Current testing facilities at The University of Sheffield

Summary

Designing systems to mitigate the effects of explosive events requires a robust understanding of the loading imposed by the expected threat. The development of reliable constitutive models for protective structures and burial media also requires careful characterisation to high pressures.

Unique testing facilities developed at The University of Sheffield enable high-pressure multi-axial material testing, and allow the temporal and spatial variation of blast loading on a target to be quantified for specific configurations of explosives and burial conditions.

High-pressure characterisation: mac^{2T}

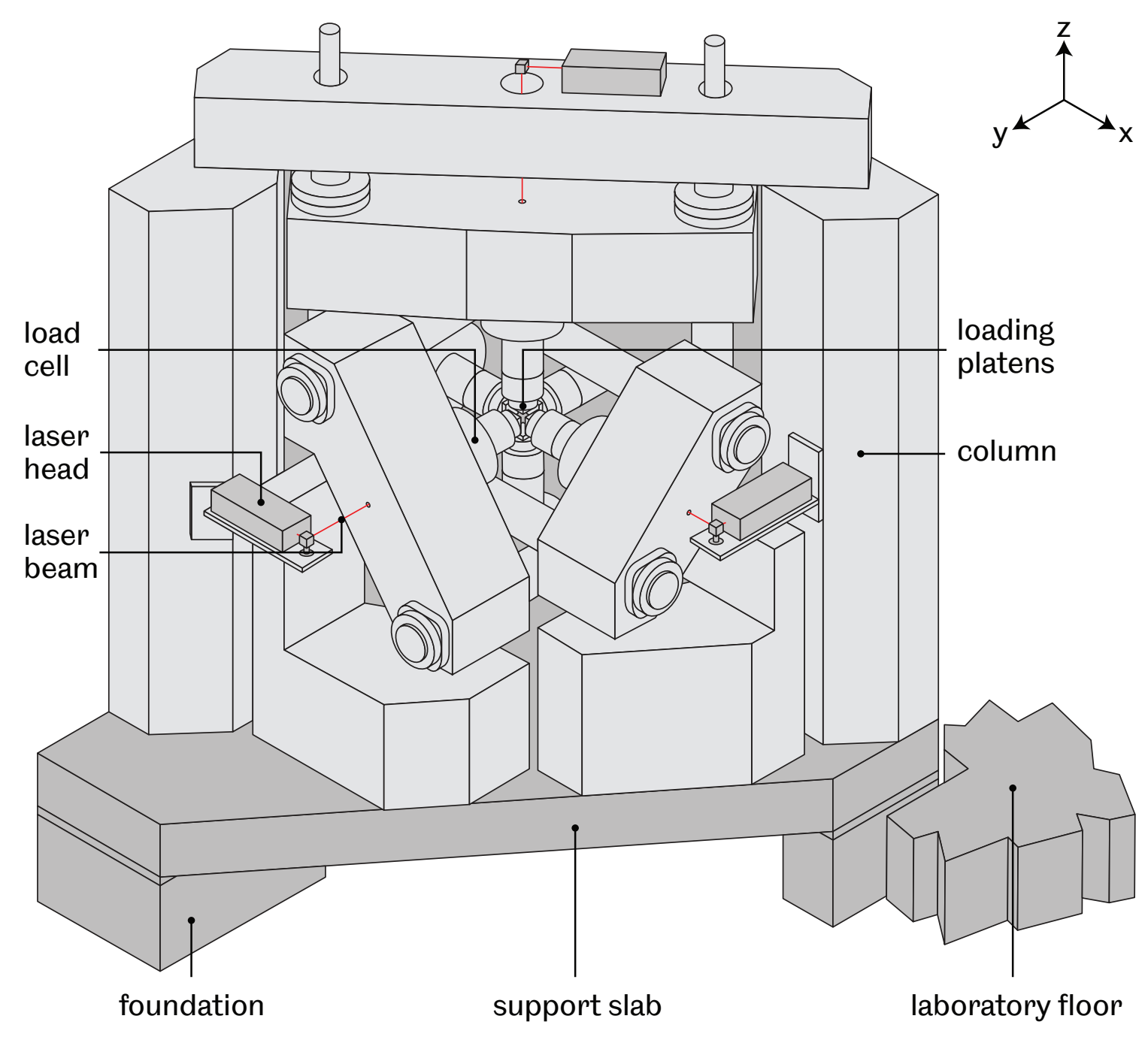


Fig. 1 – The mac^{2T} test rig.

- True multi-axial compression ($\sigma_x \neq \sigma_y \neq \sigma_z$)
- Load or displacement boundary conditions on each axis
- 4 MN hydraulic actuators in independent loading frames
- Three load cells rated at 4 MN, accurate to ±4 kN
- Six laser interferometer units, accurate to ±1 μm

Soil testing box

Cohesionless materials such as soils can be tested by placing them in a steel test box (Figure 2), which enables the initial conditions to be controlled. The geometry of the test box platens permit high stresses of over 1 GPa to be generated.

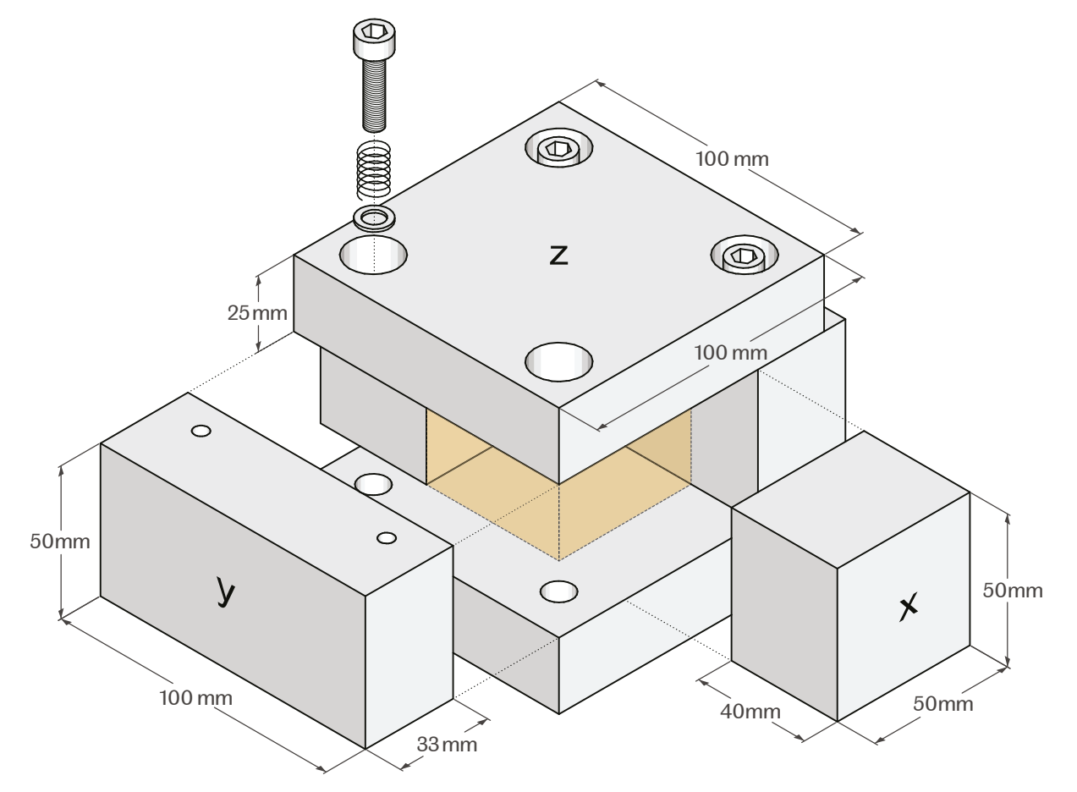


Fig. 2 – Test box for cohesionless materials.

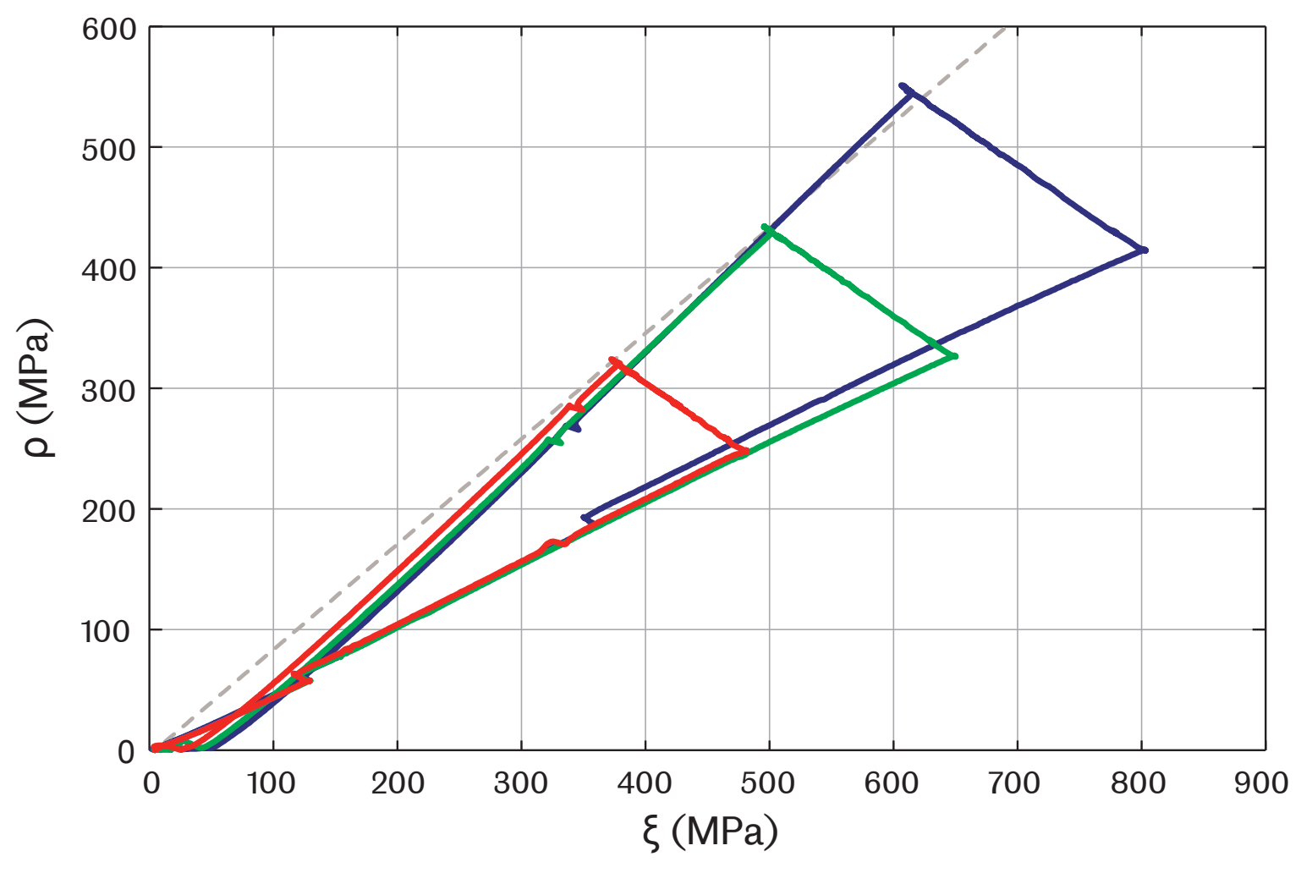
One-dimensional compression

One-dimensional compression at high stresses has been successfully applied to sands and clays by loading the x-axis while holding the y- and z-axes at zero strain. Figure 3 shows a specimen of dry quartz sand after loading axially to 800 MPa: a sufficient pressure to form a weak sandstone material.

Fig. 3 – Dry sand specimen after compression to 800 MPa.

Multi-axial loading and failure surfaces

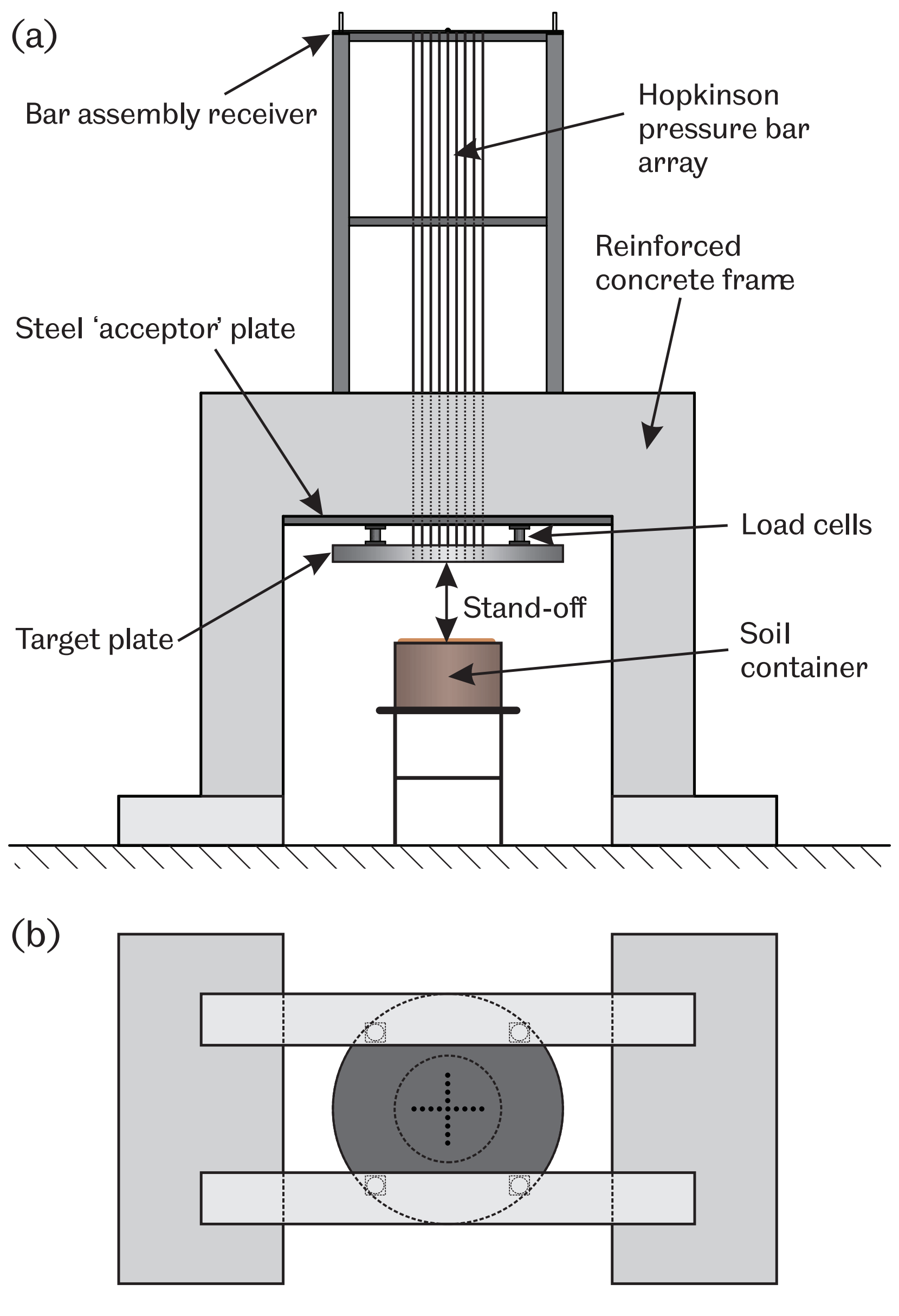
The mac^{2T} rig has also been used to locate the failure envelope of a quartz sand at very high stresses, achieved by loading hydrostatically and then reducing the lateral stresses to failure. An example of the stress paths used is shown in Figure 4. Arbitrary stress paths can be adopted as the axes are controlled independently.



ξ – Hydrostatic stress = $\frac{I_1}{\sqrt{3}}$ ρ – Deviatoric component = $\sqrt{2J_2}$

Fig. 4 – Potential failure surface of a quartz sand at very high pressures.

Spatial and temporal variation of blast loading: CoBL



- Steel fibre and bar reinforced concrete frames
- 100 mm thick steel plate fixed to frames via load cells
- Arrays of 10 mm Hopkinson bars arranged flush to plate surface
- Four radial arrays with bars at 0, 25, 50, 75 and 100 mm offset
- Buried charges prepared with close control over geotechnics

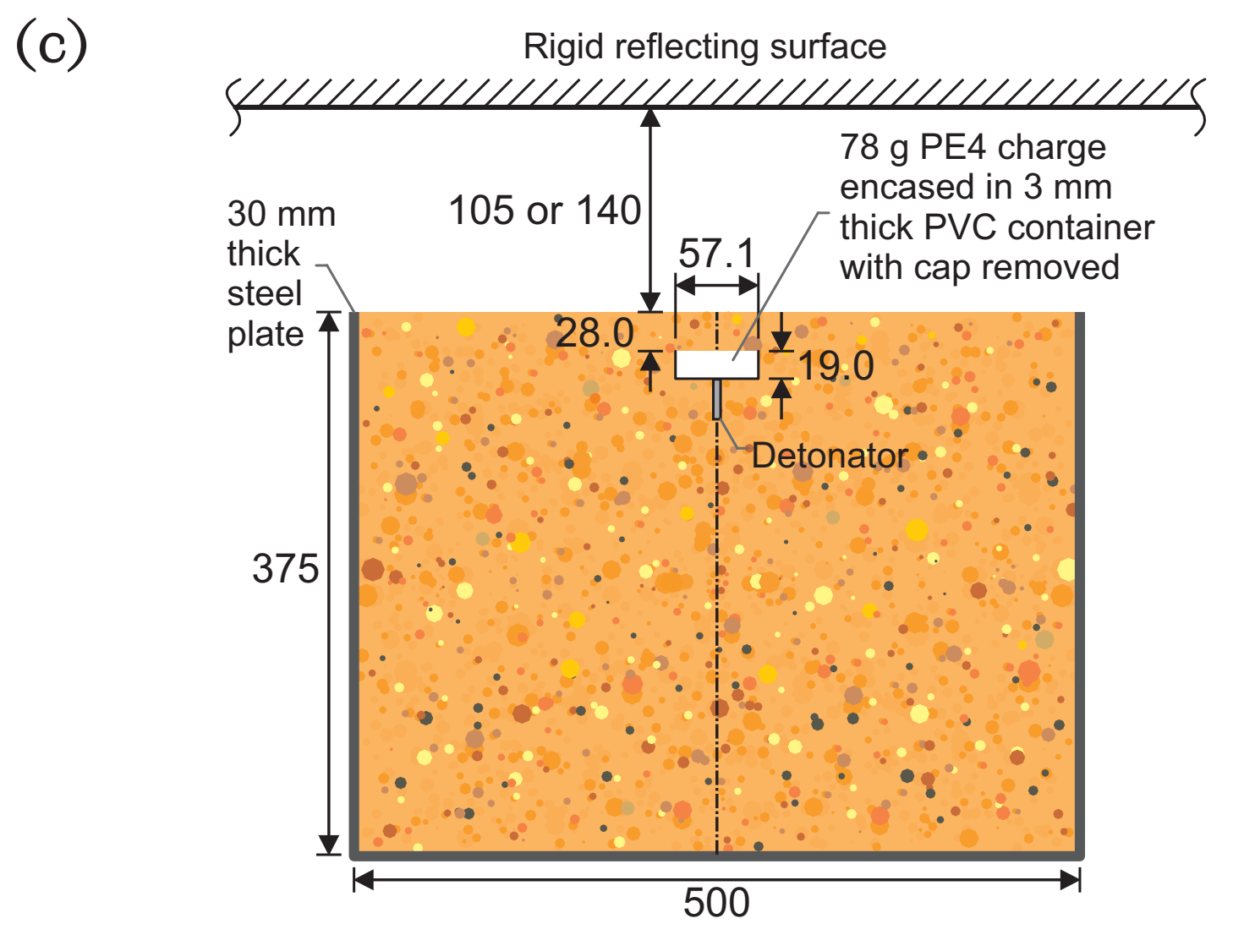


Fig. 5 – CoBL rig: a) elevation, b) plan and c) arrangement of buried charges.

Quantifying phenomena in buried explosive events

The high-speed photography and interpolated pressure measurements in Figure 6 illustrate the loading generated by a charge buried in partially-saturated sand.

The incorporation of four pressure bar arrays allows the asymmetric nature of the loading to be analysed in detail with respect to observable phenomena, including:

- Soil bubble expansion
- Detonation product breakout
- Soil ejecta and particle barrage
- Pre-cursor shock waves
- Afterburn

The ability to reliably identify and quantify these effects spatially and temporally enables numerical modelling of these events to be validated more rigorously.

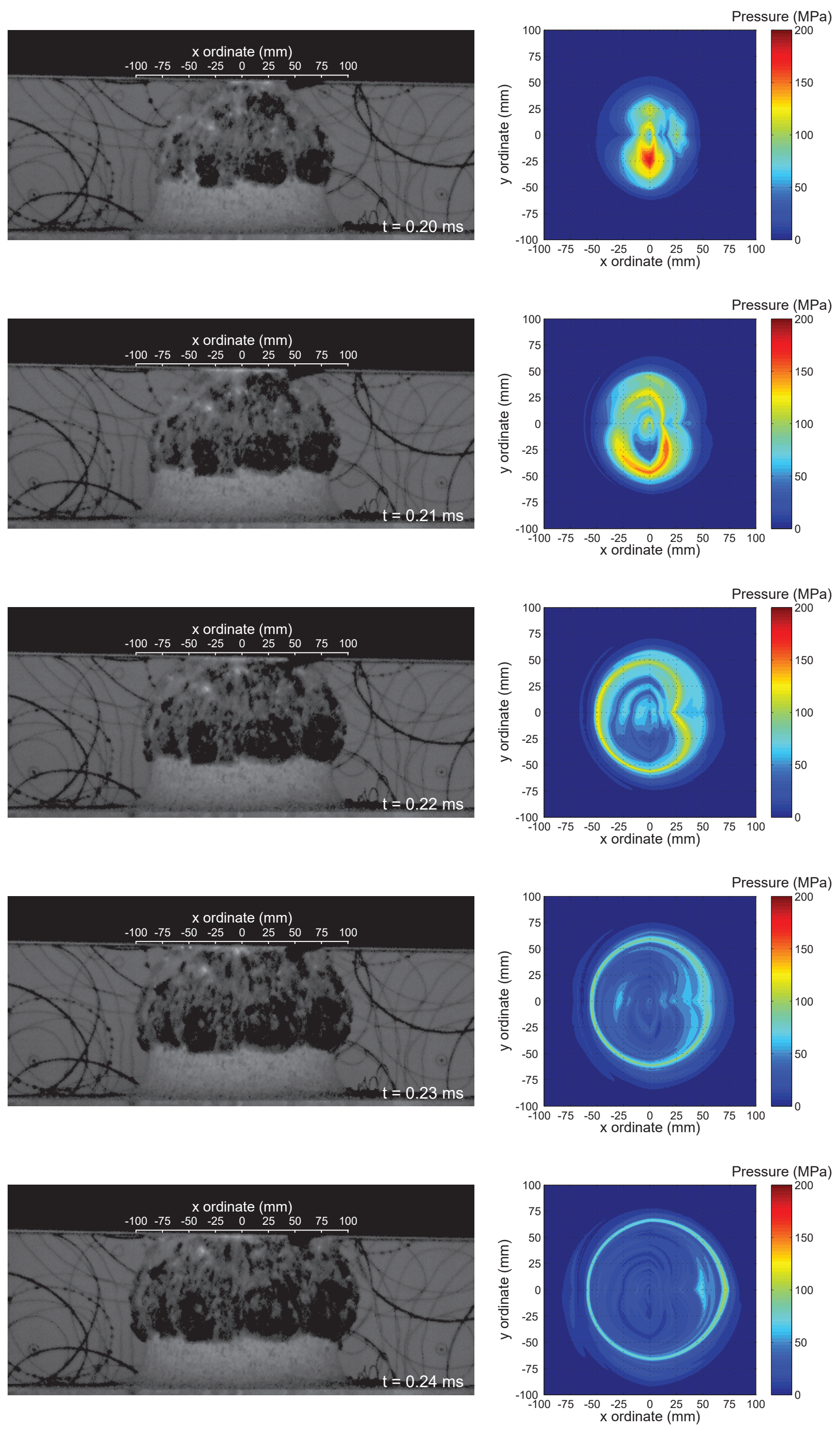


Fig. 6 – Synchronised high-speed video stills and interpolated pressures.

Andrew Barr
a.barr@sheffield.ac.uk

Sam Rigby
s.rigby@sheffield.ac.uk

Sam Clarke
sam.clarke@sheffield.ac.uk

Steve Fay
s.fay@sheffield.ac.uk

Department of Civil and Structural Engineering
The University of Sheffield, Sheffield, UK.