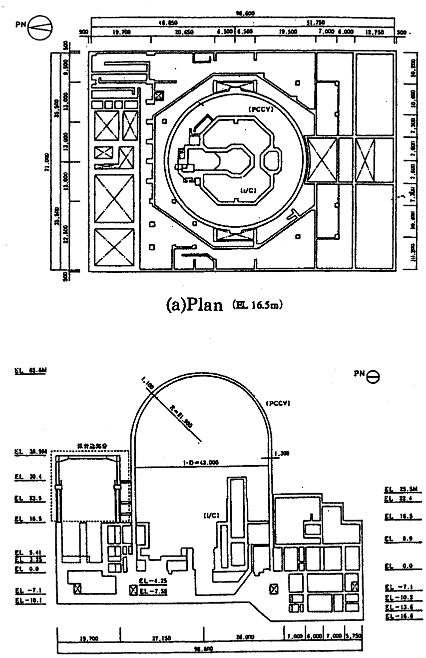
However, as for the maximum response of shear strain, the result which conventional design method showed the tendency to become bigger than the one by the proposed method.



(a)Plan (EL. 0.000)

(b)Section

Fig.1 Model for BWR type building



(a)Plan (EL 16.5m)

(b)Section

Fig.2 Model for PWR type building

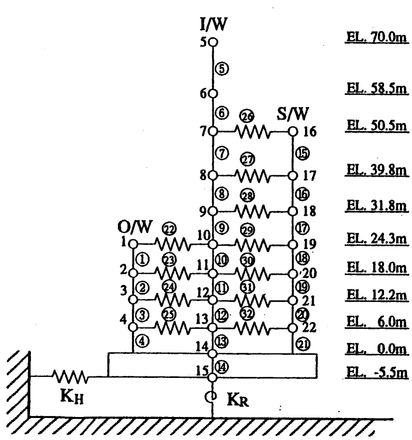


Fig.3 Analysis model of BWR type building

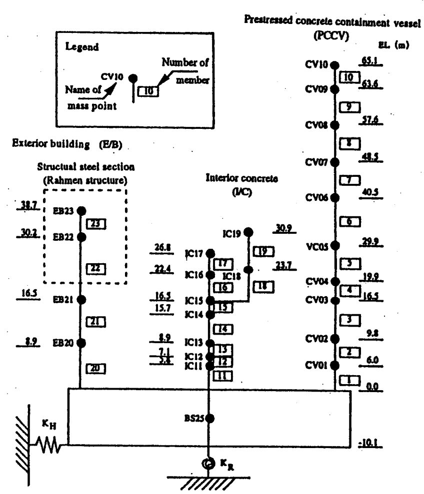


Fig.4 Analysis model of PWR type building

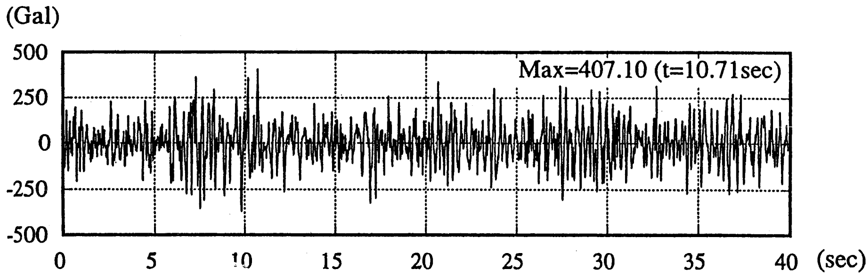


Fig.5 Acceleration time history of input motion

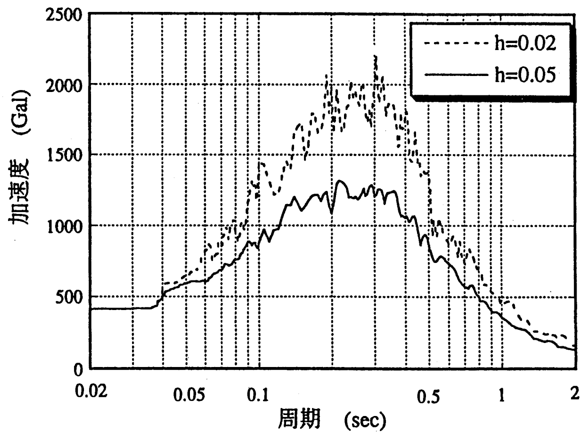
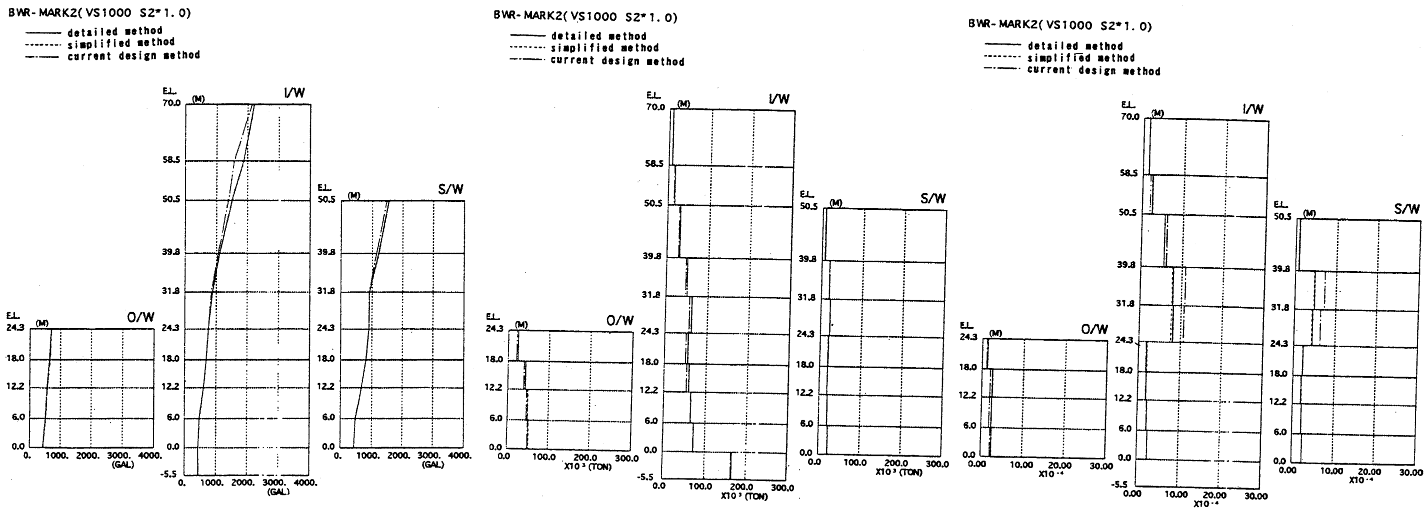


Fig.6 Response spectra of input motion

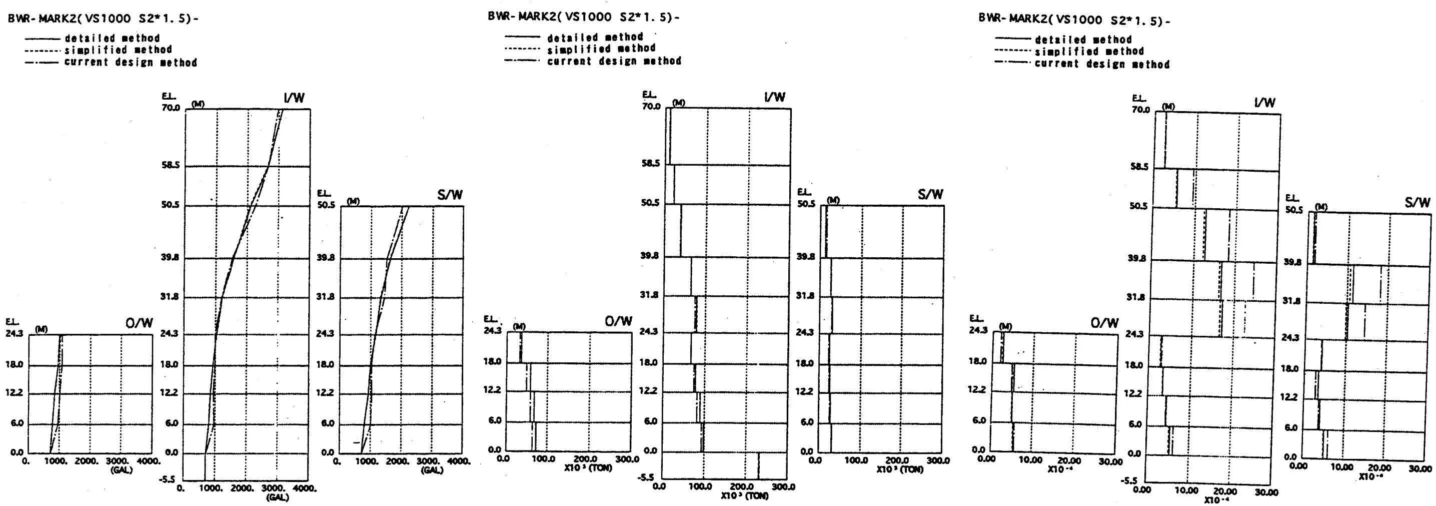
Table 1 Analysis cases for review of skeleton curve

Model	Analysis case	Shear wave velocity of the ground VS(m/s)	Input seismic motions and input level	Skeleton curve		
				detailed	simplified	conventional
BWR	case-1	1000	1.0×S2	○		
	case-2	1000	1.0×S2		○	
	case-3	1000	1.0×S2			○
	case-4	1000	1.5×S2	○		
	case-5	1000	1.5×S2		○	
	case-6	1000	1.5×S2			○
PWR	case-7	1500	1.0×S2	○		
	case-8	1500	1.0×S2		○	
	case-9	1500	1.0×S2			○
	case-10	1500	1.5×S2	○		
	case-11	1500	1.5×S2		○	
	case-12	1500	1.5×S2			○



(a)acceleration (b)shear stress (c)shear strain

Fig.7 Comparison of maximum response (BWR S2×1.0)

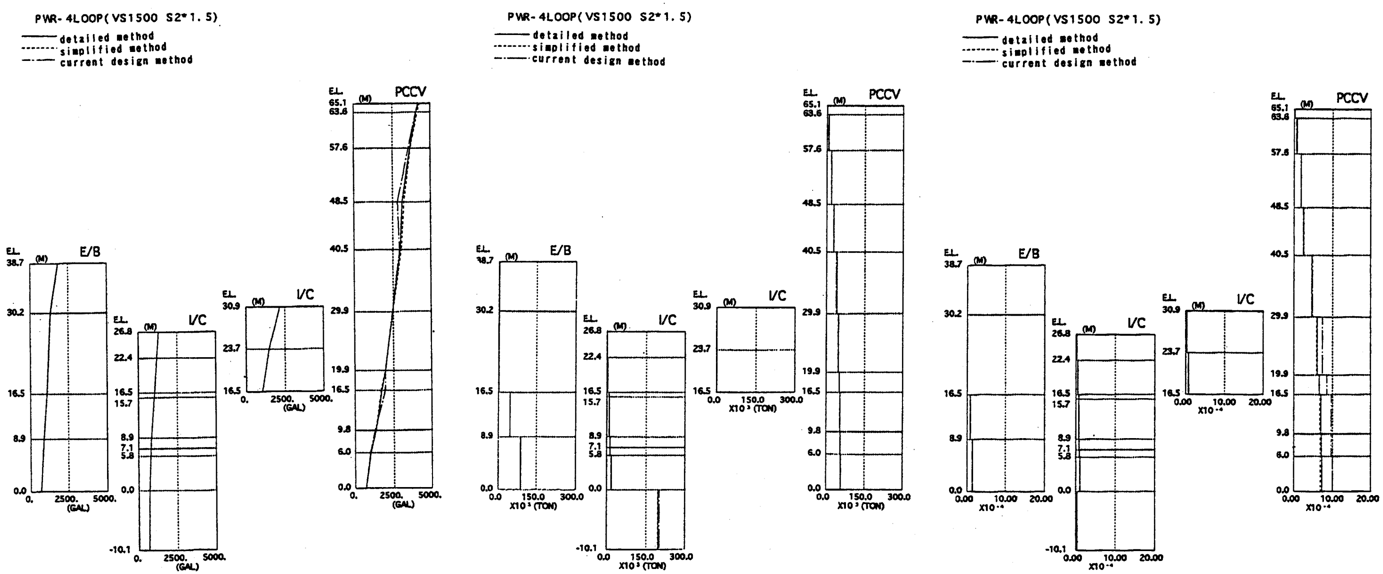


(a)acceleration

(b)shear stress

(c)shear strain

Fig.8 Comparison of maximum response (BWR S2×1.5)



(a)acceleration (b)shear stress (c)shear strain

Fig.9 Comparison of maximum response (PWR S2×1.5)

4. CONCLUSION

In PART 4, as the seismic response analysis method considering a dynamic effect in the skeleton curve, two types of method are proposed. One is the skeleton detailed method evaluate the dynamic effect of the test results as correct as possible. The other is the skeleton simplified method which can evaluate dynamic effect with less computational effort.

The response analysis of actual nuclear reactor plant buildings were performed using both proposed methods (the skeleton detail method and the skeleton simplified method) and the results were compared with the results obtained from conventional method.

Since the skeleton simplified method was able to evaluate a dynamic effect sufficiently and more easily than the skeleton detailed method, the skeleton simplified method was recommended as a practical method of a nonlinear response analysis for nuclear reactor buildings.

5. ACKNOWLEDGEMENTS

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REFERENCES

1.NUREG/CR-6241 1994. *Technical Guidelines for Aseismic Design of Nuclear Power Plants.* Translation of JEAG 4601-1987