Structural Safety Analysis on Drop Impact of Polymer Concrete Container

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1. Introduction

Nuclear energy demand has been on the increase lately. In accordance with the demand, radioactive waste quantities have been increased continuously too. Consequently, the development of radioactive waste container to transport safe and store for a long time is a very important problem. But, the radioactive waste containers that have been developed by this time have generally been made of steel or polyethylene materials. These materials are so expensive and have a weakness of storing for a long time. Therefore, it has been substituted a polymer concrete material by steel and polyethylene to make up for these weaknesses recently. The radioactive waste container made of steel has been studied in domestic research work [1,2]. Experimental study on Polymer concrete container reinforced steel structure was carried out lately [3]. The radioactive waste container must be designed to ensure safe under all potential accidents. Especially, in case of drop accident under transporting, the radioactive waste container must be maintained integrity.

In this work, a finite element analysis is carried out to evaluate structural safety on drop impact of polymer concrete container using ABAQUS explicit code [4].

2. Free Drop Analysis and Results

2.1 Container Model

Polymer concrete radioactive waste container is consisted of two parts. One is a container body that is similar to cup in shape. The other is a lid. Container body and lid were made of only polymer concrete material. Lid of container has lift rings and inclined grooves for draining. Body of container has a groove for sealant and holes for bolting also. But, these structural geometries such as ring, groove and hole were neglected in this analysis. The height and out-diameter of the container body are 1260, 1200 mm respectively. The wall thickness of the container body and the bottom is 50 mm uniformly. The height and diameter of the container lid are 100, 1200 mm respectively.

2.2 Material Properties

The property test of polymer concrete material was carried out on the Korea Institute of Construction Materials (KICM). Material tests such as Compressive, tensile strength, Young's modulus and Poisson's ratio were accomplished. Three specimens have been tested respectively. Applied material properties for analysis were used a mean value respectively. Generally, compressive strength of polymer concrete is a greater than tensile strength. As the result of test, compressive strength, tensile strength, Young's modulus and Poisson's ratio of polymer concrete material were 117.8 MPa(N/mm^2), 14 MPa, 21764 MPa, 0.16 respectively. The compressive strength test is presented in Figure 1. As the result of the compressive strength test, stress versus strain curve is presented in Figure 2.

Figure 1. Compressive strength test of polymer concrete

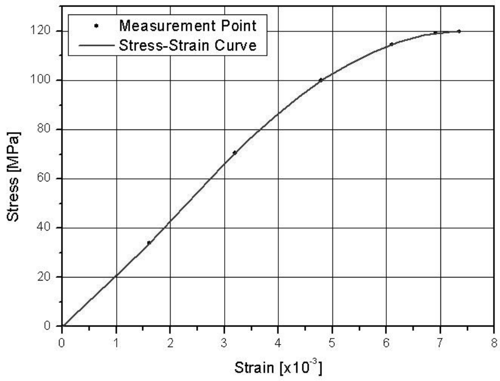

Figure 2. Stress vs. strain curve of compressive strength test of polymer concrete

2.3 Material Model

For this analysis, Drucker-Prager material model of ABAQUS was applied. Drucker-Prager model is used to model in which the compressive yield strength is a greater than the tensile yield strength, such as those commonly found in composite and polymer materials. The linear Drucker-Prager material criterion is as follow:

$$f = t - p\tan\beta - d = 0 \qquad (1)$$

Where,

$$t = \frac{1}{2} q [1 + \frac{1}{k} - (1 - \frac{1}{k})(\frac{r}{q})^3] \qquad (2)$$

β is the slope of the linear yield surface in the p-t stress plane and is commonly referred to as the friction angle of the material and d is the cohesion of the material, k is the ratio of the yield stress in tri-axial tension to the yield stress in tri-axial compression and, thus, controls the dependence of the yield surface on the value of the intermediate principal stress.

2.4 Analysis Case

To investigate the structural safety of the polymer concrete container, three hypothetical accident types were considered. These accident types were vertical free drop, horizontal free drop and corner free drop. Applied distance between ground and bottom of container was 1.2 m. Angle of corner free drop was 45°. Ground was assumed as rigid material model. Gravity, 9810 mm/sec^2 for free drop, was applied in all of cases. Initial speed of container was 4850 mm/sec in all of cases too. Container model was used 1/2 model with the symmetric condition. Contact condition between cylindrical container body and lid was applied tie contact condition. Friction between rigid ground and polymer concrete was neglected. Analysis time was 0.01 sec. A finite element analysis in all of cases was carried out using ABAQUS explicit code.

2.5 Results

Principal stresses were compared with uni-axial compressive and tensile strength. In case of vertical free drop analysis, maximum principal stress of bottom corner of container was less than uni-axial compressive strength as shown Figure 3. That is failure was not occurred in bottom corner of container in this case. But, maximum principal stress of bottom corner of container in corner free drop analysis was larger than uni-axial compressive strength as shown Figure 4. In case of horizontal free drop, failure was occurred in bottom corner and lid of container.

3. Conclusion

In order to evaluate structural safety of polymer concrete container in cases of 1.2 m vertical, horizontal, corner free drop, a finite element analysis was carried out using ABAQUS explicit dynamic code. Principal stresses of elements were investigated to interpret the fracture of container. Maximum positive principal stress and minimum negative principal stress were compared with tensile strength and compressive strength respectively. Under 1.2 m free drop, polymer concrete container is fractured in corner and horizontal cases. That is this container design is not ensured structural integrity under hypothetical drop accident. So this polymer concrete radioactive waste container must be reinforced with reinforcement material or shock absorber.

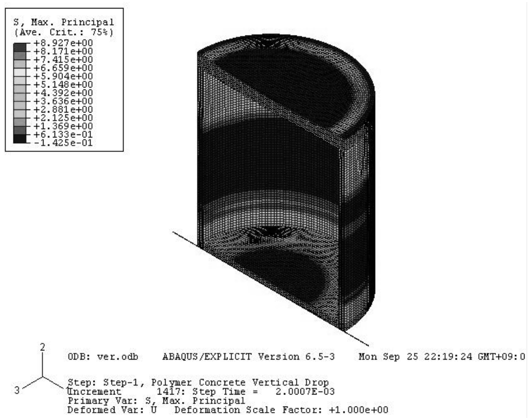

Figure 3. Maximum principal stress distribution of polymer concrete container in case of 1.2 m vertical free drop.

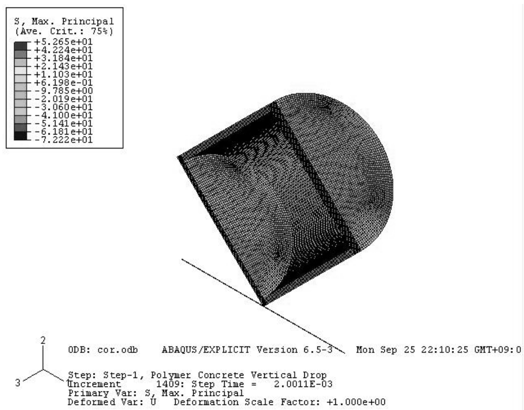

Figure 4. Maximum principal stress distribution of polymer concrete container in case of 1.2 m corner free drop.

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