A combined approach to the investigation of the mechanical response of aluminium foam panels to localised contact damage

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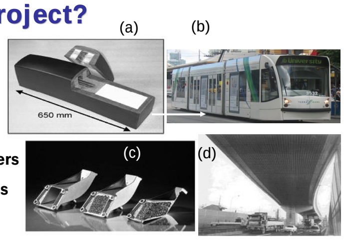
ARC Centre of Excellence
Design in Light Metals

Summary of project

Localised damage is experimentally simulated by indentations with various indenters: long flat-end, long cylindrical and a flat-bottom cylindrical punches. During indentation, panels fail by cell crushing and cell wall tearing. An energy formalism was utilised to model the panel resistance to crushing, and the experimental *P-h* curves were used to estimate the tear energy and absorbed energy. An analysis was undertaken to develop relationships between the foam core material properties, and the indentation parameters and panel thickness.

Why this project?

Why aluminium foam sandwich panels?



Transportation: (a) sacrificial crash boxes
(b) crash energy absorbers
(c) mechanical vibration absorbers

Sound absorption: (d) in halls and underside bridges

What do we want to achieve?

Material properties of foam: yield strength of parent material; compression σ-ε curve

Deformation response to local damage: failure modes: crushing + tearing; energy absorption; influence of density and panel thickness

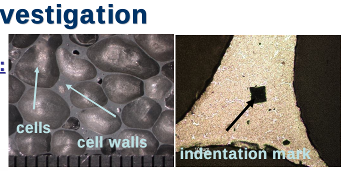
How do we achieve this?

Combine approach: experimental + analytical + numerical studies

Experimental investigation

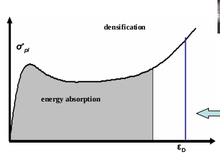
Yield strength of parent material (ALPORAS):

Micro-indentation: with Vicker's indenter:



Top view   Cell wall

Uniaxial compression



Stress-strain diagram

Local contact damage simulated by indentation:

- 2D deformation - plain strain: Long flat punch; Long cylindrical punch
- 3D deformation: Flat-bottom cylindrical punch; Hemispherical punch

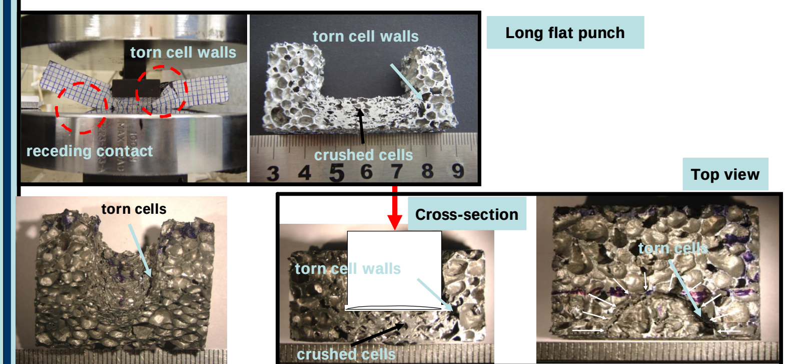
Conclusions

- In shallow and deep indentations of foam panels, panel thickness has an effect on deformation response only if indentation strain is greater than densification strain, when the foam is assisted by a back support
- Large scattering in results is observed in thin panels
- An analytical model is developed for crushing resistance in all indentations, which utilizes the uniaxial test results

Micro-structural deformation mechanism

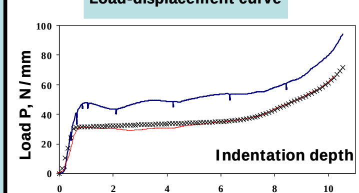
Panels: 8 to 50 mm thickness

Failure modes: (1) crushing of foam cells under indenter and (2) tearing of cell walls

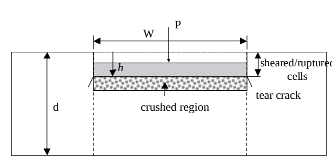


Long cylindrical punch   Flat-bottom cylindrical punch

Modelling of crushing force: flat end punch



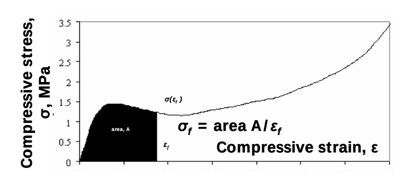
Load-displacement curve



Schematic of flat-end punch deformation

Partitioning of load: $P_{exp} = P_{crush} + P_{tear}$

- P_{crush} force crushing foam cells
- P_{tear} force tearing foam cell walls; found by fitting experiments



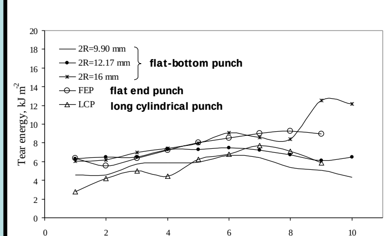
Uniaxial compression

Assumptions:

- crushing confined within V_0 = uni-axial compressive load
- $P_{crush} = \partial W_{crush} / \partial h$; $W_{crush} = \sigma_f \Delta V$
- σ_f - *effective* vertical engineering stress
- $\varepsilon_f = h/d$ *effective* vertical engineering strain

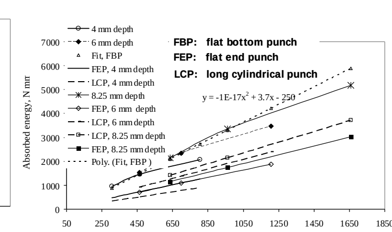
What did we find?

- Effect of indenter shape and size on tear energy and energy absorption



Tear energy vs displacement

- Tear energy γ increases with *h*
- The long cylindrical punch induces lowest tear energy, followed by flat-end punch of 2R= 9.9 mm



Absorbed energy vs replaced volume

- Local damage with flat-bottom cylindrical punch induces largest absorbed energy W_{abs}, followed by long cylindrical punch