Three Dimensional Dynamic Analysis of a Thick Reinforced Concrete Slab Subjected to the Impact of a Projectile

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ABSTRACT

The need to verify that thick floors are not perforated when a heavy low - speed projectile is falling down, has conducted us to develop a new method for the approximate design of steel reinforcement . Accurate calculations by the finite element method have been performed in some cases, and one of them is presented here.

1. INTRODUCTION

The objective of this paper is to show the calculations that have been processed by the Finite Element Code Plexus developped at the C.E.A./D.E.M.T. (1).

Our purpose was to verify that the reinforcement predicted by approximate method for dimensionning the slab was sufficient. The separating floor of the two cells of the building is thick and is subjected to the impact of a heavy-low-speed projectile ; no shear reinforcement is predicted, and this is the reason wy we are induced to work towards a three dimensional analysis.

2. DESCRIPTION OF THE HYPOTHESIS

The modelised slab is 11,33 m long. 3,95m large and 0,95m thick there is a hole near one side (dimensions 1.00 x 0,45m.)

A view of the finite element model is shown in fig.1a for the concrete and fig. 1b for the steel.

- the predicted reinforcement was :
  . 12 cm^2 /ml on upper face in the transverse direction
  . 12 cm^2 /ml on lower face in longitudinal direction
  . 32 cm^2 /ml on lower face in traverse direction

The reinforcement was placed proportionnaly as steel truss between the nodes of the finite element cubes, in each direction.

- As we want to study the center of the slab, we made the hypothesis that it was simply supported ; that is, all the nodes in the z (vertical direction) on the boundary of the slab were restrained.

- The impacting projectile is supposed infinitely rigid and is modelised as a mass attached on the upper part of the structure. Its total mass of 10.000 Kg is on a surface of 1 x 0,6 m and is put on 9 nodes of the model. The initial velocity is 7 m/s ; that is a initial impacting energy of 245.000 joules.

- As we used a Drucker Prager Criterion in Plexus (2) we have taken the following properties for the concrete :

. density	2500 kg/m^3
. Young modulus	4.10^{10} Pa Poison's ratio 0,15
. Stress limit in traction (uniaxial)	2,5 10^6 Pa
. Stress limit in compression (uniaxial)	25 10^6 Pa

- We used a Von Mises Criterion for the Steel, and the chosen properties are described below :

. density	7800 kg/m^3
. Young modulus	21 10^{10} Pa poison's ratio 0,3
. Stress limit in traction	420 10^6 Pa

the finite element model contained 2060 nodes, 1329 cubes and 1456 trusses.

3. RESULTS AND DISCUSSION

As we are interested in the maximum value of the defexion and in the state of the structure at this stage, the iterations were performed up to obtain a low velocity near the impacting points. That is, almost all the energy of impact is absorbed by the slab.

This calculation needed 300 iterations ; as Plexus is an explicit code the automatic chosen time increment was $1,4.10^{-5}$ s for all the iterations and the final time was $4,2.10^{-3}$ s (4,2 ms) the figure 2 shows the variation of the speed of points at and near the impact ; it can be seen that the velocity is tending to zero for all these points, at the end of the iterations that we have performed.

The figures 3 and 4 show the state of the slab and of the steel at the end of the calculation. The final kinetic energy was 19 000 Joules and so we can say that most of the impacting energy was input in the slab. The final deflection was 7,5 mm.

We then look at the state of the stresses and strains : the maximum values are under the impact surface and were obtained near the iteration number 50 that is at about 0,5 ms.

For the concrete, we look at the Von Mises Stresses on the upper and lower part of the the slab. They are shown on fig. 5 and 6.

The maximum values are : 110.10^6 Pa for the Von Mises (including shear effect) and 33.10^6 Pa for the hydrostatic pressure (1/3 first unvariant of Stresses).

So we can say that the concrete will be cracked on the face in tension (the lower face) and that it is not crushed on the upper face. The corresponding strains were 2.10^{-3} on the upper face, and 6.10^{-3} an the lower face. These maximum values were observed very close to the impact. The values in the other elements were lower.

For the steel, we also look at the stresses and strains. The evoluting values for some elements are shown is fig. 7 and 8. We can see that some reinforcing steel have become plastic. The maximum plastic strain was in this case 0,3% wich we think to be an acceptable value.

4. CONCLUSION

This study has permited us to verify that our design by approximate method was sufficient for proving that the slab is not perforated. We can say that cracks occur in the zone of impact and that the reinforcing steel will be in a plastic state for a few ms, but the integrety of the slab will be maintained.

REFERENCES

/ 1 / Systeme CASTEM-PROGRAMME PLEXUS (C.E.A./D.E.M.T.)

/ 2 / Le modèle de Drucker-Prager pour la rupture du béton dans le programme Plexus Système CASTEM (DEMT/SMTS/LAMS/82-14).

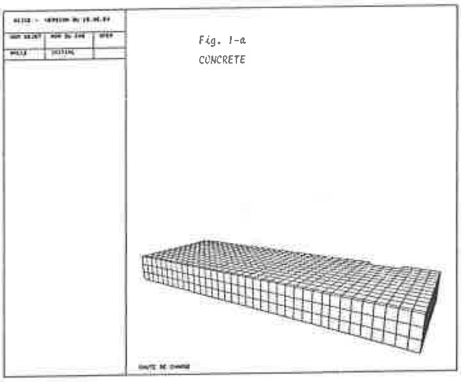

Fig. 1a CONCRETE

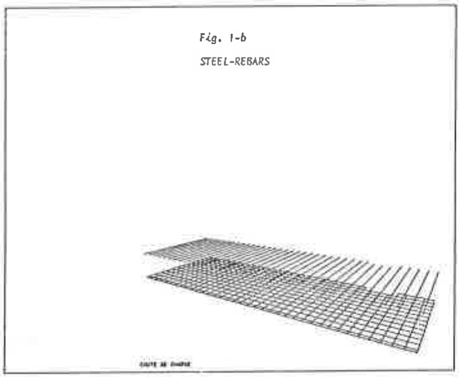

Fig. 1b STEEL-REBARS

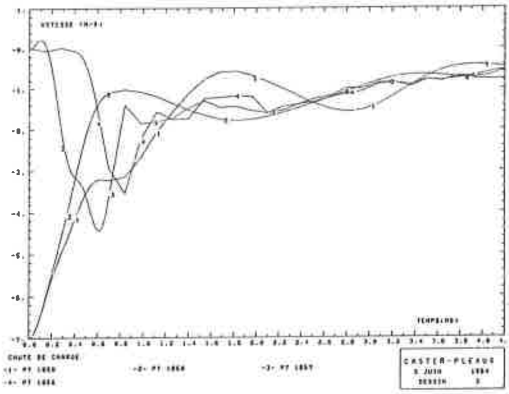

Fig. 2 SPEED OF IMPACTED POINTS

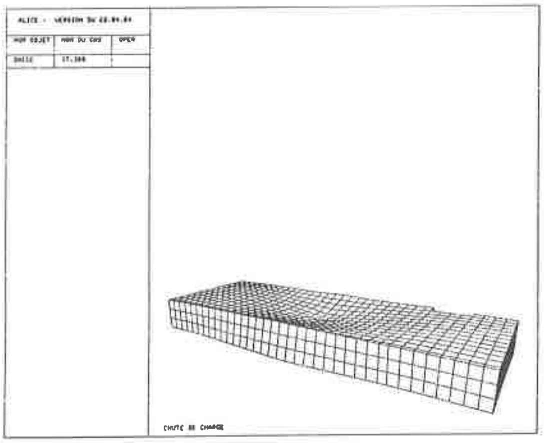

Fig. 3 DEFORMED CONCRETE

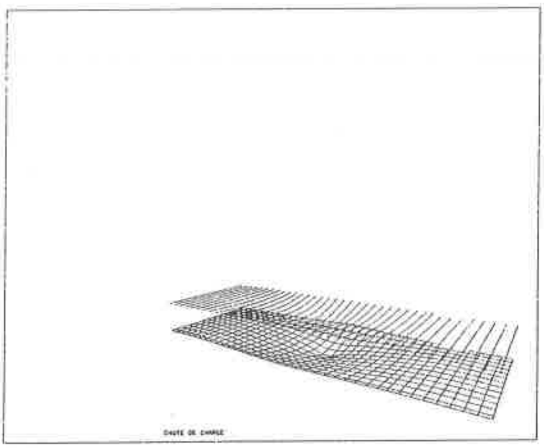

Fig. 4 DEFORMED STEEL

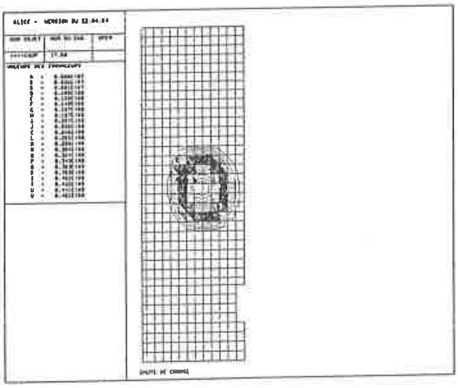

Fig. 5 VON MISES STRESSES UPPER FACE

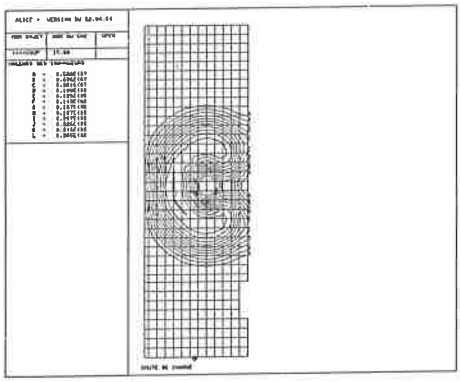

Fig. 6 VON MISES STRESSES LOWER FACE

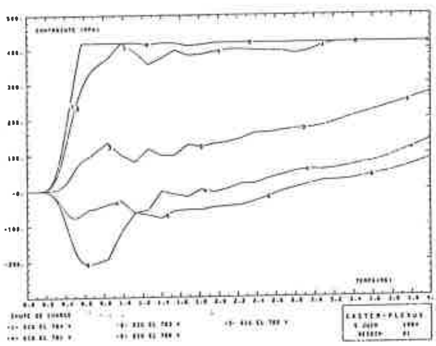

Fig. 7 STRESSES IN STEEL ELEMENTS

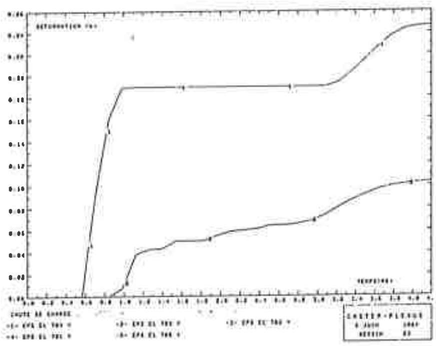

Fig. 8 STRAINS IN STEEL ELEMENTS