1/6 Scale Reinforced Concrete Model of a Containment Subjected to an Internal Pressure

Local Study in the Vicinity of a Penetration

J. Rivière, B. Barbé
CEA–CEN, Fontenay-aux-Roses, France
A. Millard, Ph. Jamet
CEA–CEN Saclay, Gif sur Yvette, France

INTRODUCTION

The pressurization test of the Sandia 1/6 scale containment model Ref (1, 2, 3) was limited to a pressure in the vicinity of 1.0 MPa due to the appearance of tears in the leaktight liner. The largest tear, which was 0.55 m in length, was located at mid-height of the containment close to the edge of a support plate surrounding a set of three penetrations.

GOALS

Global analysis of the containment using axisymmetrical finite element calculation codes does not allow modelling of special features such as penetrations. Thus, determination of the rupture mechanisms was investigated by a local approach.

Indeed, the results of the experiment showed that the tear phenomena were due to stress concentrations near studs. These secure the liner to the containment concrete to avoid buckling in the event of heavy thermal loading.

The goals of the following study are firstly to determine by finite element calculation the behaviour of the liner in the vicinity of the support plate and secondly to show the role of the studs in the appearance of the tear.

GEOMETRY

The system consisting of the support plate, the leaktight liner, the studs and the wall of the containment is shown in Figure 1. The thickness of the liner is 1.5875 mm, that of the support plate is three times greater, i.e. 4.7625 mm.

The studs are approximately 20 mm long and are 3.43 mm in diameter. In typical areas, the studs are welded to the liner in a 152.4 x 152.4 mm grid pattern. In the vicinity of the support plates, the grid density is increased to 50.8 x 50.8 mm.

MODELING AND LOADING

The liner and the support plate are modelled over a length of 78 cm and allowance is made for 13 studs providing a link with the concrete. The grid used comprises, 633 nodes, 144 isoparametric 8 node elements and 6 isoparametric 6 node elements.

Three types of loading are applied, pressure on inside surface, tangential displacement imposed at the studs and imposed vertical strain.

RESULTS

Two calculations are made :

. one under the exact conditions of the scale model under pressure,

. one with the stud (G4) welded to the liner in the immediate vicinity of the support plate deleted.

Calculation 1

This calculation is made at up to 0.95 MPa. At this pressure, the maximum equivalent Von Mises strain is located in the liner close to the support plate (Figure 2). This strain is of the order of 15% making it possible to assume that the conditions of tearing of the liner are reached, especially if allowance is made for the residual stresses induced by the weld bead. Furthermore, it is found that bending of the support plate involves separation of around 0.4 mm (Figures 3 and 4).

The Von Mises stress in the studs, located on either side of the liner-support plate joint, reaches the plasticity level at a pressure of 0.95 MPa (Figure 5).

Calculation 2 : Deletion of stud G4

Deletion of a stud results in lower Von Mises strain that in the preceding case. Indeed, the maximum strain at 0.95 MPa is roughly 7.3% (Figure 6), as compared to 15% calculated in the presence of the stud.

Strain at 1. MPa is close to 10% (Figure 7), the liner has therefore not yet reached its breaking point (approximately 16%).

The strain at a pressure of 0.95 MPa (Figure 8) shows that there is less separation of the liner than in the preceding case.

The stresses in the studs (Figure 9) are of the same order of size.

CONCLUSION

This analysis indicates that the mechanisms responsible for tearing of the liner are effectively represented. The tear is caused by the combined action of the following two factors :

. firstly, the difference between the stiffness of support the plate itself and that of the leaktight liner,

. secondly, the stud at the edge of the support plate induces a major stress concentration by limiting displacement.

Deletion of a stud reduces the strain, nevertheless, it remains to be determined whether its deletion is compatible with the design basis accident thermal loading.

REFERENCES

1. NUREG/CR 4913 May 1987 - Round Robin pretest analysis of a 1/6 scale reinforced concrete containment subject to static internal pressurization.

2. SMIRT 87 - Analysis of the SANDIA 1/6th scale concrete containment model using the CASTEM finite element system.
A., Millard, Ph., Jamet, (CEA/IRDI/DEMT), G., Nahas, (SOCOTEC INDUSTRIE) and B., Barbé, (CEA/IPSN/DAS).

3. Fourth workshop on containment integrity June 14-17 1988 - Comparison between theoretical and experimental results of the 1/6th scale concrete model under internal pressure.
J., Rivière, and B., Barbé, (CEA/IPSN/DAS), A., Millard, (CEA/IRDI/DEMT) and V., Koundy, (CISI INGENIERIE).

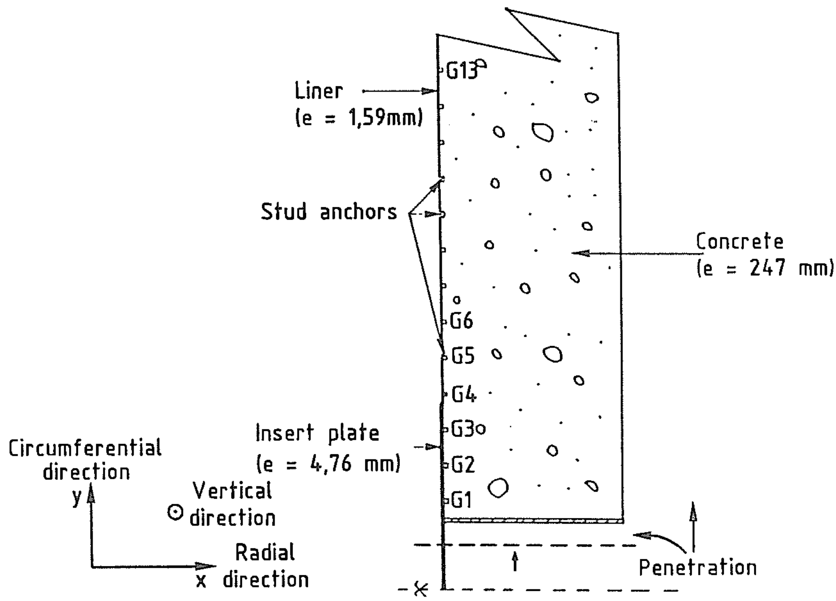

Figure 1 - Modelisation of the liner and the insert plate

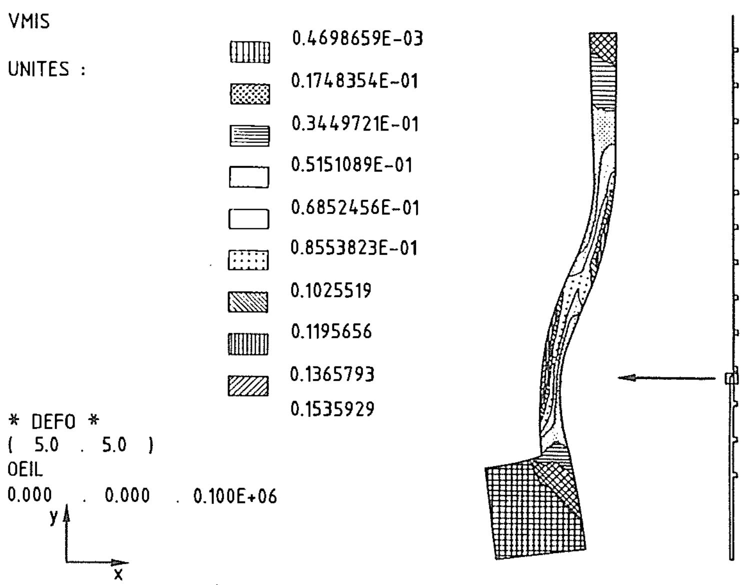

Figure 2 - Von Mises strain at 0.95 MPa

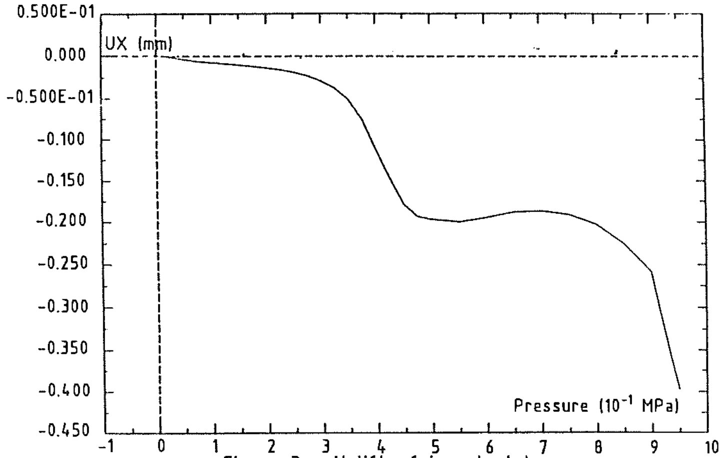

Figure 3 - Uplift of insert plate

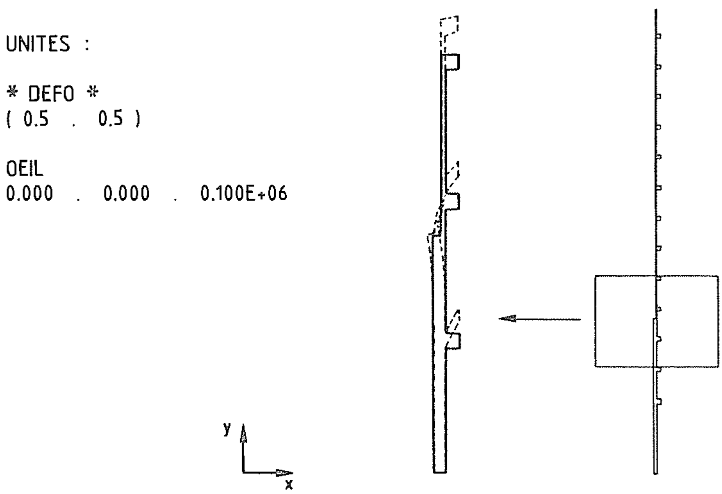

Figure 4 - Deformed structure at 0.95 MPa

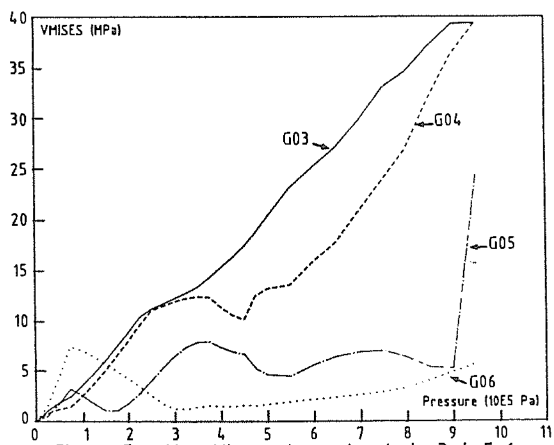

Figure 5 - Von Mises stress in studs 3-4-5-6

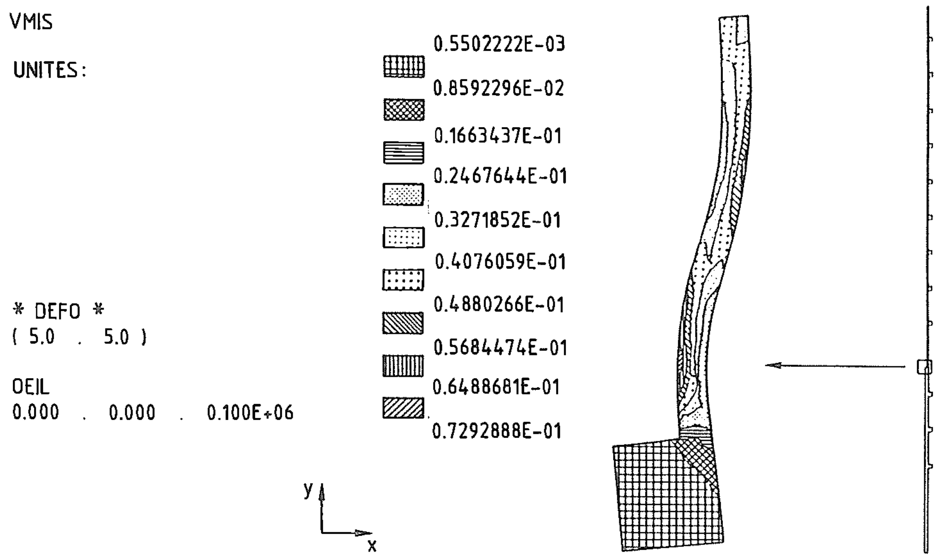

Figure 6 - Von Mises strain in the structure without the stud G4 at 0.95 MPa

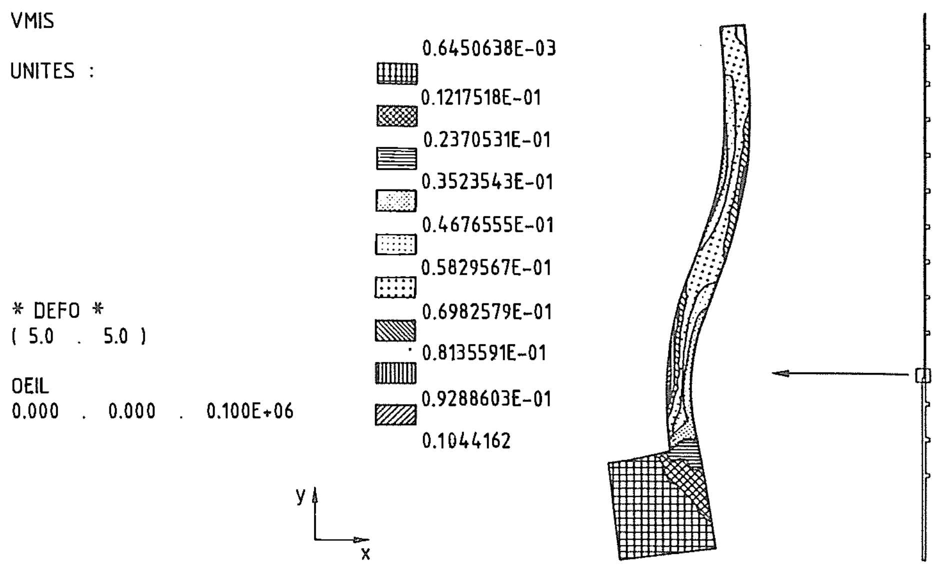

Figure 7 - Von Mises strain in the structure without the stud G4 at 1 MPa

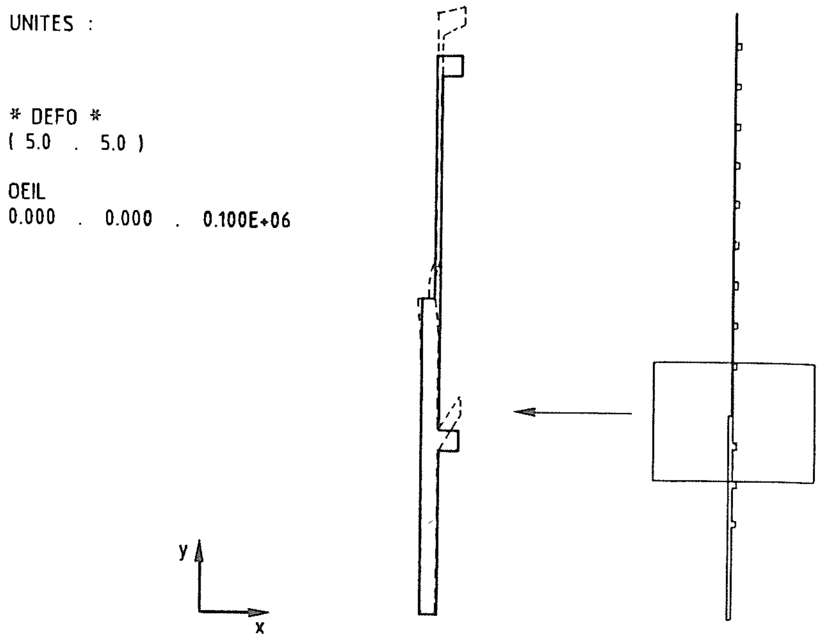

Figure 8 – Deformed structure without the stud G4 at 0.95 MPa

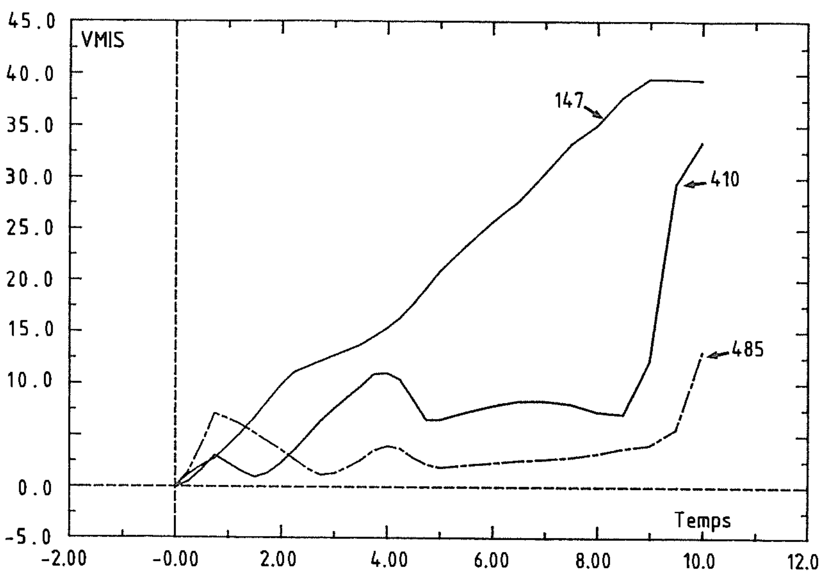

Figure 9 - Von Mises stress in studs 3-5-6