LOCAL BEHAVIOUR OF REINFORCED CONCRETE WALLS UNDER HARD MISSILE IMPACT

C. BERRIAUD
Département des Études Mécaniques et Thermiques.

A. SOKOLOVSKY
Département de Sûreté Nucléaire.
C.E.A. — Centre d'Études Nucléaires de Saclay, B.P. N° 2, F-91190 Gif-sur Yvette, France

R. GUERAUD, J. DULAC
Electricité de France, S.E.P.T.E.N. — Tour EDF/GDF, F-92080 Paris La Défense — Cedex N° 8, France

R. LABROT
C.E.S.T.A. — Service Expérimentation, B.P. N° 2, Le Barp, F-33830 Belin-Béliet, France

SUMMARY

Studies on extreme load conditions for reactor containment include aircraft crash hazards effects. This problem has still not been completely solved in a satisfactory way. In the case when a soft missile model may be considered computation leads to realistic assessment of the impact effects. On the contrary, in the case when hard missiles are involved, at present time only empirical ballistic formulae are used. Despite various former available formulae and experimental results describing impacts of hard missiles on concrete walls, one was not able to estimate damages with a sufficient reliability.

Since 1974 C.E.A. and E.D.F. developed in France a large programme with the aim to work out a means of computation reliable enough for the knowledge of the behaviour of reinforced concrete walls under missile impacts. The rough results of the first tests planned in this work were outlined in the ELCALA Seminar (Berlin 1975). In this paper are described the subsequent tests and the interpretation of the whole programme.

The shots were performed on reinforced concrete slabs, thickness of which were chosen to represent in a realistic way the thickness of the wall of a reactor containment. The scales used in this modelling were mainly one half and one third. In any case the similarity law used in this work is such to keep the value of velocity unchanged.

In a first step the following parameters were kept constant: thickness and properties of the concrete, reinforcement ratio, geometric shape of the missile. On the other hand were studied the effects of variation of parameters like the missiles velocity (90 to 200 m/s), the missiles diameter (0.2 to 0.3 m) and its mass (20 to 300 kg). This part of the work allowed us also to observe the importance of parameters like the ratio of the diameter of the projectile to the thickness of the slab as well as the ratio of the mass of the missile to the mass of a concrete cylinder with a diameter equal to the diameter of the missile and a height equal to the thickness of the slab.

Taking into account this first series of tests formulae for computation of a limit perforation velocity, \( V_p \), and of a minimum protection depth, \( e \), were worked out as functions of the characteristic parameters of projectile and wall, i.e. compression resistance \( \sigma \), and density \( \rho \), of the concrete as well as diameter \( \phi \), and mass \( M \), of the projectile. This may be summarized in a more general but less usefull formula which is:

\[
\frac{\rho V_p^2}{\sigma} = k \left( \frac{M}{\rho \phi^2 e} \right)^a \left( \frac{\phi}{e} \right)^b
\]

where \( k, a, b \) are experimental values.

In a second step it was tried to define the limits of validity of these formulae in the case of variation of the following parameters: ratio of the missile diameter to the thickness of the slab (0.24 to 2.9), velocity of the missile (25 m/s to 450 m/s), characteristics of the concrete, characteristics of the steel reinforcement, shape of the projectile. In the same time some tests with prestressed concrete were planned.

All results were compared to predictions computed by means of finite elements method. The main difficulty consists in the choice for the modeling of concrete supporting a rapidly varying load.