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Seismic Response Analysis of Spent Nuclear Fuel Metal Storage Cask considering Soil-Structure Interaction Effects

Chang-Yeal Baeg [a*], Kyung-Ho Lee [a], Dae-Ki Lee [a],
In-Su Jung [b], Won-Tae Song [b], Han-Uk Jin [b], Jong-Soo Kim [b]
[a] *Nuclear Engineering & Technology Institute, Korea Hydro and Nuclear Power Co., Ltd., 25-1 Jang-dong, Yuseong-Gu Daejeon, 305-343, Korea*
[b] *KONES, 210-2 Hapdong Bldg., Yangjae, Seocho, Seoul, Korea*
Corresponding Author : baegcy@khnp.co.kr

1. Introduction

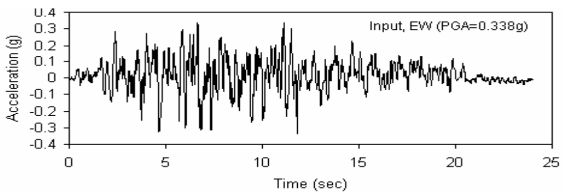
Maintaining of the structure safety for the metal storage cask is important to store spent nuclear fuel under a seismic events. Sliding and overturning behavior must be estimated because the metal cask systems are to be installed as free standing structures on reinforced concrete pads. This behavior can cause a serious problem in the integrity of spent nuclear fuel by the impact between neighboring casks. Also, soil condition should be considered since the cask's behavior is strongly affected by the characteristics of the base soil condition.

In this study, the seismic response analysis was carried out in order to evaluate the behavior of the metal storage cask under earthquake envelopment considering Soil-Structure Interaction (SSI) effects.

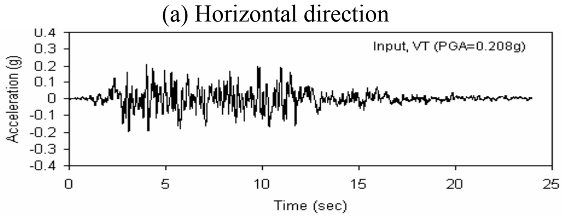
2. Numerical Analysis

2.1 Input Motion

As shown in Fig. 1, the input motion for storage cask design is defined as artificial acceleration time histories generated conforming to USNRC SRP 3.7.1 [1] requirements, which also envelope USNRC RG 1.60 response spectrum having the peak ground acceleration (PGA) of 0.3g in horizontal and 0.2g in vertical, respectively.



(a) Horizontal direction



(b) Vertical direction

Fig. 1 Artificial acceleration time-history

2.2 Soil-Structure Interaction Analysis

The six soil profiles proposed to consider site conditions of nuclear power plants are summarized in Table 1. The computer program SHAKE [2] is used in the site response analysis.

Table 1 Shear wave velocities in soil stratum (unit : ft/sec)

Depth (ft)	Case A-1	Case B-1	Case B-2	Case C-1	Case C-2	Rock Case
0~53	1,000 ~ 1,300	1,000 ~ 1,450	2,000 ~ 3,125	1,000 ~ 1,800	4,250 ~ 4,530	*Rock*
53~100	*Rock*	2,000 ~ 5,450	3,150 ~ 4,250	2,000 ~ 4,650	4,810 ~ 4,880	*Rock*
100~200	*Rock*	*Rock*	*Rock*	5,050 ~ 6,250	4,950 ~ 5,510	*Rock*
200 more than	*Rock*	*Rock*	*Rock*	*Rock*	*Rock*	*Rock*

The SSI system constituted by reflecting the site response analysis results is shown in Fig. 2. SSI analysis by SASSI [3] program is performed assuming the contact condition between the cask and concrete pad.

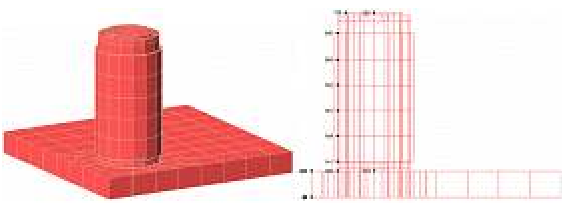


Fig. 2 SSI analysis model

As shown in Fig. 3, the maximum floor acceleration appeared in C-1 soil condition. Therefore, SSI analysis results for soil condition C-1 are used as the input motion in the subsequent seismic analysis of the cask by ABAQUS.

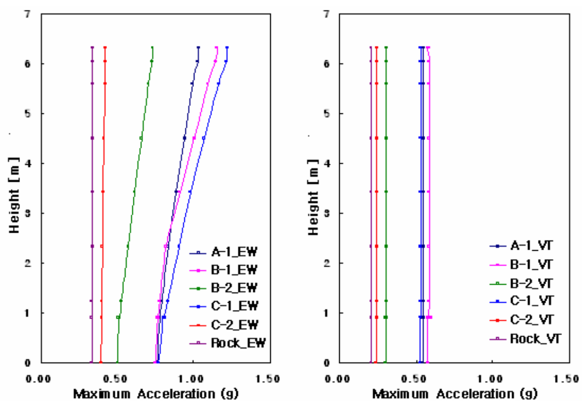
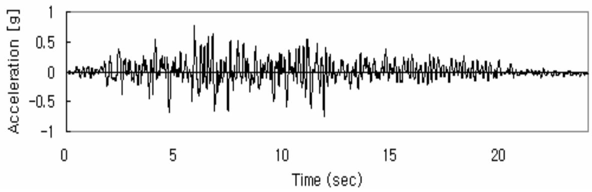


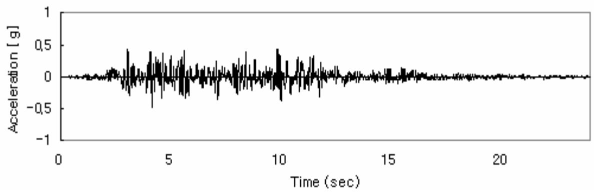
Fig. 3 Comparison of maximum floor accelerations

2.3 Seismic Analysis

The seismic analysis for storage cask was performed considering the SSI analysis result reflecting the base soil condition. Peak ground accelerations used for seismic input motions are of 0.8g in horizontal and 0.5g in vertical, respectively [Fig. 4].



(a) Horizontal direction



(b) Vertical direction

Fig. 4 Seismic input motions

Dimension of metal storage cask for seismic analysis are summarized in Table 2. Analysis model was composed of storage cask body and canister which can load 24 spent nuclear fuel assemblies [Fig. 5].

The friction coefficient between storage cask and concrete pad was assumed to be 0.484 [4]. For the numerical analysis, the computer program ABAQUS 6.5 was utilized.

Table 2 Dimension of metal storage cask

Item	Canister	Cask body
O.D (mm)	1,915	2,459
Overall Length (mm)	4,845	5,402
Total Weight (ton)	141.6	

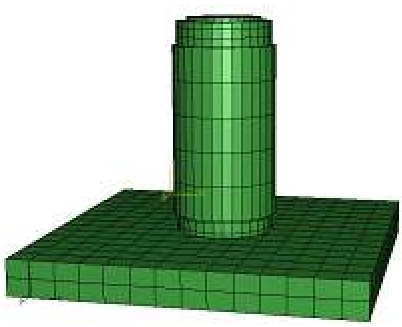
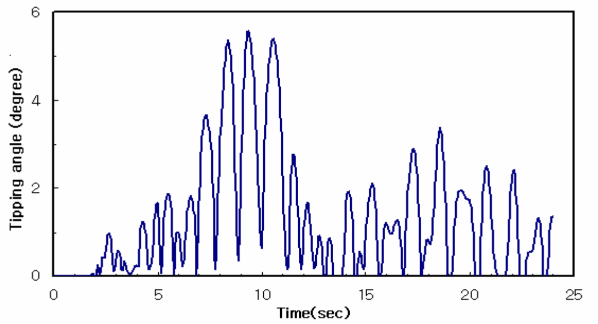


Fig. 5 Seismic Analysis Model

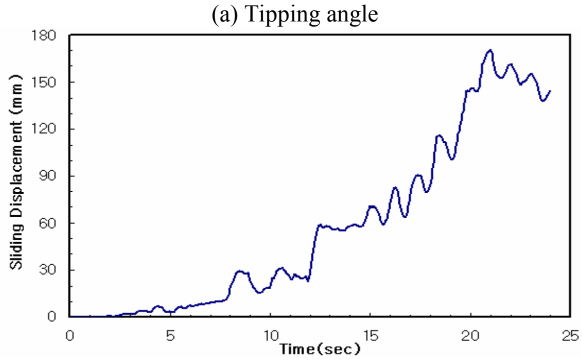
2.4 Analysis Results

The maximum sliding displacement and tipping angle of storage cask were 17cm and 5.6° , respectively.

From the results, it is supposed the cask's stability be secured since these results have lower values as compared with the interval (180cm) and critical angle of tipping (25°) of existing storage cask [5].



(a) Tipping angle



(b) Sliding displacement

Fig. 6 Seismic analysis results

3. Conclusions

The seismic response analysis for metal storage cask installed as free standing structure was performed. Thus, sliding and overturning behavior of cask system were evaluated subsequently. The analysis results show that the storage cask maintain the stability under the design basis seismic events.

The seismic response analysis shall be performed so that dynamic behavior should be evaluated to maintain the safety of structure.

REFERENCES

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