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A Seismic Isolation Device Test for the evaluation of Performance Criteria of Seismic Isolated NPPs

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1. Introduction

Seismic safety of NPP is one of the most important issues in a nuclear field after great east Japan earthquake in 2011. For the improvement of seismic safety of nuclear power plant, a seismic isolation is the easiest solution for increasing the seismic safety. Otherwise, the application of seismic isolation devices for nuclear power plants doesn't make the seismic risk of NPP increases always. According to the applying seismic isolation systems in NPPs, an acceleration response can be decreased but the relative displacement might be increased. Also the performance of isolation system is one of the most important parts of application of isolation system

In this study, seismic isolation device tests were performed for the evaluation of performance criteria of isolation system. There are two kinds of tests were performed as below;

1. Basic mechanical property test
2. Dynamic performance test

2. Performance criteria of seismic isolation system

Now US NRC preparing a NUREG report for 'Technical Considerations for Seismic isolation of Nuclear Fascilities'. A NUREG report provided one of very important concept for performance criteria as shown in Figure 1. And NUREG proposed that the mechanical properties of the isolation system should not vary over the lifespan of the structure by more than ±20% from the best-estimate values.

	Isolation system	
Ground motion levels	**Isolation unit and system design and performance criteria**	**Approach to demonstrating acceptable performance of isolator unit**
GMRS+[2] The envelope of the RG1.208 GMRS and the minimum foundation input motion[3] for each spectral frequency	No long-term change in mechanical properties. 100% confidence of the isolation system surviving without damage when subjected to the mean displacement of the isolator system under the GMRS+ loading.	Production testing must be performed on each isolator for the mean system displacement under the GMRS+ loading level and corresponding axial force.
EDB[4]GMRS The envelope of the ground motion amplitude with a mean annual frequency of exceedance of $1x10^{-5}$ and 167% of the GMRS+ spectral amplitude	90% confidence of each isolator and the isolation system surviving without loss of gravity-load capacity at the mean displacement under EDB loading.	Prototype testing must be performed on a sufficient number of isolators at the CHS[5] displacement and the corresponding axial force to demonstrate acceptable performance with 90% confidence. Limited isolator unit damage is acceptable but load-carrying capacity must be maintained.

Figure 1. Performance criteria of isolation bearing

3. Basic Mechanical Property Test

For the evaluation of the variation of mechanical properties for lead rubber bearing, scale model LRBs were manufactured. A drawing and manufactured LRBs are shown in Figure 2.

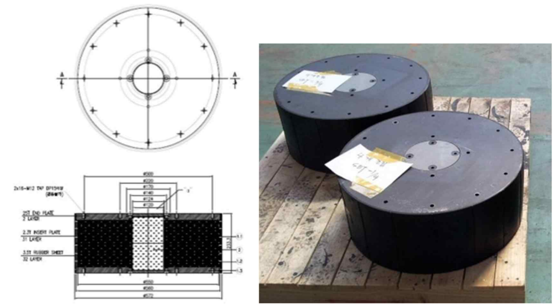


Figure 2. Drawing and LRB for Mechanical property test

A basic property tests were performed for all 20 specimens. Test results are shown in Figure 3 and 4. As shown in Figure 3 and 4, mechanical properties of all 20 specimens were not many differences but in the case of compare to the target properties, the variation is not so negligible.

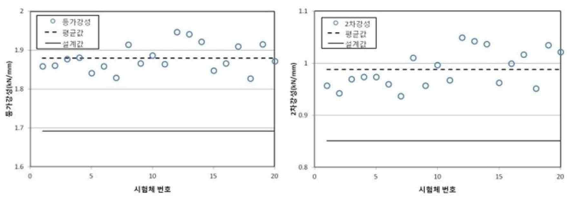


Figure 3. The variation of effective stiffness and 2ndary stiffness of all LRB specimens

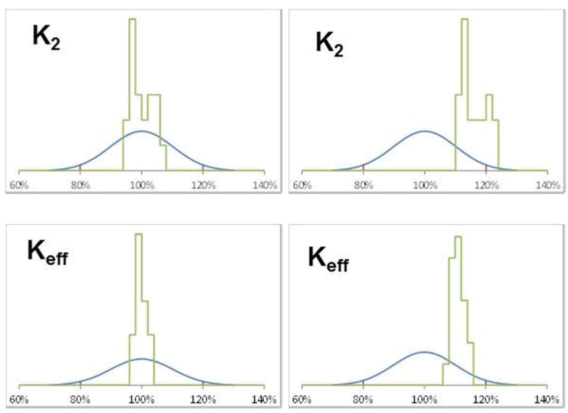


Figure 4. The distribution of mechanical properties for LRB specimens

4. Dynamic Performance Test

In general, mechanical property tests are performed in the static speed situation. But in the case of earthquake isolation bearing must move dynamically. So, the dynamic property should be considered for performance criteria of isolation bearing. For the performing a dynamic property test, an isolation system which combined 4 LRB specimens as shown in Figure 5 was prepared.

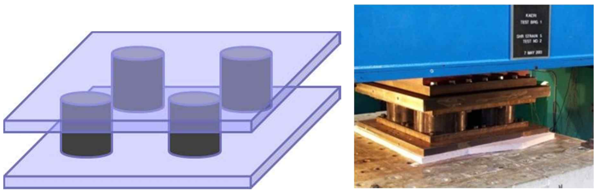
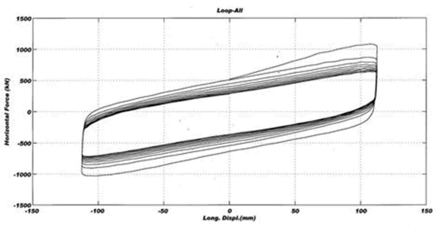
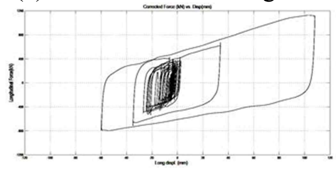


Figure 5. An isolation system for performing a dynamic test

In the case of 100% shear strain, harmonic loading case and earthquake loading case were compared and shown in Figure 6. As shown in Figure 6, a shape of displacement-force hysteresis loop was little different and a damping of earthquake input case are bigger than that of harmonic loading condition.



(a) A harmonic loading case



(b) An earthquake loading case

Figure 6. Compare the hysteresis loop of harmonic loading and earthquake loading cases

The results of static loading and dynamic loading case were compared in Figure 7. As shown in Figure 7, the scragging effect of dynamic test is bigger than that of static test. But, the hysteresis of over 3rd loop, static and dynamic cases are similar results.

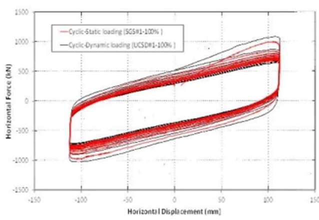


Figure 7. Compare the hysteretic results of static and dynamic harmonic loading test

The tests of one and two dimensional earthquake loading are compared in Figure 8. As shown in the Figure 8, in the case of two dimensional earthquake input, bi-linear behavior is not much clear compare to one dimensional loading condition. All one and two dimensional earthquake loading cases according to shear strain level are shown in Figure 9. As shown in Figure 9, load-displacement relations are slightly different according to loading condition. The response results of dynamic and static loading case and one and two dimensional loading conditions are little different in this study, the structural behavior should be examined.

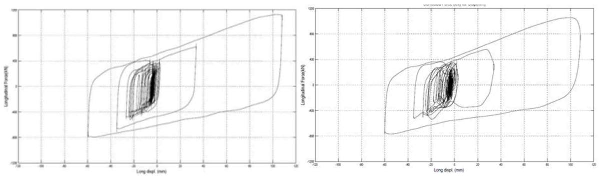


Figure 8. The hysteretic loop of one and two dimensional loading cases

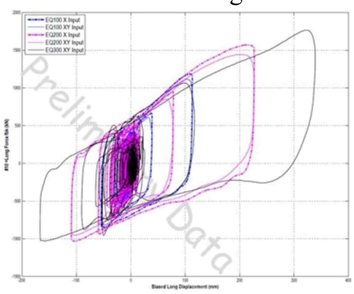


Figure 9. One and two dimensional earthquake loading cases according to shear strain level

5. Conclusions

In this study, seismic isolation device tests were performed for the evaluation of performance criteria of isolation system. Through this test, it can be recognized that in the case of considering a mechanical property test, dynamic and multi degree of loading conditions should be determined. But these differences should be examined how much affect to the global structural behavior.

ACKNOWLEDGEMENT

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