# Effect of Angles against the Ground on Seismic Assessment of a Dry Storage Facility

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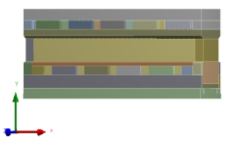
## 1. Introduction

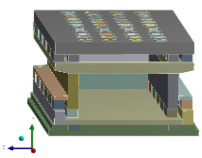
The spent nuclear fuel (SNF) contains long half-life fission products and most of radioactive nuclei are exposed to high temperature and radiations for a long time. As SNF wet storage facilities in nuclear power plants are saturated, it is anticipated that the application of dry storage facilities will increase because of its ease of space expansion [1]. Also, since frequency of earthquakes is increasing such as 683 times from 2014 to 2018, the interest of structural integrity on nuclear facilities as well as reactor containments [2] are growing. Moreover, among the top 3, two major earthquakes of magnitude 4.1M and 3.8M occurred near Wolsung site. The present study is to address comparative seismic assessments of a dry storage facility. In particular, 18 initial conditions were set taking into account different angles against the ground and acceleration scales of the earthquake. Both modal and response spectrum analyses were performed, from which vulnerable regions and conditions were derived through comparison of calculated strains and stresses.

## 2. Analysis Model and Conditions

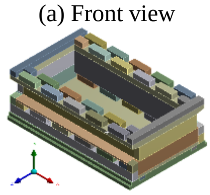
Fig. 1 depicts schematics of the dry storage facility [3]. Upper and lower airflow channels for cooling as well as circular plugs on the top for sealing a passing way of SNFs storage were modeled.



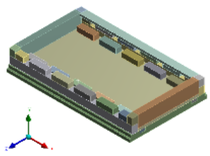
(a) Front view



(b) Side view



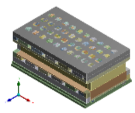
(c) Upper airflow cutaway view



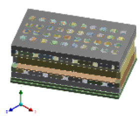
(d) Lower airflow cutaway view

Fig. 1. Schematics of the facility

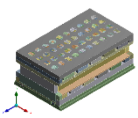
Fig. 2 represents angles between the facility and the ground, and Table 1 summarizes the angles and peak ground accelerations (PGAs) considered in this study. An operating basis earthquake (OBE; 0.1g), a safe shutdown earthquake (SSE; 0.2g) and a Wolsung's design basis earthquake (DBE; 0.3g) were referred [4, 5]. Further, according to the NUREG-1864 [6] and ASCE / SEI 4-16 [7], 0.4g ~ 0.6g were assumed as beyond design basis earthquake (BDBE) conditions.



(a) 0° model



(b) 30° model



(c) 90° model

Fig. 2. Angles of the facility against the ground

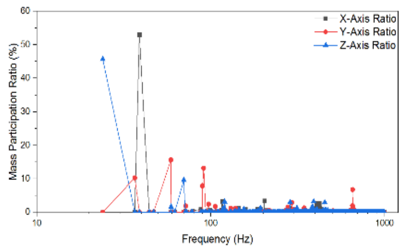
Table 1. Analysis conditions

| | |
|---|---|
| Angle (°) | 0, 30, 90 |
| PGA (g) | 0.1, 0.2, 0.3, 0.4, 0.5, 0.6 |

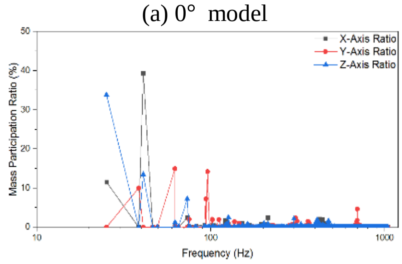
## 3. Analysis Results

### *3.1 Modal Analyses*

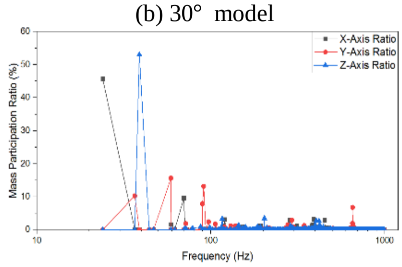
In case of modal analyses, Block Lanczos method was employed to determine the value of frequencies, mode shapes and mass participation factors. Fig. 3 shows typical mass participation ratios which were examined to validate an effectiveness of analysis conditions and to confirm an appropriateness of analysis results via effective masses over 90%.




(a) 0° model




(b) 30° model




(c) 90° model

Fig. 3. Mass participation ratios under DBE (0.3g)

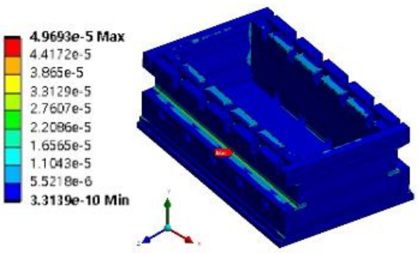
### *3.2 Response Spectrum Analyses*

Total responses were calculated through the square root of the sum of squares method for all the individual modal response. While strains should be compared with a corresponding allowable design criterion of concrete structure [8], stresses were additionally examined. Table 2 summarizes response spectrum analysis results under DBE by employing each model. From the view point of angles, the highest shear strain and von-Mises stress were calculated from the 30° model, and the highest normal strain was calculated from the 90° model.

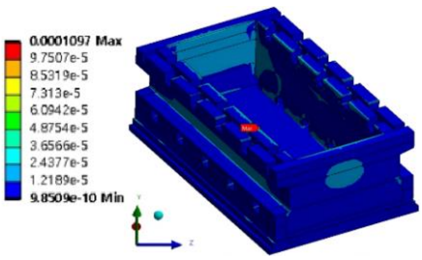
Table 2. Analysis results under DBE (0.3g)

| Analysis model | 0° | 30° | 90° |
|---|---|---|---|
| Maximum normal strain | 1.46e-5 | 1.49e-5 | 2.48e-5 |
| Maximum shear strain | 2.88e-5 | 5.48e-5 | 3.69e-5 |
| Maximum von-Mises stress (Pa) | 1.17e+6 | 1.73e+6 | 1.21e+6 |

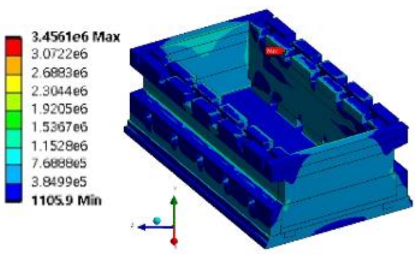
Fig. 4 shows typical response spectrum analysis results under 0.6g among BDBE conditions. As expected, maximum values of each parameter were obtained from the largest PGA condition. Also, the maximum shear stains were larger than the maximum normal strains.




(a) Maximum normal strain
90° model : 4.97e-5 (mm/mm)




(b) Maximum shear strain
30° model : 1.10e-4 (mm/mm)




(c) Maximum von-Mises stress
30° model : 3.46e+6 (Pa)

Fig. 4. Analysis results under a BDBE (0.6g)

Based on the seismic assessment results, three vulnerable regions of the facility were determined as the upper airflow wall, the middle body corner and the upper part of the sidewall. All the DBE and BDBE conditions led to the same tendency.

The most severe values were calculated from the 30° model. For instance, the maximum normal strain and shear strain were 2.98e-5 and 1.10e-4, respectively. In the 90° model, the maximum normal strain was 2.48e-5 under 0.3g and increased twice as 4.97e-5 under 0.6g. Comparing to the concrete failure strain value of 0.005, the dry storage facility meets the design criteria.

## 4. Conclusions

In this paper, comparative seismic analyses were conducted for a dry storage facility and the following key findings were obtained.

(1) The most severe results were obtained from the 30° model and the stress was concentrated on the corner irrespective of PGA conditions.

(2) Both 90° and 0° models provided similar tendency. The von-Mises stress values were almost the same, however, different strains were calculated

(3) Since the facility is a cuboid type structure having stress-intensive corner, effect of angles against the ground was examined. As a result, up to 47.72% of the difference was observed.

## ACKNOWLEDGMENTS

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## REFERENCES

[1] KAERI, Analysis of short-term management technologies of spent nuclear fuel, CR-332, 2009.

[2] Choi, I. K., Choun, Y. S., Ahn, S. M., Seo, J. M., Probabilistic seismic risk analysis of CANDU containment structure for near-fault earthquake, Nuclear Engineering and Design, Vol. 238, pp.1382-1391, 2008.

[3] Lee, K. H., Youn, J. H., Choi, B. I., Lee, H. Y., Heat transfer analysis of consolidated dry storage system for CANDU spent fuel considering environmental conditions of Wolsung site, Proceedings of the KNS Spring Meeting, 2004.

[4] U.S.NRC, RG 1.60 Design response spectra for seismic design of nuclear power plants, ML13210A432, 2014.

[5] Nuclear Energy Agency, Differences in approach between and conventional seismic standards with regard to hazard definition, NEA/CSNI/R(2007)17, 2007.

[6] U.S.NRC, A pilot probabilistic risk assessment of a dry cask storage system at a nuclear power plant, NUREG-1864, 2007.

[7] ASCE, Seismic analysis of safety related nuclear structures, ASCE 4-16, 2005.

[8] Kim, S. H., Chang, Y. S., Cho, Y. J., Jhung, M. J., Modeling of reinforced concrete for reactor cavity analysis under energetic steam explosion condition, Nuclear Engineering and Technology, Vol. 40, pp.218-227, 2016.