STRUCTURAL ANALYSIS METHODS AND MODELS USED FOR THE EVALUATION OF A RADIOACTIVE WASTE TRANSPORT PACKAGING

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ABSTRACT

This paper describes the structural analysis methods and models developed to analyze a packaging which was designed to transport transuranic radioactive waste from waste generating sites to a final repository. The packaging is a rectangular box consisting of two inner containers surrounded by polyurethane foam and an outer protective structure.

The methods and models described are those developed to evaluate the effects on the packaging of the 30 ft. drop hypothetical accident as defined in Title 10 of the Code of Federal Regulation, 10CFR71 (1). The packaging is a complex composite structure so several different models were required. The ANSYS finite element computer program (2) was used extensively in the structural analysis. The approach selected was to use an overall system model to perform dynamic analyses to determine the packaging response for different drop orientations so that the worst orientation for the 30 ft drop could be determined.

DISCUSSION

The subject of this paper pertains to a packaging developed to transport transuranic radioactive waste from waste generating sites to a final repository. The packaging is a rectangular unit consisting of double inner containers surrounded by polyurethane foam and an outer protective structure consisting of a structural tubular frame to which are attached puncture resistant panels, insulation blankets and an outer skin. The packaging is schematically shown in Fig. 1.

The two inner containers are constructed of metal honeycomb panels which form rigid, pressure tight boxes or containments. These containers have hinged doors which are bolted in place and sealed with rubber gaskets. The inner container is bolted to the outer container at the door end and supported elsewhere within the outer container by spacer pads. The outer container is not mechanically attached to the outer protective structure but is supported within this structure by polyurethane foam. This leads to a nonlinear design which is difficult to analyze for the dynamic loads to which it is subjected.

The methods and models described are those developed to evaluate the effects of the 30 ft. free drop hypothetical accident specified in 10CFR71 (1). The packaging is a complex composite structure so several different models were required. The ANSYS finite element computer program (2) was used extensively in the structural analysis. The approach was to use an overall system model to perform dynamic analysis to determine the packaging response for different drop orientations so that the worst orientation for the drop could be determined for a single full scale compliance test.

The regulations require that the worst drop orientation be determined and evaluated. For vertical and horizontal drop orientations relatively simple analytical models can be developed since the motion is one dimensional. The most difficult analytical problem to solve is to determine the worst orientation for shallow angle drops. The motion during the shallow angle drop is three dimensional (vertical, horizontal and rotational). The shallow angle impact produces both primary and secondary impact and the term "slapdown" is used to described this motion. This paper deals basically with describing the models used to determine the maximum model translational and rotational deceleration, the contact forces, and the model bending moments during the slapdown impact.

The two inner containers must withstand the drop accident without sustaining appreciable damage so they were assumed to behave elastically during the impact. These containers are supported within the outer protective structure by a low density polyurethane foam layer approximately 8 in. thick on the sides and over 30 in. thick on the ends. The outer structure and foam are designed to serve as a sacrificial protective structure for the containers by absorbing the kinetic energy of the packaging as inelastic strain energy during the impact.

The analysis approach involved first, developing a relatively simple beam model of the inner containers attached by nonlinear springs at discrete locations along the beam to the outer protective structure. This model was then used to perform numerous time history impact analyses in order to determine the critical packaging orientation at impact based on impact loads and container deceleration. Then a detailed shell model of the containers, shown in Fig. 2, was developed using laminated shell elements to represent the

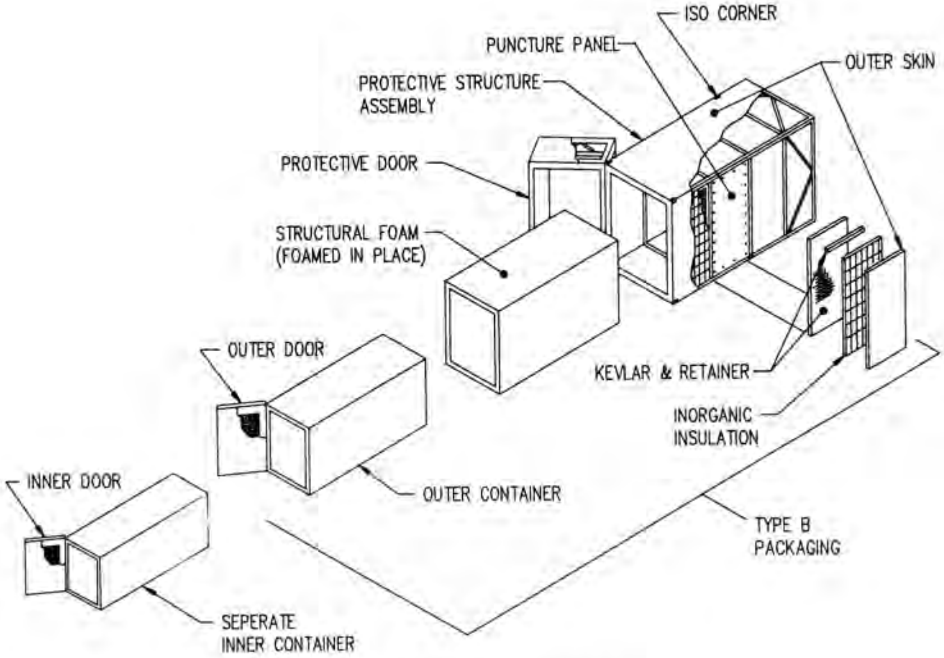

Fig. 1. Packaging Schematic.

honeycomb walls of the containers. The containers are modeled separately but coupled together at spacer pad locations. Since the container model is elastic, a superelement of this model was generated for use with the nonlinear springs to repeat the time history analysis for the most critical orientation. Two variations of the simple beam model were developed, one for flat side impact and one for edge impact.

The initial step in the analysis was to obtain the nonlinear spring characteristics of the foam and outer protective structure. This was accomplished by using a two dimensional slice of the packaging. Since the characteristics of the packaging are dramatically different when impacted on the side versus the long edge two models were required. These are shown in Figs. 3 and 4. Each model is based on a 2D slice of the packaging and is used to determine the average displacement of the containers relative to the contact surface for various inertia G loads. These models consider all factors important to distortion of the section including foam shear and crushing, shell bending and even distortion of the containment cross section during edge contact. The containment and outer structures are modeled with plastic beam elements and the foam with nonlinear brick elements. The mass was distributed on the members based on size and density. The force versus deflection curve for input to the slapdown model as a nonlinear contact element was determined from the model mass multiplied by input acceleration (force) and the average containment deflection relative to the contact surface (deflection). These force vs. deflection curves are also illustrated in Figs. 3 and 4.

To determine the critical orientation of the packaging during slapdown in a cost effective manner, two simplified overall system models were developed, one for contact on the flat side and one for contact on the long edge. For each of these models which are represented in Fig. 5, the inner and outer containers were stimulated as a single beam with the section properties equal to the total of the two containers. The mass of the contents and containers was distributed on the beam at the appropriate locations. The orientation of the beam and the initial gap of the gap elements were adjusted to study different contact angles. Numerous time history analyses were performed with the problems started when the lowest point on the packaging first touches the rigid surface. At this time, the model was given an initial velocity. The output from the analyses performed with these models included the nodal displacements and accelerations, the impact forces and the beam bending moments as a function of time. These analyses showed that the shallow angle slapdown case with the closed end contacting first and an impact angle of 10 degrees from horizontal was most severe.

After the worst orientation was identified, the container superelement shown in Fig. 2, was then substituted for the container beam in the slapdown model. Both of the containers are modeled in the superelement. They are connected at the door end and at the spacer pad locations by node coupling. The critical time history impact case was

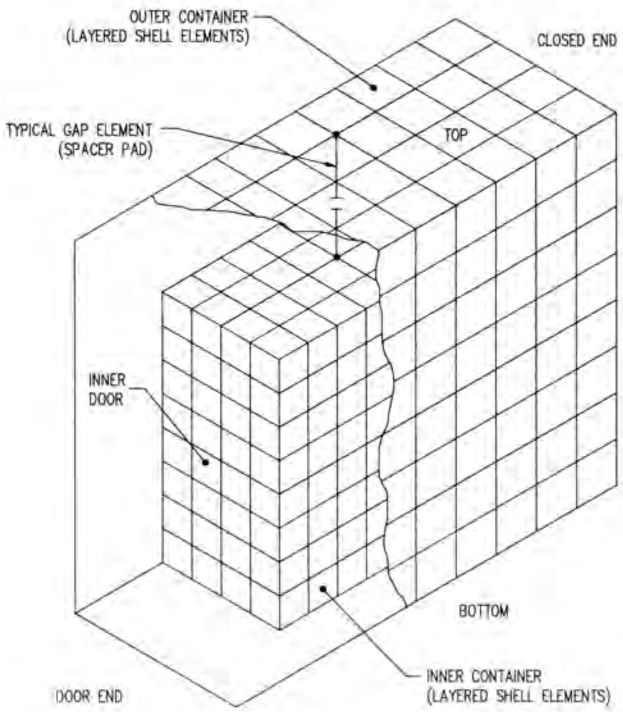

Fig. 2. Inner and Outer Containment.

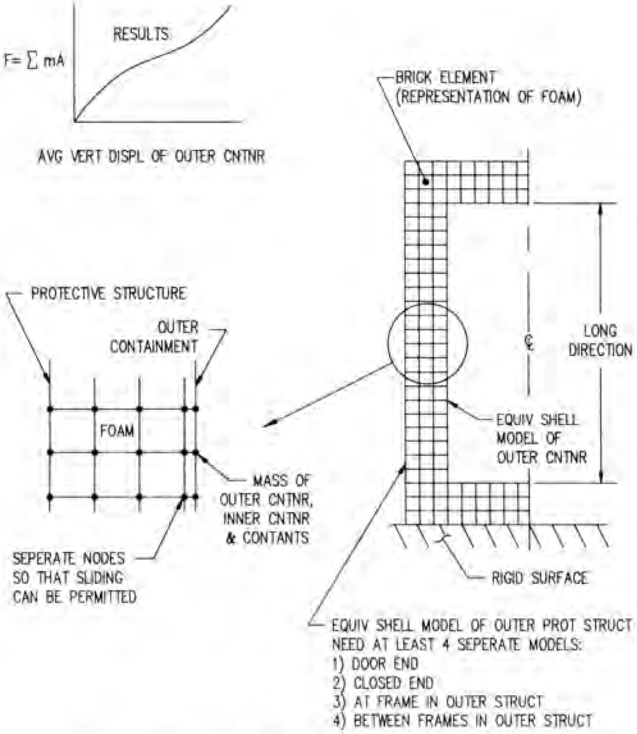

Fig. 3. Section Model - Flat Side Contact.

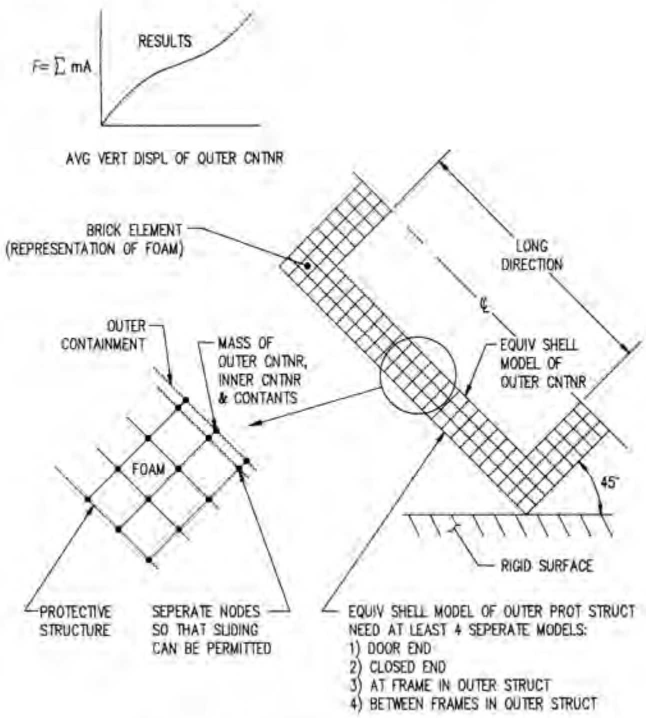

Fig. 4. Section Model - Edge Contact.

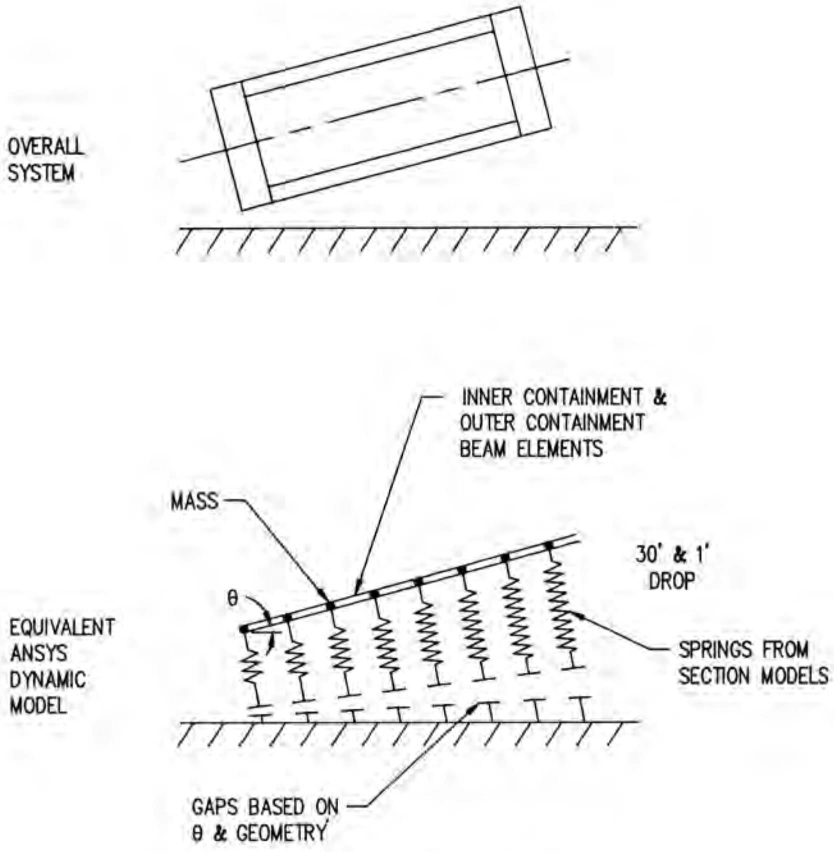

Fig. 5. "Slapdown" Models.

then repeated. The stresses in the containers due to the inertia loads during the slapdown were determined by performing superelement stress solutions at times where impact forces and container accelerations were maximum. Output from the analyses included detailed stresses and strains throughout the containers.

The final time history run required a much move expensive run (than with the beam model) even using the superelement approach. The previous parametric analysis to determine the worst case orientation would have been prohibitively expensive with this model. It was concluded that the approach of using the simple beam models to determine the worst orientation for analysis (or test) was practical and appropriate. Use of the superelement model to perform the stress analysis to evaluate the design in detail proved practical.

REFERENCES

1. Title 10, Part 71 of The Code of Federal Regulations, (10CFR71)"Packaging and Transportation of Radioactive Materials"

2. ANSYS, Engineering Analysis System User's Manual, Revision 4.2, Volume I and II, Swanson Analysis Systems, Incorporated, Houston, PA.