Modelling of a Reinforced Concrete Panel Subjected to Blast Load by Explicit Non-linear FE Code

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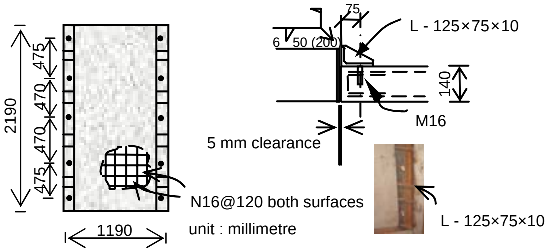
Summary: A 5000 kg TNT blast test was conducted at Woomera, South Australia on a reinforced concrete panel. This poster reports on the numerical analysis of the 1.19m×2.19m×0.14m RC panel under the blast load. Blast pressure time histories obtained from CONWEP and AIR3D generally agree with the pressure measured in the experiment. The dynamic structural behavior of the RC panel is modelled by the explicit numerical analysis code, LS-DYNA. The built-in CONWEP blast pressure in LS-DYNA was applied to the FE model. The comparison of the results obtained from numerical analysis and experiment demonstrates the capabilities of these software packages to simulate the structural behavior of a RC panel under explosion.

1. EXPERIMENTAL PROGRAM

The tested RC panel with 40 MPa compressive strength concrete was subjected to 5T TNT at 40m standoff distance. N16 reinforcing bars@120 mm spacing with minimum yield strength of 500 MPa were distributed in two directions inside both the front and rear faces of the RC panel. The maximum and rebound displacements of the tested panel were recorded by means of a mechanical device.



2. EXPERIMENTAL RESULTS

The displacement measurement device recorded a maximum deflection for the RC panel of 36 mm. By measuring deflection of the aluminium plate attached to the main measurement device, a 5 mm rebound of the tested panel was reported. Flexural cracks at the rear face and some spalling at the front face of the tested RC panel were observed from the blast test.

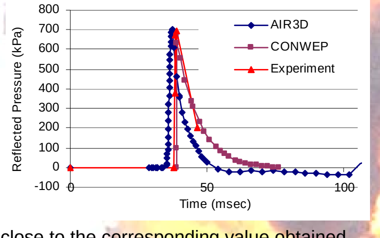
Rear Face (top part)

Rear Face (bottom part)

Front Face

3. BLAST PRESSURE PREDICTION AND MEASUREMENT

The blast pressure time histories predicted by an analytical model based on equations and curves of TM5-855-1, CONWEP and the Computational Fluid Dynamics (CFD) code, AIR3D are presented and compared to the measured blast pressure. The AIR3D program predicts the peak reflected overpressure close to the corresponding value obtained from the experiment as shown in the graph above.



4. NON-LINEAR FINITE ELEMENT ANALYSIS

A simulation of the dynamic behavior of the 1.19m×2.19m×0.14m panel was performed by using commercial software, LS-DYNA. The concrete model (MAT_CONCRETE_DAMAGE_REL3) which considers three failure surfaces, i.e. initial yield failure surface, maximum failure surface and residual failure surface, was used to model concrete.

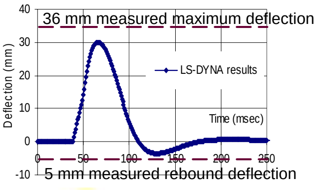
$$\Delta\sigma_m = a_0 + \frac{p}{a_1 + a_2 p} \qquad \Delta\sigma_r = \frac{p}{a_{1f} + a_{2f} p} \qquad \Delta\sigma_y = a_{0y} + \frac{p}{a_{1y} + a_{2y} p}$$

Maximum failure surface	Residual failure surface	Yield failure surface
$a_0 = 1.182\times10^{7}$ $a_1 = 0.4463$ $a_2 = 2.02\times10^{-9}$	$a_{1f} = 0.4417$ $a_{2f} = 2.958\times10^{-9}$	$a_{0y} = 8.928\times10^{6}$ $a_{1y} = 0.625$ $a_{2y} = 6.438\times10^{-9}$

Automatic input data generation (pressure unit : N/m²)

The boundary conditions of supports were achieved by restraining the translation in the x- and y-directions at nodes located at the positions of the centre line of L-125×75×10 mm in the tested RC panel. By using the blast impulse obtained from CONWEP, the ratio of time to reach maximum displacement and blast positive phase duration (t_m/t_d) was around 0.47. This value corresponds to the pressure loading regime instead of impulsive loading regime. Even though the impulse reported by CONWEP is much higher than the measured impulse, this does not significantly affect the behavior of the panel under the blast pressure loading regime. Therefore, the built-in CONWEP blast pressure in LS-DYNA was applied to the FE model with reasonable confidence.

Maximum and rebound deflections obtained from numerical analysis compared to the observed values.



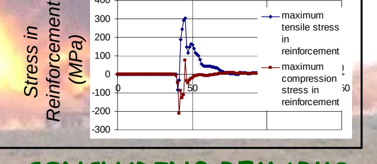
Contours of the damage parameter of concrete at the rear and front faces of the analysed panel.

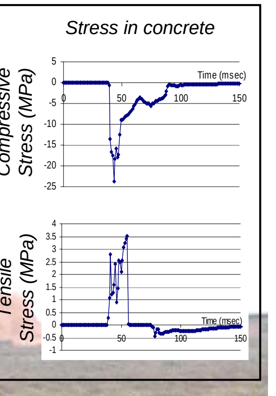
Rear Face

Front Face

5. STRESS IN CONCRETE AND REINFORCEMENT

The maximum concrete compressive stress of 23.8 MPa (60% of the concrete compressive strength) is reported. The calculated concrete tensile strength, based on CEB-FIP (1990), is 3.55 MPa which is close to the maximum concrete tensile stress reported by LS-DYNA (3.5 MPa). Only 300 MPa of tensile stress and 200 MPa of compression stress have been reached in the N-16 reinforcement.





6. CONCLUDING REMARKS

Blast pressure time histories obtained from CONWEP and AIR3D generally agree with the pressure measured in the experiment. This study shows that the behavior of a RC panel under blast loads can be simulated with a reasonably acceptable accuracy by the explicit non-linear finite element program LS-DYNA.