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DEPARTAMENTO DE CIENCIA DE MATERIALES

CISDEM
CENTRO DE INVESTIGACIÓN EN SEGURIDAD
Y DURABILIDAD ESTRUCTURAL Y DE MATERIALES

Blast response analysis of reinforced concrete slabs. Experimental procedure and numerical simulation.

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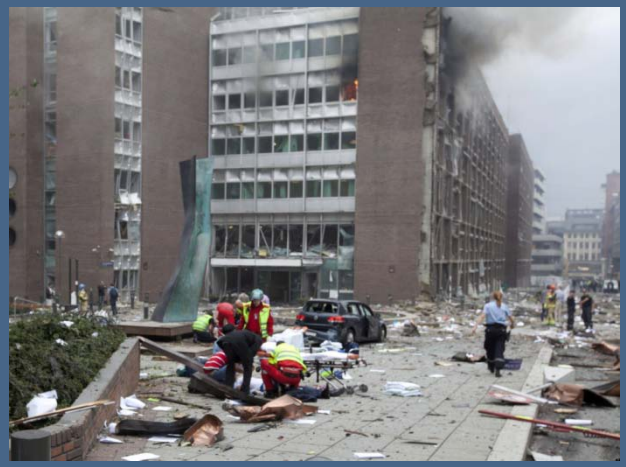
Blast response analysis of reinforced concrete slabs.

Experimental procedure and numerical simulation.

- Introduction
- Experimental Program
- Numerical Simulation
- Conclusions

December 30th, 2006. Madrid-Barajas Airport, Spain

April 19th, 1995. Oklahoma, USA



July 22nd, 2011. Oslo, Norway

Scope: Numerical Simulation ⇨ Constitutive Models for RC

Most of currently used models: Plasticity – based, complex in compression, simple in tension

Validation of existing models requires experimental results

Blast tests results are not easy to find in scientific literature

New experimental set – up for blast tests & numerical simulations with existing models are presented

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Experimental Program

Threefold goal:

- Generate open results of blast tests on RC elements
- Identify main parameters governing material & structural response
- Validation, adjustment and development of numerical tools

New set – up for testing up to four RC samples subjected to blast

Design criteria of experimental set – up:

1. Up to four slabs are to be tested with each detonation

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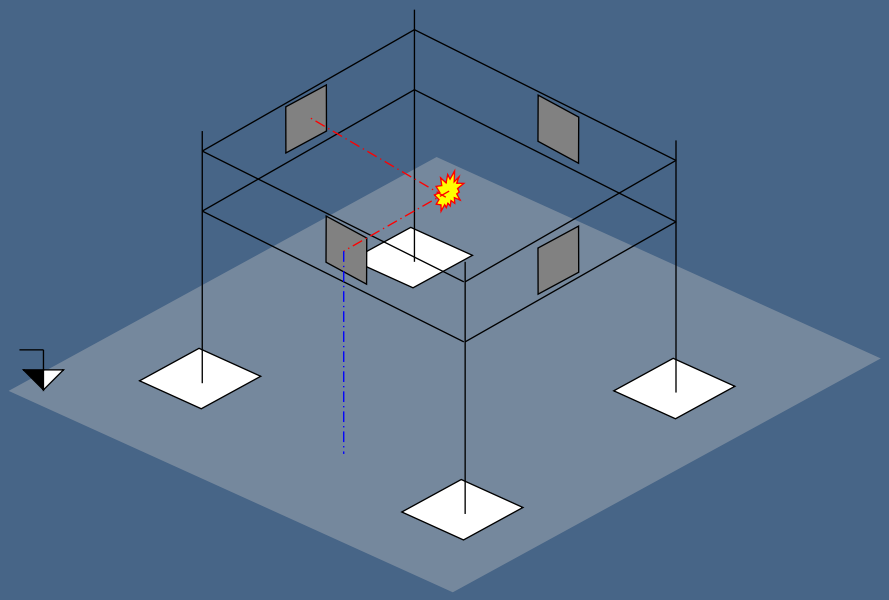

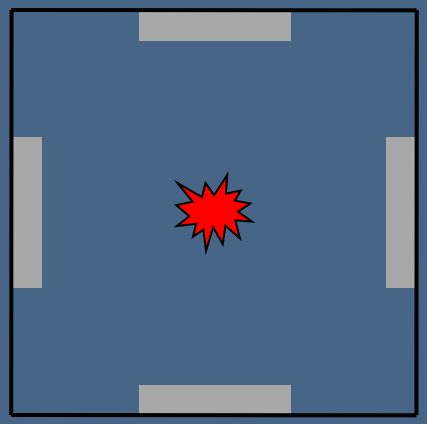

Design criteria of experimental set – up:

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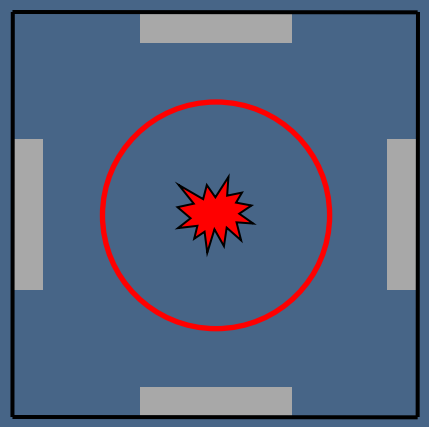

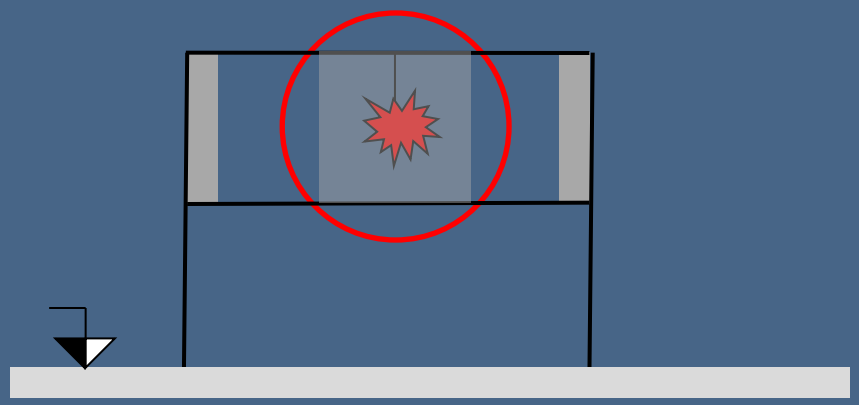

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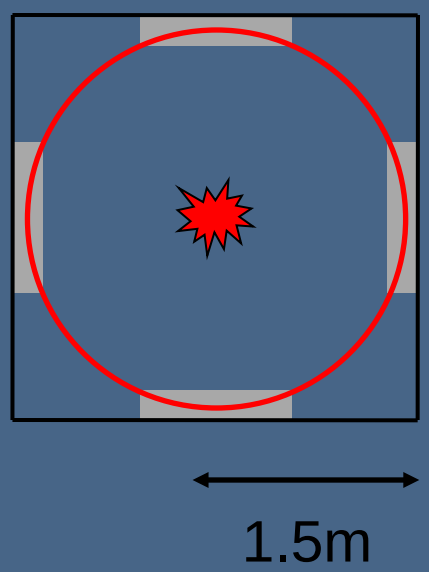

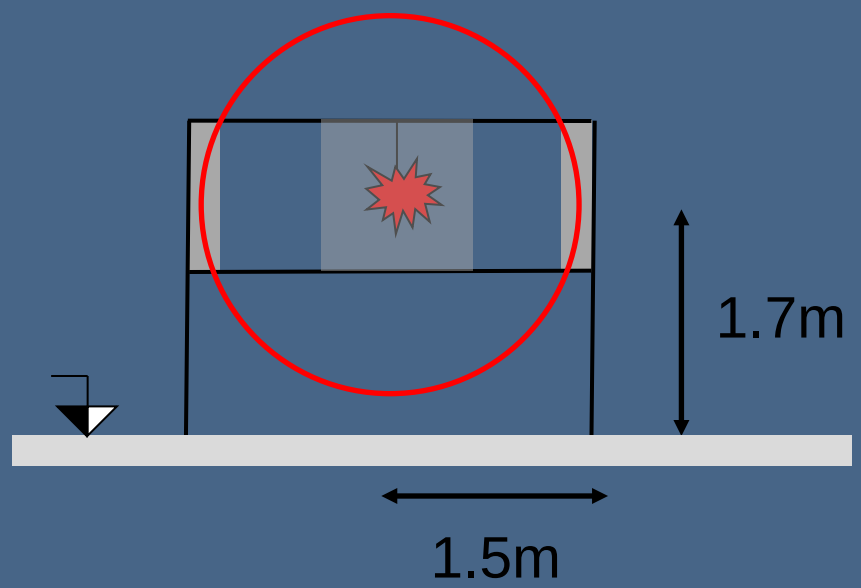

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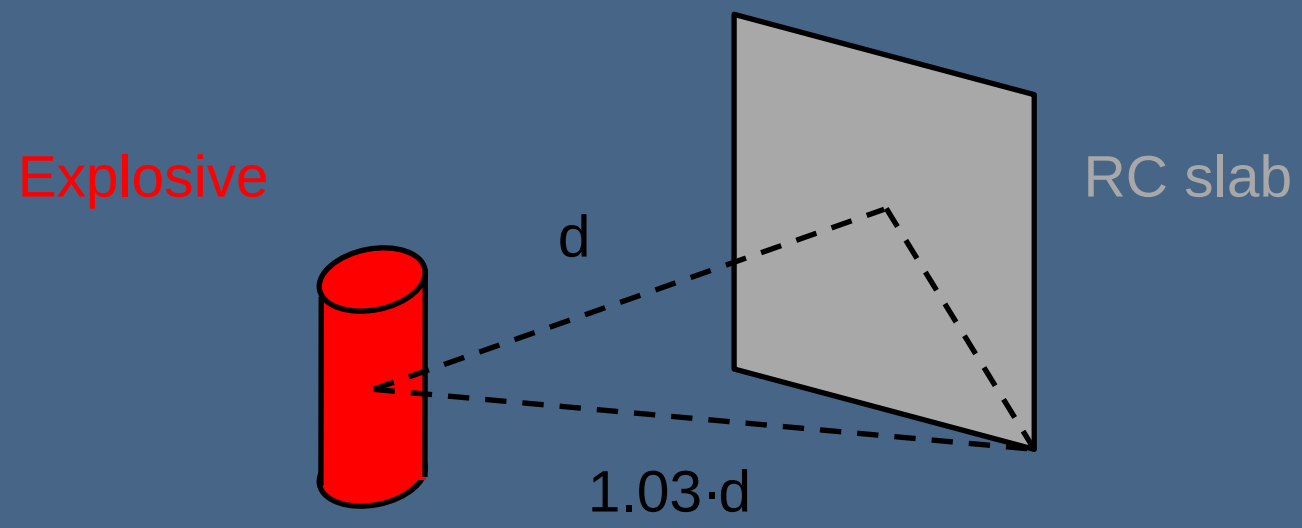


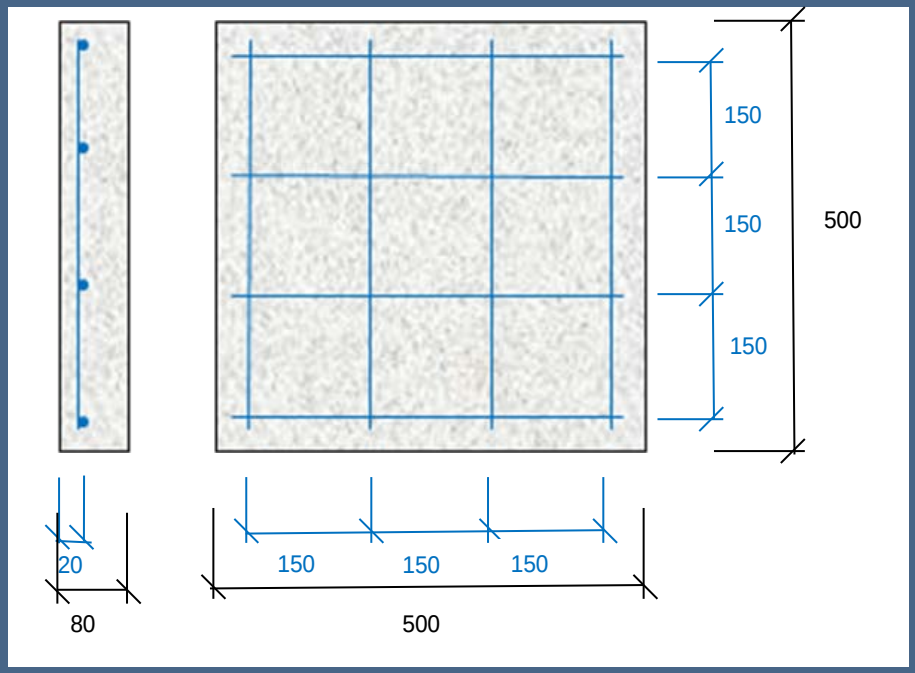
Experimental set – up :

Major assets of the of experimental set – up:

1. Control of experimental scattering
2. Cost effectiveness: reduction of complexity and time expenses

Materials:

Reinforced concrete slabs:



Six slabs of Normal Strength Concrete (NSC) σ_c = 50 MPa
Six slabs of High Strength Concrete (HSC) σ_c = 91 MPa

Experimental procedure:

- The amount of explosive was the same in every detonation, and equivalent to 5 kg TNT
- The explosive was hung with its axis vertical and detonated from its center

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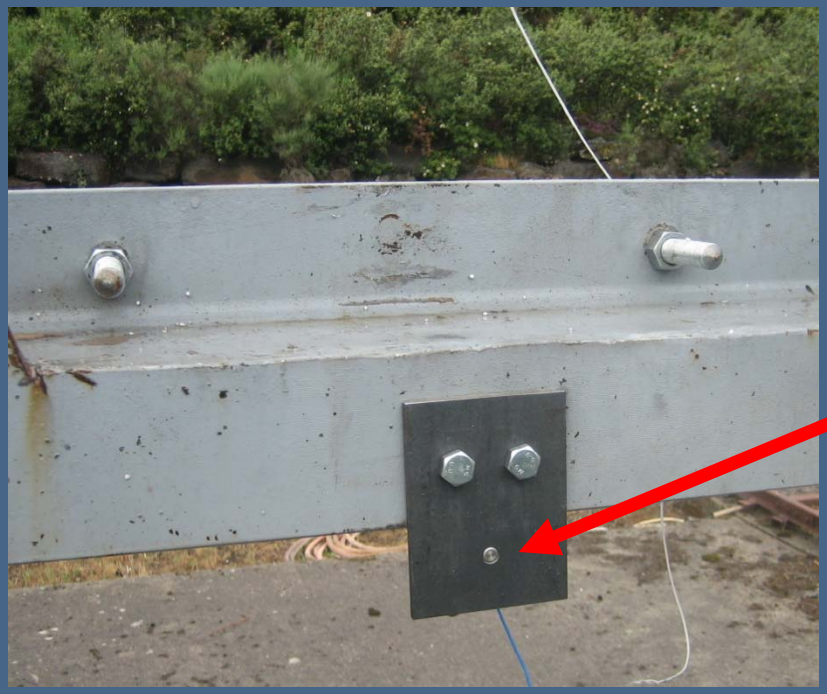
- The amount of explosive was the same in every detonation, and equivalent to 5 kg TNT
- The explosive was hung with its axis vertical and detonated from its center
- Three out of the four positions were used for reinforced concrete slabs of the same type
- On the fourth position, a control Aluminum (5083 H112) plate was placed

Instrumentation:

1. Pressure sensor for the measurement of reflected pressure



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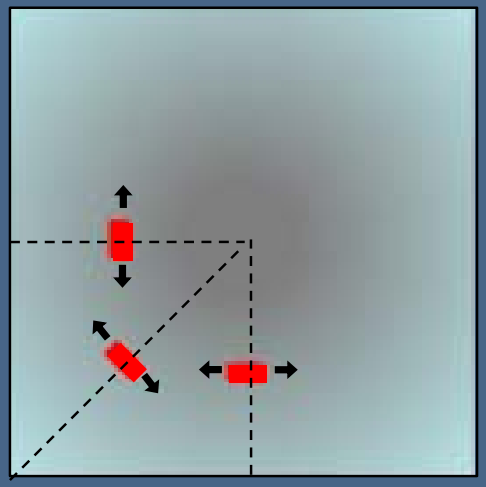
3. Control Aluminum plates with strain gauges



Instrumentation:

1. Pressure sensor for the measurement of reflected pressure
2. Filming of crack pattern development on tensioned side of slab
3. Control Aluminum plates with strain gauges
4. Control of rear spalling projections

Results on Normal Strength Concrete (tests #6 & #7):

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Bending failure mode Shear failure mode

Results on High Strength Concrete (tests #8 & #9):

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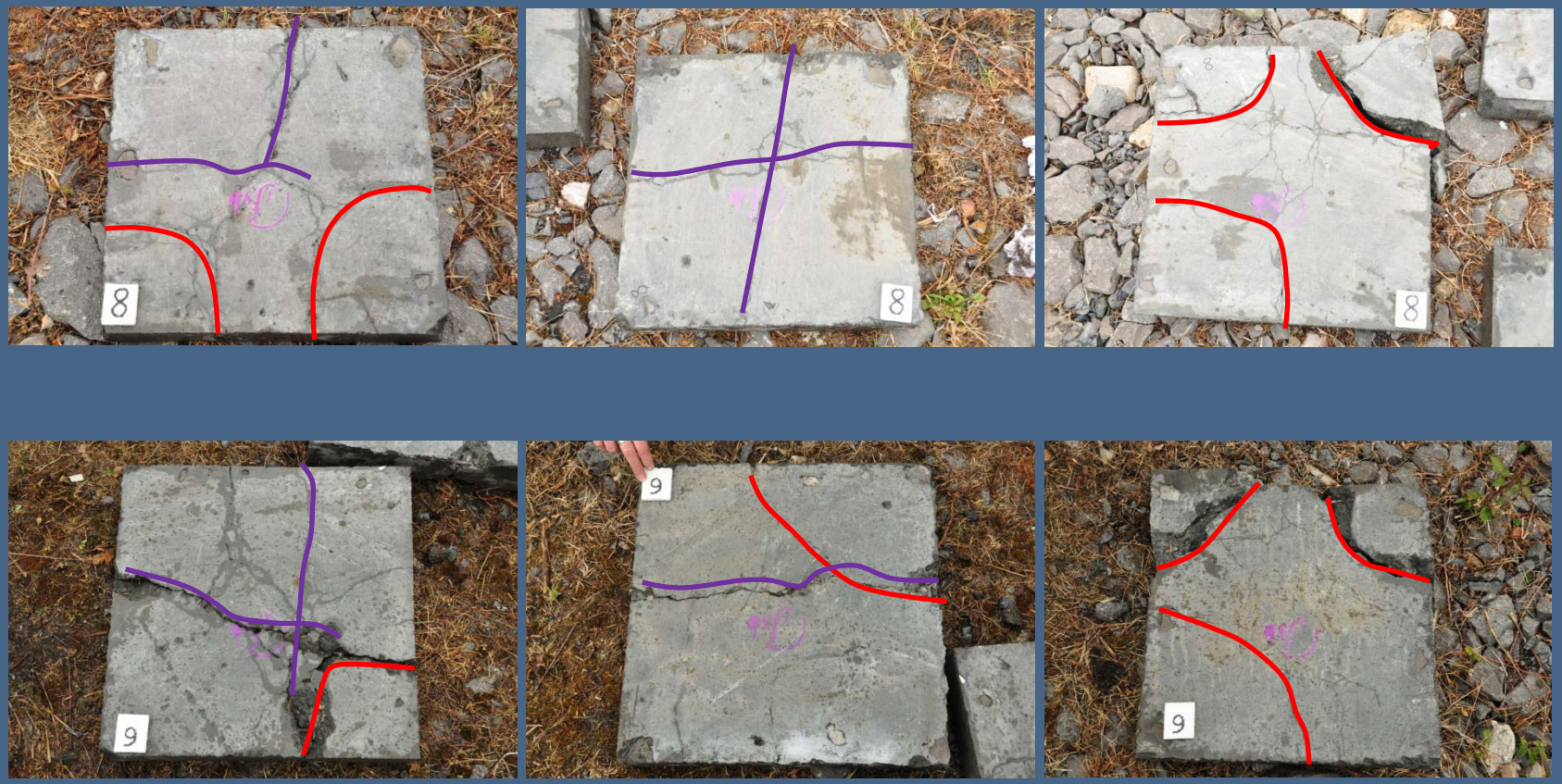

Bending failure mode Shear failure mode

Results:

Concrete type	Failure mode (number of specimens)		
	Bending	Shear	Mixed mode
Normal Strength Concrete	1	5	0
High Strength Concrete	2	2	2

The ability of both concrete types to withstand the same explosive load is similar.
This is blamed on the tension strength of concrete, which is thought to be governing the failure of the slabs.

Results:

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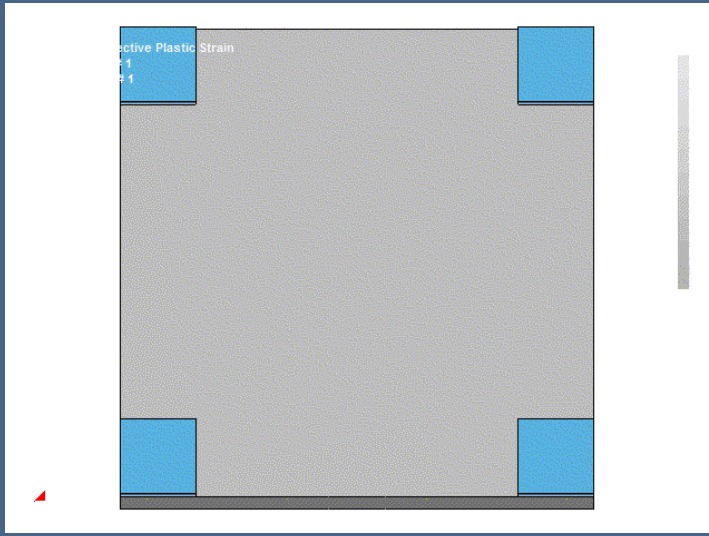
Finite Element Analysis with LS-DYNA

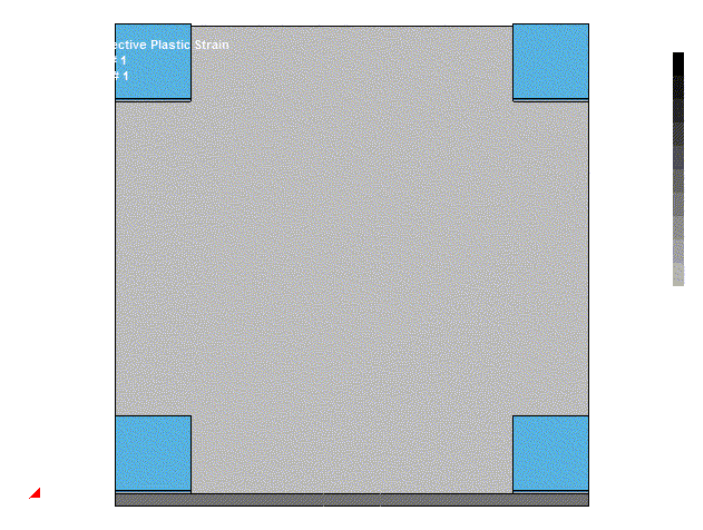
Twofold goal:

- Analyze the experimental results obtained
- Verify the adjustment of existing constitutive models:
    - Model #1: Winfrith Concrete Model
      Plasticity - based
      Compressive behavior: Ottosen surface failure
    - Model #2: Brittle Damage Model
      Compressive behavior: Linear elastic (no failure)

Concrete slabs simulation:

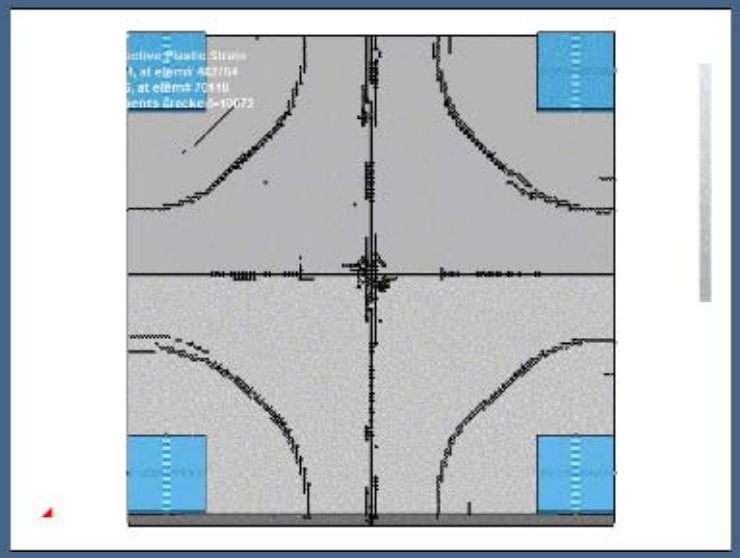


Winfrith Concrete Model

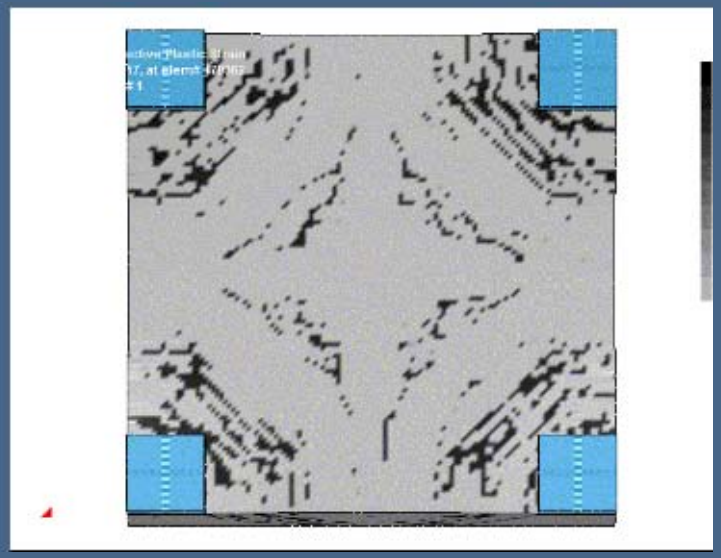


Brittle Damage Model

Concrete slabs simulation:



Winfrith Concrete Model



Brittle Damage Model

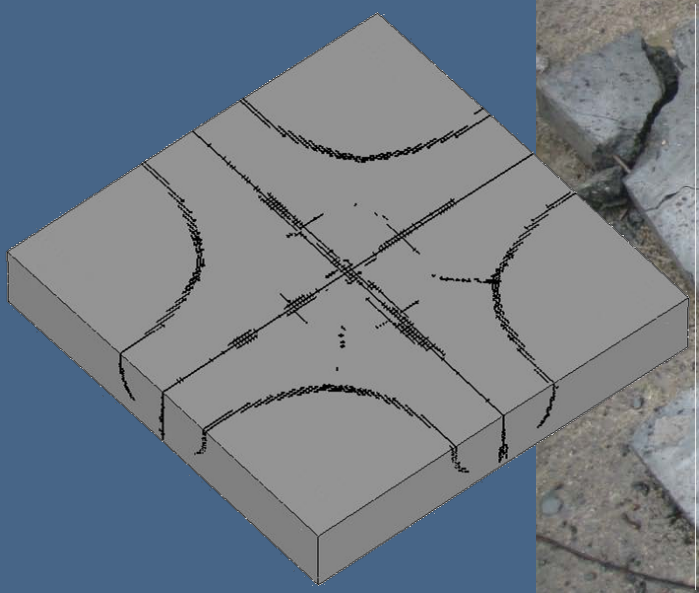
Concrete slabs simulation. Results on Normal Strength Concrete:

Winfrith

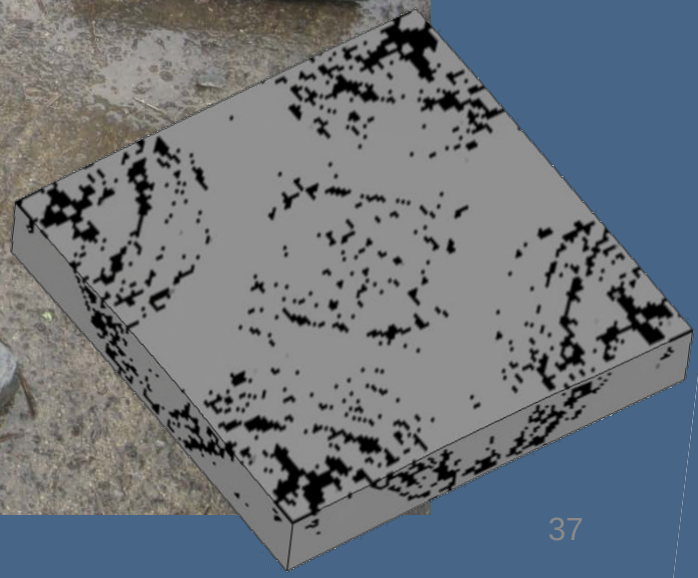
Brittle Damage

Concrete slabs simulation. Results on High Strength Concrete:

Winfrith



Brittle Damage



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Conclusions

An experimental set – up that allows testing up to four RC elements under the same blast load is presented

The results from the experimental program suggest that the ability of RC structures to withstand blast loads is primarily governed by its tensile strength

Numerical simulations on LS-DYNA show that good results can be achieved using simplified material models with suitable cracking and tensile failure criteria

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