COMPARISON BETWEEN CALCULATIONS AND TESTS FOR A SUPPORT STRUCTURE OF A LMFBR TANK UNDER THE HCDA

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SUMMARY

The aim of this paper is a review of the non linear dynamic behaviour of a particular support structure for a LMFBR tank under the effects stemming from a hypothetical Core Disruptive Accident (HCDA). The support structure is made up by an L-shaped flange, wich supports the tank, connected by means of nine square beams to a rigid box-type ring,fixed to the concrete. The plug of the tank is connected to the L-shaped flange by means of a group a SS holddown bolts.

The CNEN and JRC Ispra are engaged in a collaborative experimental program for testing the tank and support structure of PEC LMFBR under HCDA. All the informations related to the tests are presented in a companion paper.

In this paper only the experimental results related to support structure are discussed and compared with theoretical values obtained by using the calculation procedures presented in papers E2/7 and E2/8 4th SMIRT.

The non-linear dynamic analysis of the explosive accident is carried out on a simple lumped mass model, with elastic plastic elements wich simulate the main components of the support structure and the tank. The impulsive loads stemming from the explosive accident are derived from experimental pressure time histories en the plug and on the bottom of the tank and are modelled (on the basis of extensive comparative studies carried out) as two equivalent triangular pressure impulses acting on the plug and on the bottom of the tank. The dynamic transient on the support structure during and after the explosive accident is analyzed by ADINA program running on a CDC 7600 computer. A large amount of experimental results, wich describe displacements of the plug and of the support structure,together with the strains in the main structural components are presented and compared with theoretical ones.Although a rather simple calculation model is used,the comparison yields significant and satisfactory agreement between experimental and theoretical results.

1. Introduction

The aim of this paper is a review of the non linear dynamic behaviour of a particular support structure for a LMFBR tank under the effects stemming from HCDA. The support structure is part of the PEC project, owned by CNEN-DRV, and will be manifactured by CMI-Genova

The CNEN-DRV and JRC Ispra are engaged in a collaborative experimental program for testing 1/6 scaled models of the tank and support structure under HCDA /1/. All the informations related to the tests are presented in a companion paper /2/. Here only the experimental results related to the support structure are discussed and compared with theoretical values obtained by using the calculation procedures presented in papers E2/7 , E2/8 4th SMIRT, /4/ , /5/.

The support structure is made up (fig.1) by a L shaped flange, connected by means of mine square beams to a rigid box type ring fixed to the concrete and the plug of the tank is connected to the L-shaped flange by beams of a group of SS holddown bolts.

The impulsive loadings stemming from HCDA are characterized, as well known /4/,/5/, by very large pressures developed in very short time. It is impossible to absorb the effects of the HCDA with responses in the elastic field; the only way of absorbing the released energy in to allow a plastic deformation of the support structure.

Then the support structure was designed so that upwards-forces acting on the plug of the tank were absorbed by plastic elongation of SS hold down bolts , while downward forces, due to the action of the tank supported on the L-shaped flange, were absorbed by plastic deformation of the square beams.

Elastic response was supposed for all the other components of the support structure.

2. Experimental tests and pressure impulses

A 1/6 scaled model of the tank and of the support structure has been tested by JRC and CNEN at Ispra /1/,/2/.

In fig.1 the position of the strain gauges on support arms and of the displacement trasducers on plug and L shaped flange is shown. For all these positions a continuons time history of deformations and displacements was recorded during the explosion test.

Moreover at the end of the explosion test distance A as from fig.1 and final elongation of holddown bolts were measured.

In fig.2 and fig.3 pressure time histories for the plug and the bottom of the tank are plotted, together with the ITSI (idealized triangular shape impulse) used for the calculations.Extensive analyses /4/ carried out by means of NON SAP code /6/ have produced substantially equivalent results either by characterizing the impulsive load as from experimental records either as somewhat regularized time history.

The natural period of the structure is much larger than the impulse duration; then it is obvious that the actual shape of the impulse is not very important on the determination of the structural response, but the only parameters necessary are the total momentum and duration of the impulse. For all these reasons the two ITSI of fig.2 end fig.3 were used in the calculations.

Strains, displacements and pressures were recorded for three equaly spaced angular positions : the results confirm the prediction of axismmetric response of the structure.

3. Calculation model

The mass and stiffness distribution of the support structure was simulated by ADINA program using a simple but realistic model (fig.4). For the characterization of the stiffness distribution the basic resistant members, i.e. square beams , are simuled by elastic-plastic beam elements (IV of fig.4) with Von Mises isotropic hardening.

The SS holddown bolts are simulated as elastic-plastic truss elements, with Von Mises isotropic hardening (I of fig.4) . The connection members between SS bolts and L shaped flange are simulated as elastic trusses (II of fig.4).

The tank is simulated as non linear elastic, with resistance only for traction forces, in order to simulate a simple support (downward) of the tank on the L shaped flange (III of fig.4). For the mass distribution, due to the typology of the "short" impulsive load and following "show" response of the system, only global masses need to be simulated and a lumped mass scheme was found realistic : M1 is the mass of the plug and M2 is the mass of the tank.

An updated Lagragian Formulation with equilibrium iterations was used in the solution of the equations.

4. Comparison between experimental and theoretical results

In fig.5 displacement history of the top of the L-shaped flange is plotted together with calculated results. Agreement is quite satisfactory for the downward displacements , while for the following upward displacements due to the plastic elongation of the holddown bolts, theoretical values underestimate the effect and we have a final downward displacement of the L shaped flange.

$$\delta_{f} = 4.5 \times 10^{-3} \text{ m}$$

against a measured value (A fig.1) $\Delta A = 2.4 \times 10^{-3}$ m

This may be due to the difficulty of a correct simulation of the behaviour of the beams wich undertake a complete reverse of the moment in the plastic field; in effect the formulation used for the material - Von Mises isotropic hardening - can't take into account the

Bauschinger effect that experimental values show as important in the response of the material.

This is clear in figs.6 and 7 where experimental and theoretical strain histories for the plastic zone of the beam are plotted. Agreement is quite satisfactory until plastic strain increase, while theoretical values underestimate the decrease of plastic strains due to the reverse of the bending moment and we have a final plastic strain

$$\varepsilon_f^T = 1.5\ \%$$

against a measured value $\varepsilon_f^M = 0.9\ \%$.

Comparison between fig.6 and fig.7 show as the hypothesis of cantilever behaviour for the beam is well confirmed by experimental results. In fig.8 displacement history of the plug is plotted together with calculated results.

Agreement is quite satisfactory; differences for the values after $8\mathrm{x}10^{-3}$ sec are influenced by the lower computed values for the upward displacements of the L flange; in effect we have a final plastic strain in the bolts

$$\varepsilon_f^T = 3.2\ \%$$

against a measured mean value $\bar{\varepsilon}_f^M = 3.8\ \%$

Agreement is confirmed by experimental and theoretical results plotted in fig.9 related to the elastic strains in the elements that connect SS bolts to the L shaped flange.

Experimental results plotted in fig.10 confirm that in the remaining of the structure the response is in the elastic field; some local low plastic strain are present, as predicted , in the upper portion of the L shaped flange.

5. Conclusions

The comparison between experimental and theoretical results for the response of the support structure to the impulsive loads stemming from HCDA allow the following conclusions:

- the predicted axisimmetric behaviour of the structure is confirmed by tests
- the use of ITSI instead of experimental records for the pressure impulse doesn't introduce significant differences in the response of the structure
- the "design philosophy" of introducing simple structural elements, as SS bolts and cantilevers , in order to absorb the plastic deformation energy , due to upward and downward impulses, is widely confirmed by tests as well as the predicted elastic response of the remaining of the structure
- the use of a simple but realistic lumped mass model to determine the time response of the structure allow to obtain results in satisfactory agreement with experimental ones.

References

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/3/ K.J. BATHE "ADINA - A finite element program for Automatic Dynamic Incremental Analysis" - Report 82448-1, M.I.T. Sept. 1975

/4/ V. GIULIANO, L. LAZZERI "On LMFBR typical impulsive loading characterization and its application to simplified structural models" 4th SMIRT Conference, E 2/7, St. Francisco - Aug. 1977

/5/ V. GIULIANO, L. LAZZERI "Main aspects of the design of a support structure of a LMFBR with particular reference to the explosive accident consequences" 4th SMIRT Conference, E 2/8, St. Francisco - Aug.1977

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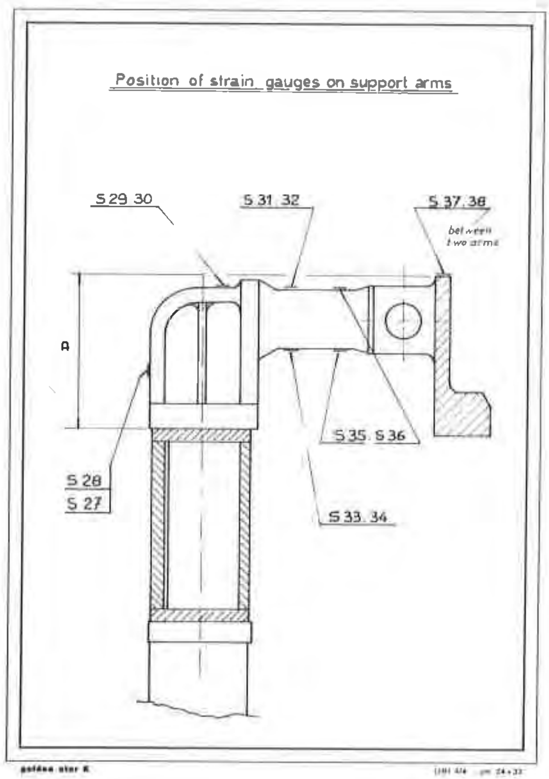

Fig. 1 Positions of strain gauges on support structure

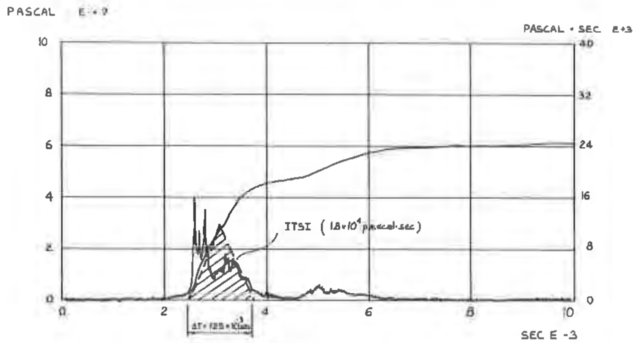

Fig.2 Upward pressure impulse

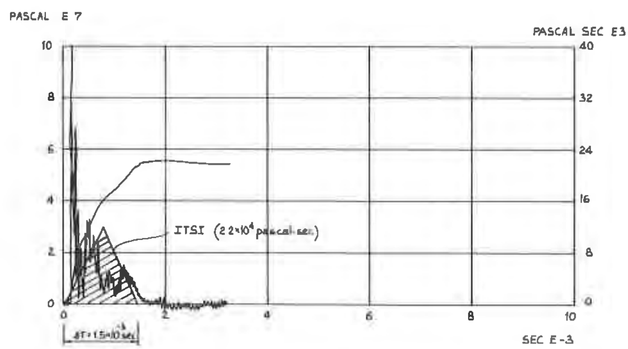

Fig. 3 Downward pressure impulse

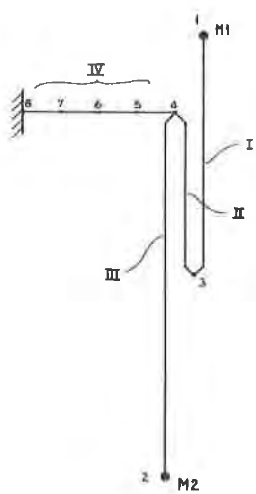

Fig. 4 Calculation model

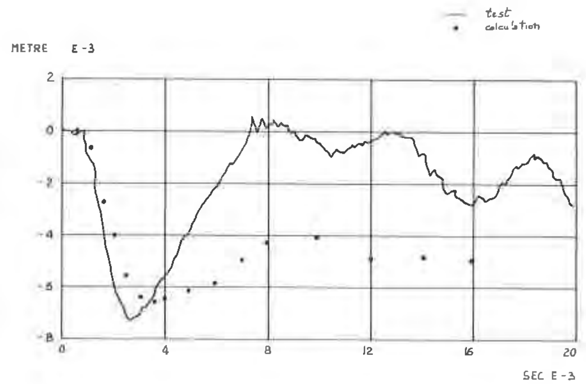

Fig. 5 Displacement history for L shaped flange

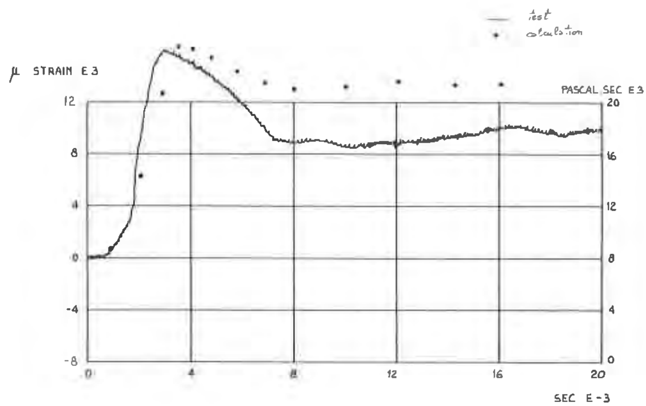

Fig. 6 Strain history for S31 on support arm

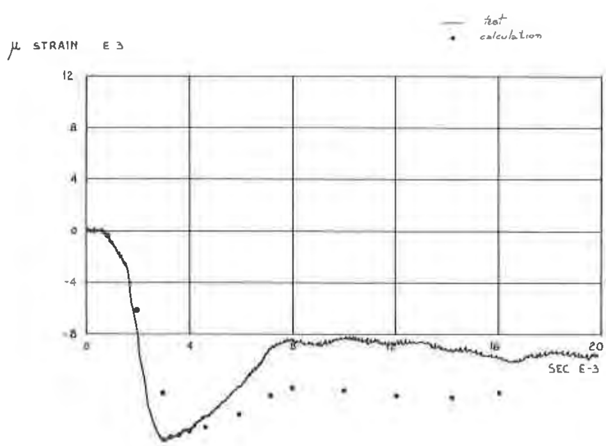

Fig. 7 Strain history for S33 on support arm

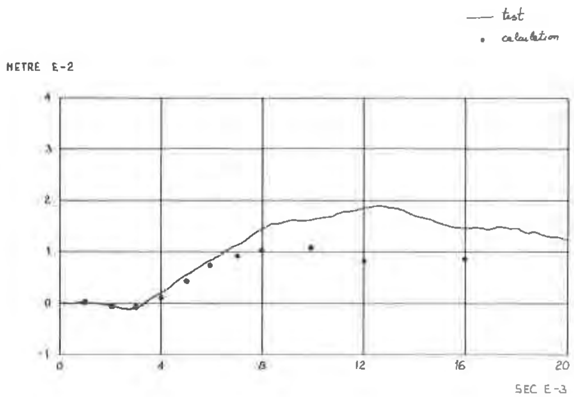

Fig. 8 Displacement history for the plug

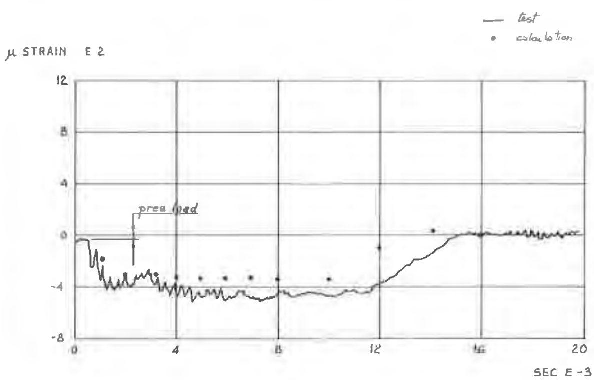

Fig. 9 Strain history for bolts connecting members

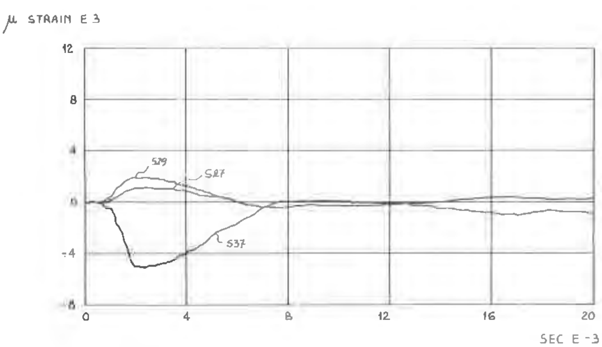

Fig.10 Strain history in S27, S29 and S37 points