Seismic Fragility Analysis of Surface Facilities in Low-Intermediate Level Radioactive Waste Repository

Junhee Park [a*], Minkyu Kim [a], In-Kil Choi [a]
[a] *Korea Atomic Energy Research institute, 1045 Daedeok-daero, Youseong, Daejeon, 305-353*

[*] *Corresponding author:jhpark78@kaeri.re.kr*

1. Introduction

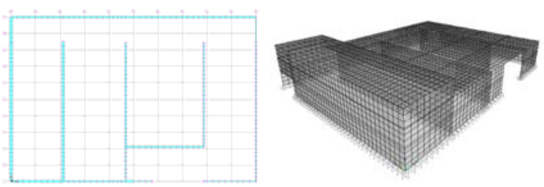
Considering the functional operation of low-intermediate level radioactive waste (LILRW) repository, the surface facilities as well as the silo of underground is an important structure. Especially it is necessary to evaluate the seismic safety of the surface facilities because the acceleration at the surface subjected to the seismic excitation is higher than that of the underground.

Although the surface facility temporary reposit a radioactive waste, the seismic capacity of surface facility should be ensured in order to operate continuously and safely the surface facilities. But the research on the seismic safety of radioactive wastes repository has not been reported.

The main purpose of this study is to evaluate the seismic capacity of LILRW repository using the fragility analysis. The receipt-storage and radioactive-waste facility of wolsong radioactive waste repository system were used as example model.

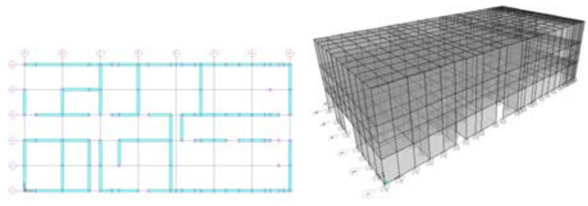
2. Modeling of surface facilities

The receipt-storage facility (RSF) consists of intermediate level storage, low level radioactive, and receipt & inspection space. The height of intermediate level storage is 13.6m higher than other space. RSF is three story RC shear wall systems as shown in figure 1 a). The length of longitude is 71m and the length of transverse is 53m. The strength of concrete and steel equal to 2.35kN/cm^2 and 40.00kN/cm^2, respectively. The steel ratio is 0.092.



(a) Plan (b) FEM model
Fig. 1. Receipt-storage facility (RSF)

The radioactive waste facility (RWF) which is composed of RC shear wall having steel yield strength and concrete ultimate strength of 40.00 kN/cm^2 and 3.14 kN/cm^2, respectively is 3-story with 60m × 30m square plane shape(fig. 2). The thickness of slab is 45cm. The steel ratio is 0.167. The wall and slab of two analytical models is made of multi layered shell elements.



(a) Plan (b) FEM model
Fig. 2. Radioactive waste facility (RWF)

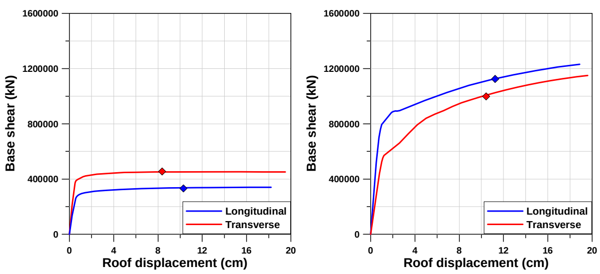
3. Capacity of surface facilities

3.1 Pushover curves

The natural frequency of RSF and RWF is the longitudinal direction transformation (9.84Hz) and the transverse direction transformation (9.70Hz), respectively.

Pushover analysis was performed for calculating the seismic capacity of surface facilities in LILRW repository system. The lateral load was applied as first mode shape. Figure 3 presents the force-displacement curves of analytical model. The stiffness and strength of transverse for RSF is higher than that of longitudinal direction because many internal walls are located parallel with transverse direction. While the strength and stiffness of longitude for RWF was higher than that of transverse because the moment arm of longitudinal direction is higher than that of transverse direction.

The diamonds of figure 3 present the displacement of surface facilities when the minimal damage proposed by ASCE 43-05 [1] is discovered.



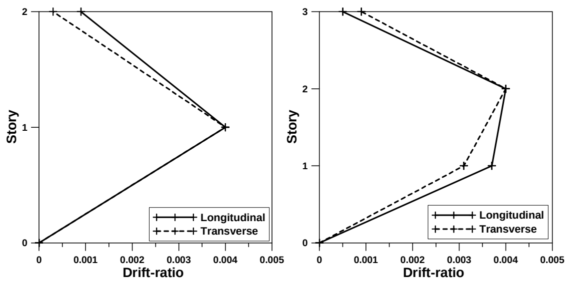
(a) RSF (b) RWF
Fig. 3. Pushover curves of example models

3.2 Inter-story drift ratio

The structural damage and performance is directly related to the inter-story drift ratio which is the relative translational displacement between consecutive floors.

RSF is shear wall system which is governed by shear behavior. Therefore it was presented that the displacement of lower story was higher than upper story under lateral load as shown in figure 4. Figure 4 presents the inter-story drift ratio when the displacement of structure reaches at the ultimate state proposed by ASCE 43-05.

From this result, it was found that the damage of lower story of example models is higher than that of higher story.



(a) RSF (b) RWF

Fig. 4. Inter-story drift ratio of example models

4. Fragility curves of surface faicilitys

4.1 Safety factors

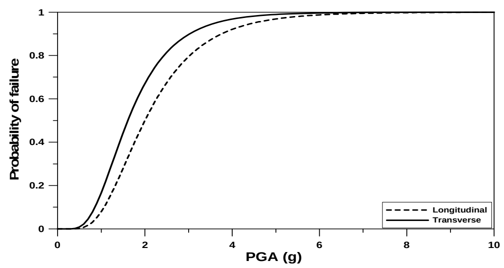
The safety factors for seismic fragility are composed by strength factor, inelastic energy absorption factor and response factor. Among the safety factors, the strength factor related to the force capacity (e.g. shear, moment and axial) of structures or equipment. The earthquake demand was calculated by using a ground motion response spectrum proposed by Kim et. al. [2].

Inelastic energy absorption factor is the factor with related to the nonlinear behavior of structures.

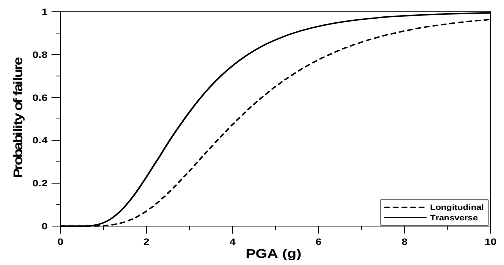
In this study, the effective Riddell-Newmark method [3] which defined the factor according to the frequency range of input response spectrum was used for calculating the factor. The ductility for inelastic energy absorption factor was calculated based on minimal damage of structure.

4.2 Fragility curves

Figure 5 presents the seismic fragility curves of surface facilities according to the axis of the structures. It can be observed that the seismic capacity is mainly changed by the shear stiffness of structure. For RSF, although the shear capacity of transverse direction is higher than that of longitudinal direction, the seismic capacity of transverse direction is low because of the high seismic response. The high confidence-low probability of failure (HCLPF) of RSF and RWF was 0.52g and 0.93g, respectively.



(a) RSF



(b) RWF

Fig. 5. The mean fragility curves by structural axis

5. Conclusion

In this study, the seismic capacity of surface facilities in LILRW repository was evaluated by conducting the seismic fragility analysis. It was observed that the HCLPF of RSF and RWF was 0.52g and 0.93g, respectively. Based on the structural failure, therefore the seismic fragility results show that the surface facilities have the enough seismic capacity.

A functional failure for the equipments attached to the wall as well as a structural failure should be considered to evaluate exactly the seismic fragility of surface facilities.

Acknowledgement

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