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Test for Verifying the Numerical Analysis for a Dry Concrete Storage Cask under Accident Cask Drop Conditions

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1. Introduction

Storage cask is required to prove its safety under the normal, off-normal and accident conditions according to the related regulations.[1,2] Among the accident conditions, a cask drop is the important condition. Generally either the maximum height to which the cask may be lifted when handled outside the reactor site building or the maximum acceleration that the cask could experience in a drop is considered as its design basis. The total weight of a dry concrete storage cask which can store 24 PWR spent fuel assemblies is about 15.45 ton. The weight of the overpack and canister are about 116.3 ton and 38.2 ton, respectively. It's too heavy so a drop test of a real concrete storage cask is very difficult. However analytical methods such as finite element methods are of advantage for analyzing experimental results and design calculations as the effects of the parameters can be investigated with a small amount of effort when compared to tests. The numerical structural analyses have been carried out for a concrete storage cask under the accident cask drop condition. In this study, in order to obtain a verification of the calculation results through experimental investigations a drop test of a 1/3 scale model for a 24 PWR spent fuel dry concrete storage cask is conducted. And the numerical structural analysis is studied for the same model. Strains and accelerations in the time domain by the analytical methods are compared with those by a test.

2. Drop Test of 1/3 scale model

Drop Test of a canister onto the concrete pad of the concrete overpack was conducted as in Figure 1. The difference between the outer diameter of the canister and the inner diameter of the overpack is 48 mm. It is too small for the canister to be impacted on the inner side of the overpack during the free drop. To protect the data cable and to carry out an accurate impact on the concrete pad, three plates with a 10mm thickness are installed at the inner area of the overpack. To acquire the strains and accelerations in the time domain during a drop test 12 strain gauges and 6 accelerometers are installed as shown in Figure 2.

The acquired strains and accelerations for a free drop test are shown in Figure 3. The data is filtered with 1,400Hz lowpass filtering. The values of the maximum test acceleration at the measured points are different but the trend of then in the time domain is similar. At some positions the early strains show the maximum strains and at other positions the oscillatory values appear. The maximum acceleration is 766.9 g at the position A6 and the maximum strain is 1,190 $\mu\varepsilon$ at the position S4.

Figure 1. Free drop test of a canister onto the concrete pad of the overpack.

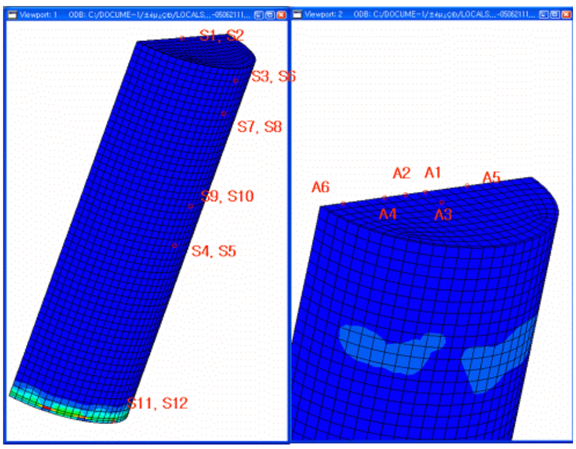


Figure 2. Positions to measure the strains and accelerations.

3. Verification of the numerical Structural Analyses

A three-dimensional analysis of a 1/3 scale model under a drop test are studied using ABAQUS[3]. Using a symmetry the half model was evaluated as shown in Figure 4. Total numbers of elements and nodes are 15,278 and 20,390, respectively. The concrete pad and the canister with a basket and dummy fuels are considered. The C3D8R element type is used for the FE model of the canister, the concrete pad and the dummy fuel and the S4R element type is used for the FE model of the basket. All the surfaces of each material are considered as a frictionless contact surface. The concrete pad is rested on the rigid plate and the canister with the basket and the dummy fuel experiences the equivalent initial velocity (5.87 m/s) for the 1.89m free drop.

In Figure 5 the strains and accelerations for a numerical structural analysis at the positions as shown in Figure 2 are shown. The data is also filtered with a 400Hz lowpass filtering. The trends in the numerical acceleration results between at the measurement points are different.

The test results are compared with the numerical results as shown in Fig. 6. The numerical results of the acceleration are larger than the test results. For the strain, the numerical results are similar with the test results. The maximum acceleration, 1,819 g appears at the position A5 and the maximum strain is 1,198 $\mu\varepsilon$ at the position S4.

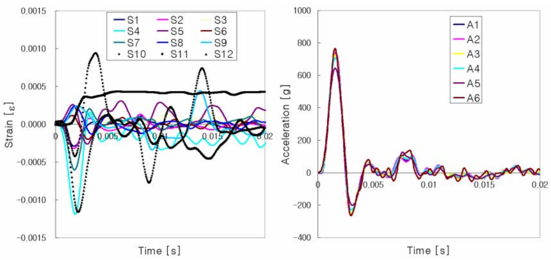


Figure 3. The acquired test results of strains and accelerations for a free drop test of the canister.

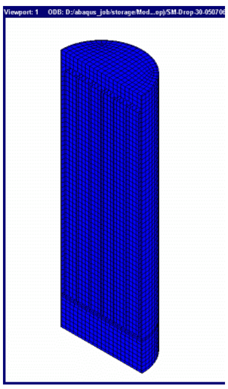


Figure 4. The finite element model of the canister drop on the concrete pad of the dry storage cask.

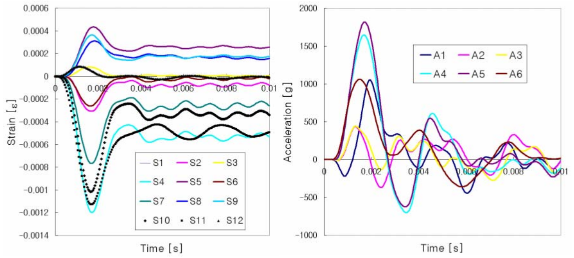
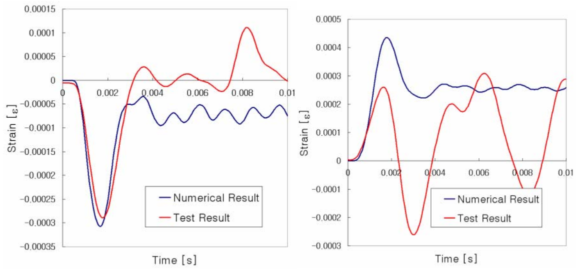
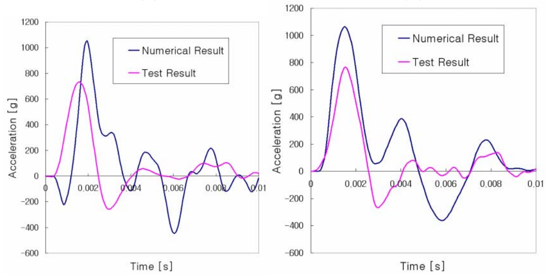


Figure 5. The numerical results of strains and accelerations.



(a) at S1 (b) at S5



(c) at A1 (d) at A6

Figure 6. The comparison between the numerical and test results of strain and acceleration

4. Conclusion

In order to obtain a verification of the calculation results through experimental investigations, in this study, drop tests of a 1/3 scale model for a 24 PWR spent fuel dry concrete storage cask are conducted. And the numerical structural analysis is studied for the same model. Strains and accelerations in the time domain by the analytical methods for a 1.89m free drop condition are compared with those by the test. The numerical results of the acceleration are larger than the test results. For the strain, the numerical results are similar with the test results. So the numerical method of simulating the free drop test for the dry concrete storage cask is verified and the numerical results are reliable.

REFERENCES

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[3] Hittit, Karlson and Sorensen, "ABAQUS/Explicit User's Manual for Revision 6.5," 2005.