Effect of Structure-Anchor-Component Interaction on the Safety-related Component for Nuclear Power Plants

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1. Introduction

Many components are attached to major structures by a bolting and welding in nuclear power plants. In the case of a components with well-designed embedded headed studs, the behavior of the structure and components is considered as rigid. The floor response on the floor where the equipment is located is used as the input load for the seismic response analysis or experiment of the components.

However, a damage to the anchorage of the components may occur due to external loads such as vibration and earthquake, and the anchorage damage may transmit a load that was not considered in design to the components.

In order to evaluate the accurate seismic performance of the equipment anchored to the structure, it is necessary to study the interaction between the structure and the components.

In this study, a shaking table test was performed to analyze the structure-anchor-components interaction (SACI).

2. Test specimens and input load

The shear wall structure corresponding to the auxiliary building and the reinforced concrete mass corresponding to the CCW surge tank were manufactured for the SACI test.

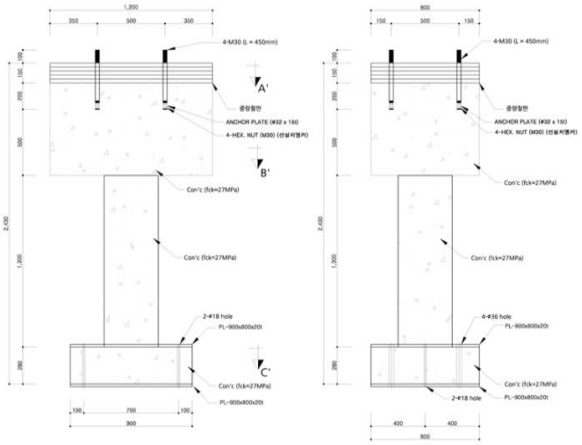
2.1 Test specimens

The specifications of the test specimen (Unit under test, UUT) are shown in Table I.

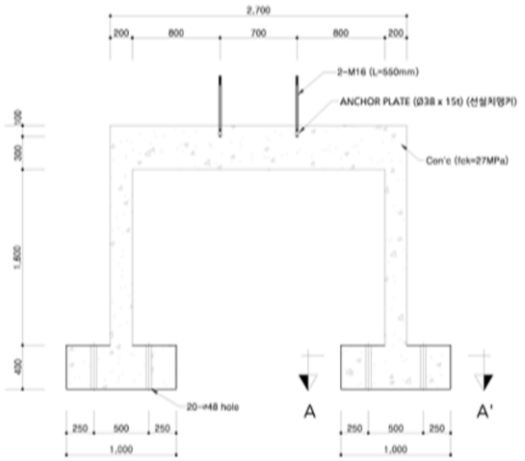
Table I: Information of test specimens

UUT No.	Specimen	Dimensions, (mm)			Weight (kg)
		Width	Height	Length	
UUT1	Component	1 200	2 430	800	2,801*
UUT2					2,802*
UUT3	Structure	3 000	2 000	2 000	16,000
UUT4		3 500	2 400	2 500	10,000

* The weight of 4 steel masses of 300 kg is not included.



(a) component



(b) structure

Fig. 1. Test specimens

Shear wall structures (UUT3, UUT4) were manufactured with reinforced concrete shear walls in consideration of the natural frequency and the structural system of the auxiliary building.

UUTs 1 and 2 were made of concrete mass considering the natural frequency of the CCW surge tank.

Anchor bolts were designed by "Concrete Anchor Design Criteria" [1] so that they can be destroyed under the maximum load of the shaking table.

M16 anchor bolts were embedded and installed in the structure slab so that it could be combined with the component. The embedding depth was set to 100 mm.

2.2 Test procedure

In order to analyze the seismic response of the component according to the SACI, a shaking table test was performed.

In this study, three tests were performed. The first test is a resonance search experiment to confirm the dynamic characteristics of structures and component, the second test is a shaking table test for each structure and component that does not consider SACI, and the SACI was considered in third test.

2.3 Input load

As shown in Figure 2, the required response spectrum (RRS) for the seismic simulation test was used in one direction with increasing the excitation force from 0.1g of zero period acceleration (ZPA).

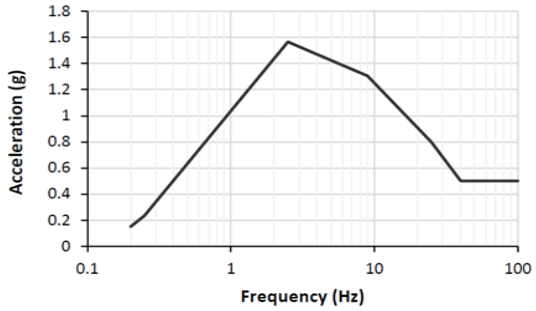


Fig. 2. Input load for shaking table test of structure

3. Test results

3.1 Without SACI

The figure below shows the acceleration response of the UUT2 mass body using FRS of the UUT4 structure. The acceleration response of A4X was amplified about 11 Hz, which is the natural frequency of the component. The RRS of figure 3 is the floor response spectrum of structure (UUT4).

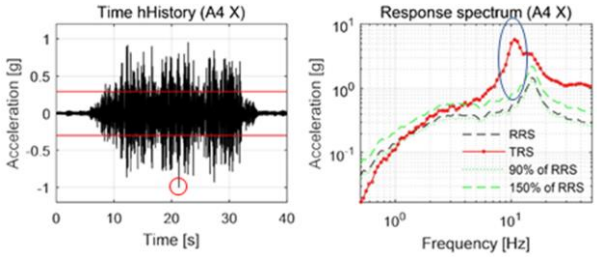
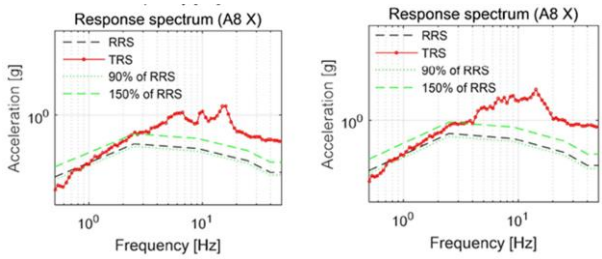


Fig. 3. Acceleration response without SACI (UUT4, ZPA=0.1g)

3.1 With SACI

The figure 4 shows the acceleration response spectrum at the top of the mass with SACI. The response peaks occurred near the natural frequencies of component and structures.

The maximum acceleration of the component using the floor response acceleration of the structure (UUT4) increased about 10 times compared to the ZPA. But the maximum acceleration of the component considering the SACI increased about 3 times compared to the ZPA.



(a) ZPA = 0.1 g (b) ZPA = 0.2 g

Fig. 4. Spectral acceleration with SACI (UUT4)

The response of the component which is anchored in structure is determined by the natural frequency ratio and the mass ratio between structure and component.

Therefore, in order to accurately analyze the earthquake response of the component, it is necessary to perform the earthquake response analysis by considering SACI.

4. Conclusions

In the seismic response analysis of the component, the floor response of the structure has been used as the input load by assuming that the behavior of the structure and the component was fixed. However, according to this experiment, this method cannot derive a realistic seismic response evaluation result of component. In particular, damage to the bolts makes it impossible to fully rigid behavior between the structure and component.

Therefore, it is judged that accurate seismic risk assessment of nuclear power plants can be derived by considering the bolt behavior.

5. Acknowledgement

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REFERENCES

[1] Korean Design Standard. (2016). “Concrete Anchor Design Criteria.” Ministry of Land, Infrastructure and Transport.