University of Cassino and Southern Lazio, Italy

INVESTIGATION ON BLAST RESISTANCE OF PRECAST REINFORCED CONCRETE FLOOR SLAB

Bonora N. | Gentile D. | Iannitti G. | Marfia S. | Ruggiero A. | Sacco E. | Testa G.

Department of Civil and Mechanical Engineering

Introduction

The knowledge of the effective blast resistance of civil infrastructures is a fundamental information for risk assessment and modelling consequences of terrorist attack in high population density urban environment.

In this work, blast resistance of precast reinforced concrete floor slab, commonly used for commercial parking, was investigated performing blast tests, detonating bare explosive charge of EXEM 100 in contact with the slab. The charge mass was varied in order to generate different damage extents, from visible to fully breached condition.

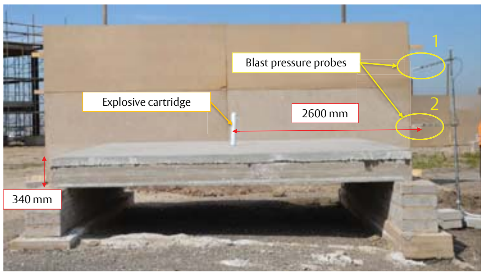
Numerical simulations of the tests were performed considering all slab structural elements with the aim of analyzing the failure modes of the slab.

Experiments

Setup

Explosive cartridges were vertically positioned at the center of the slab to maintain symmetries and facilitate numerical simulations.

Blast pressure profiles were measured at two different distances, in order to obtain different amplitudes and arrival times, to be used in the comparison with the calculated signals.



Test results

2.1 kg – 1 explosive cartridge.
Damage visible only on the top of the slab.

Crater size:

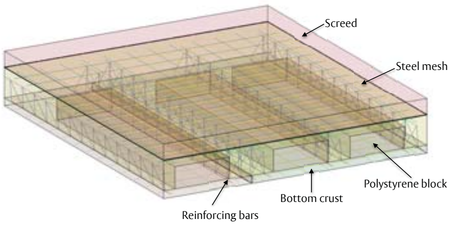
- diameter 230 mm;
- depth 50 mm.

6.3 kg – 3 explosive cartridges.
Crater on the top and bulging on the bottom.

10.5 kg – 5 explosive cartridges. Slab fully breached.

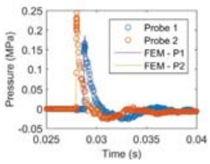
Numerical simulation

Numerical simulations were performed with the explicit commercial finite element code LS-DYNA. The explosive and blast wave-structure interaction were simulated using arbitrary Lagrangian-Eulerian method (ALE).

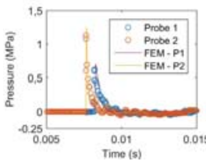


Blast wave calibration

Detonation law was set with the command MAT_HIGH_EXPLOSIVE_BURN [1]. EoS : Jones-Wilkins-Lee.



Blast pressure profiles: 2.1 kg



Blast pressure profiles: 10.5 kg

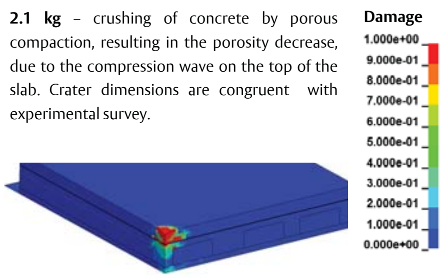
Slab elements constitutive modelling

Strength and failure behaviour of the steel used for meshes and reinforcing bars were described by the Johnson & Cook model [2-3].

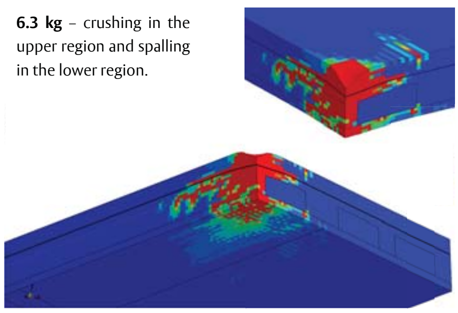
Mechanical behaviour of concrete was described by the Riedel-Hiermaier-Thoma model [4]. The model couples an EoS, that accounts for the porous compaction of concrete, with a strength model composed of three limit surfaces accounting for pressure, stress triaxiality and strain rate. Model parameters were calibrated on breach size and shape observed in the experiments.

Numerical results

2.1 kg – crushing of concrete by porous compaction, resulting in the porosity decrease, due to the compression wave on the top of the slab. Crater dimensions are congruent with experimental survey.

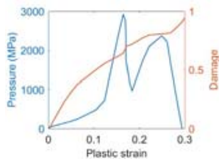


6.3 kg – crushing in the upper region and spalling in the lower region.

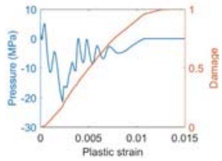


Pressure and damage profiles on top and bottom surfaces confirm the occurrence of two distinct failure modes.

- Crushing in the upper region is associated to an intensive compression wave.
- Spalling in the lower region is produced by the tensile wave generated by the reflection of the compressive wave at the free bottom surface.

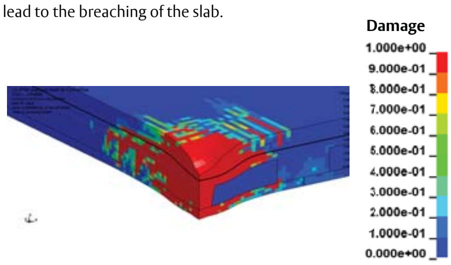


Pressure and damage paths on the top surface (6.3 kg)



Pressure and damage paths on the bottom surface (6.3 kg)

10.5 kg – due to the higher energy in play, the two failure modes lead to the breaching of the slab.



For all configurations:

- ➢ damage extension at the bottom surface is correctly predicted;
- ➢ damage calculated in the interior of the slab is more extensive than on the lower and upper surfaces, in agreement with experimental observation.

Conclusions

- Blast tests were performed on precast reinforced concrete floor slab using different charge masses.
- A numerical model for simulating the blast tests was realized. Once constitutive models parameters have been calibrated, the damage status calculated in all configurations was found to be in good agreement with experimental observations.
- Two different damage mechanisms of concrete were identified: crushing by porous compaction and spalling.

References

[1] "LS-DYNA - Keyword user's manual," ***vol. I, LS-DYNA R7.1***, 2014.

[2] Johnson G.R. and Cook W.H., ***7th International Symposium on Ballistics***, The Hague, The Netherlands, 1983.

[3] Johnson G.R. and Cook W.H., ***Engineering Fracture Mechanics***, Vol. 21, 1985.

[4] Riedel W., Thoma K., Hiermaier S., and Schmolinske E., ***Proc. 9 ISIEMS***, Berlin Strausberg, 1999.

Contact information

- Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Cassino I-03043, Italy
- Email: **nbonora@unicast.it**
- **www.cdmunicas.it**