Mechanical Tests of the 3D-printed W prototype

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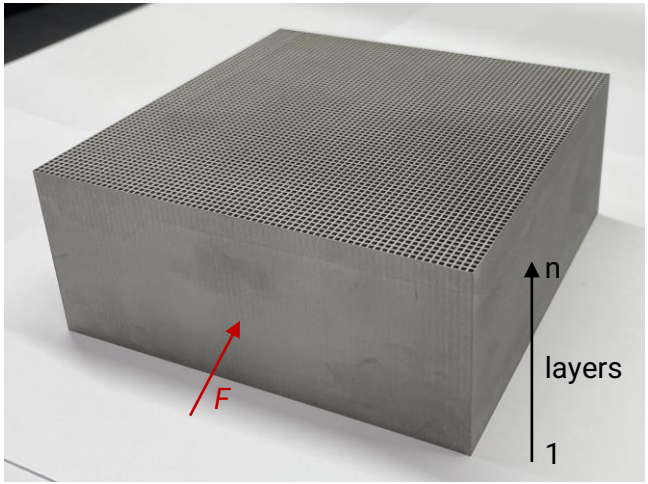
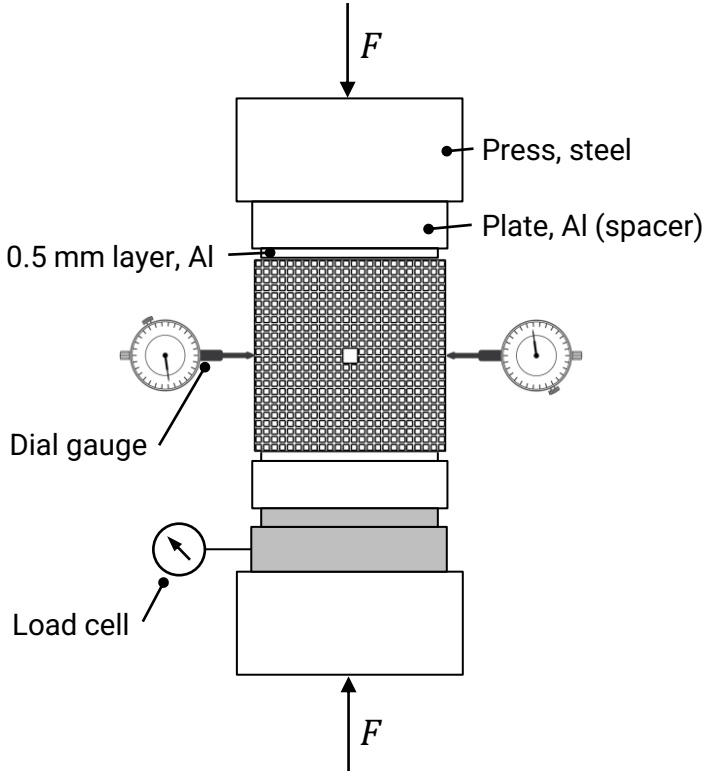
W Absorbers for the LHCb ECAL

- Additive manufactured W absorber
- 1.2 mm square holes
- Printing direction as shown in the photo
- Load perpendicular to the printing direction
- Expected load per absorber ~450 kg

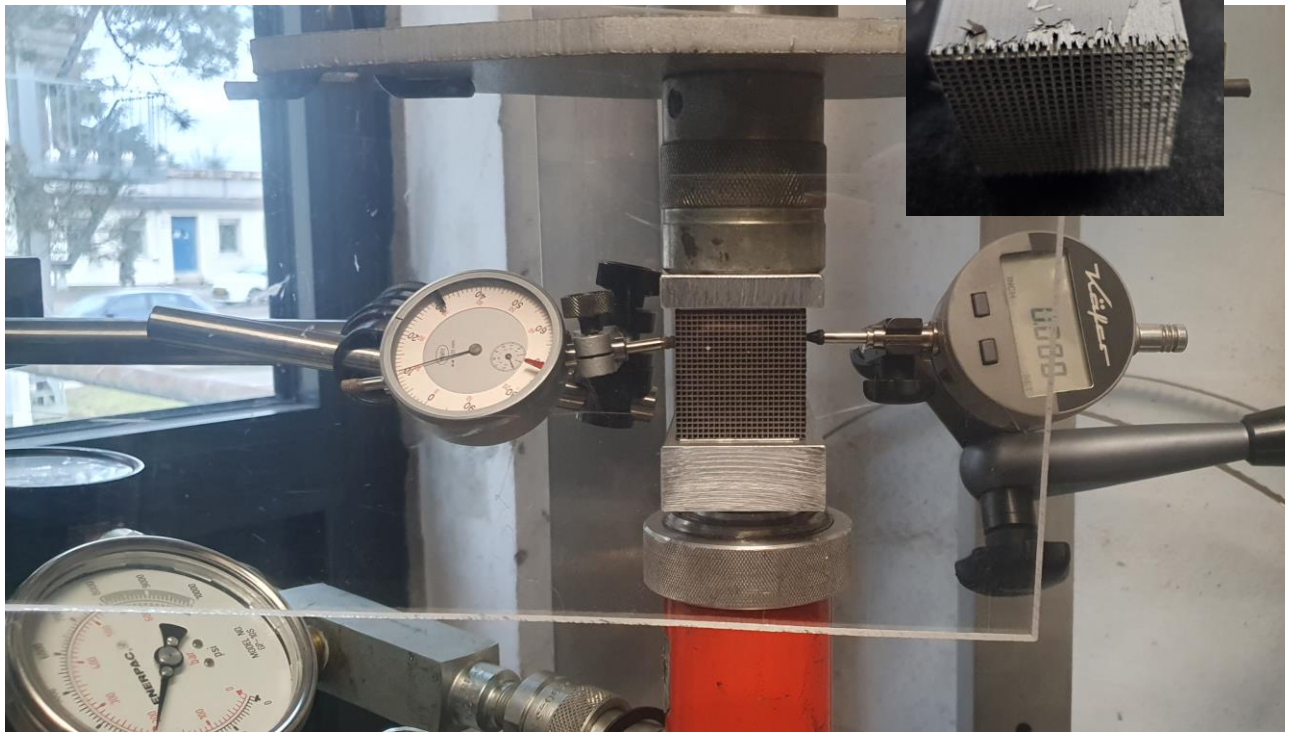


Compression Test Setup

- Load cell to monitor the vertical load
- Dial gauges to measure horizontal deformation
- Thin soft layer (0.5 mm aluminium) between press and absorber
- Plates between press and thin layer for smooth surface
- Expected load: 212 kg (50% overload)



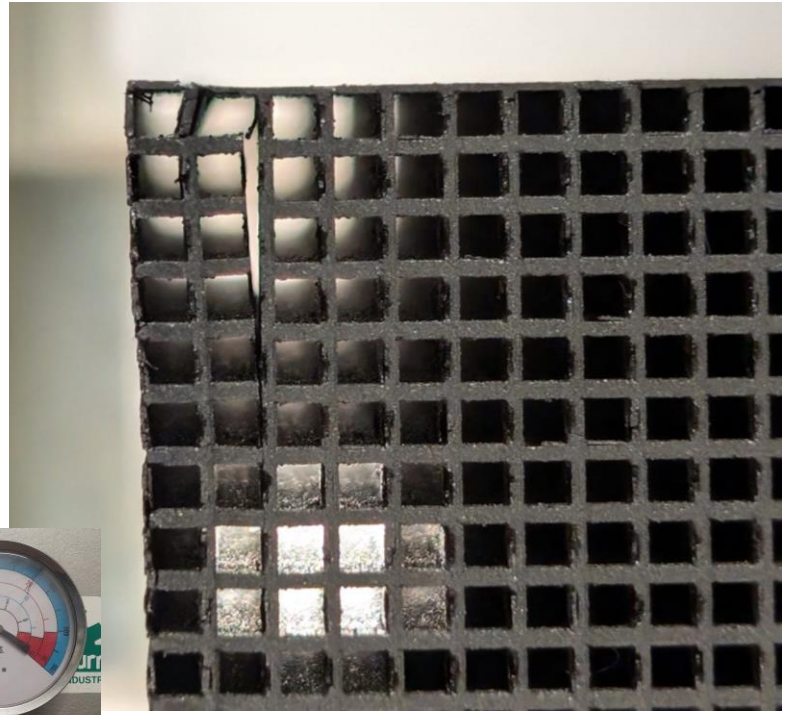
Test Setup



Absorber after EDM

Loading Cycle 1: Initial Crack

- Audible crackling from ~5 t onwards
- Increasing load in increments (due to manual hydraulic cylinder)
- Maximum load (crack) ~9.5 t (red scale)
- $\sigma_{ult} = \frac{9500\ \mathrm{kg} \cdot 9.81\ \mathrm{ms}^{-2}}{564\ \mathrm{mm}^2} = 165.24\ \mathrm{MPa}$
- Cracking confirms brittle characteristics of the absorber
- Afterwards deloading, since the limit of the load cell is reached



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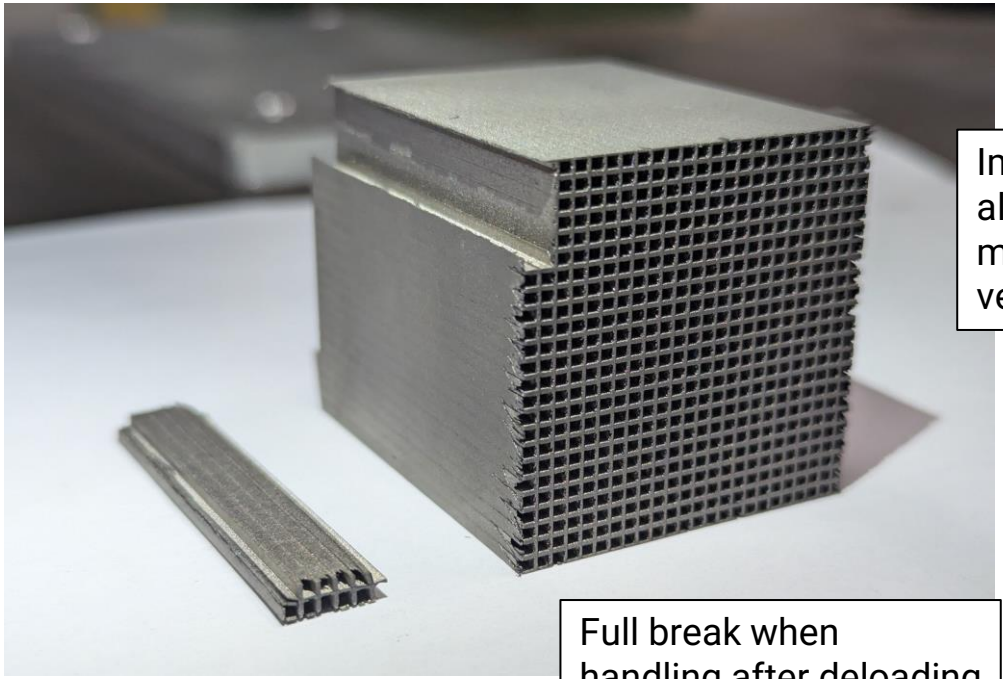
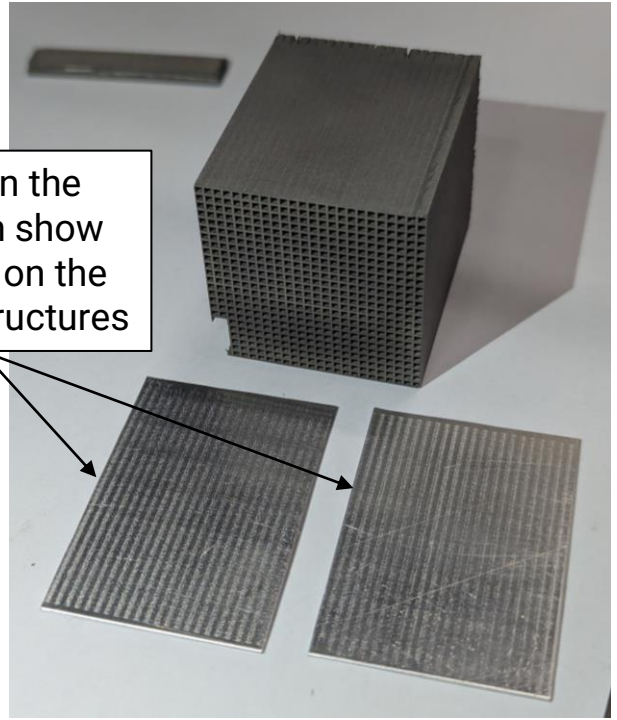


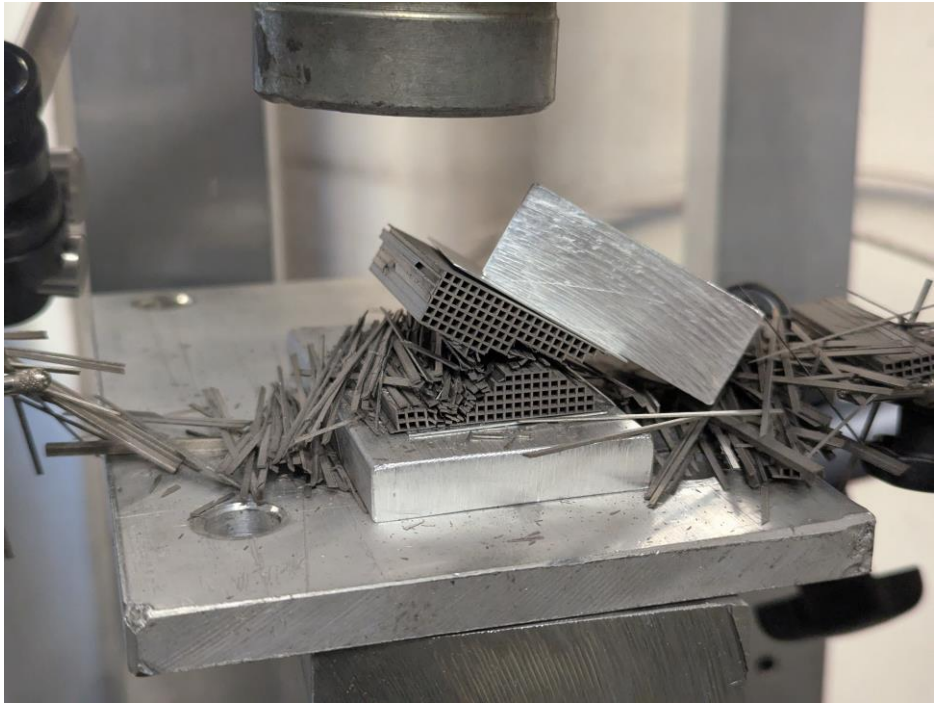
Full break when handling after deloading



Imprints on the aluminium show main load on the vertical structures

Loading Cycle 2: Shattering

- Reloading without load cell
- Audible crackling during entire loading process – likely crack propagation
- Shattering of the absorber at ~5 t
- Loud bang
- Shattered into hundreds of slim fragments and dust



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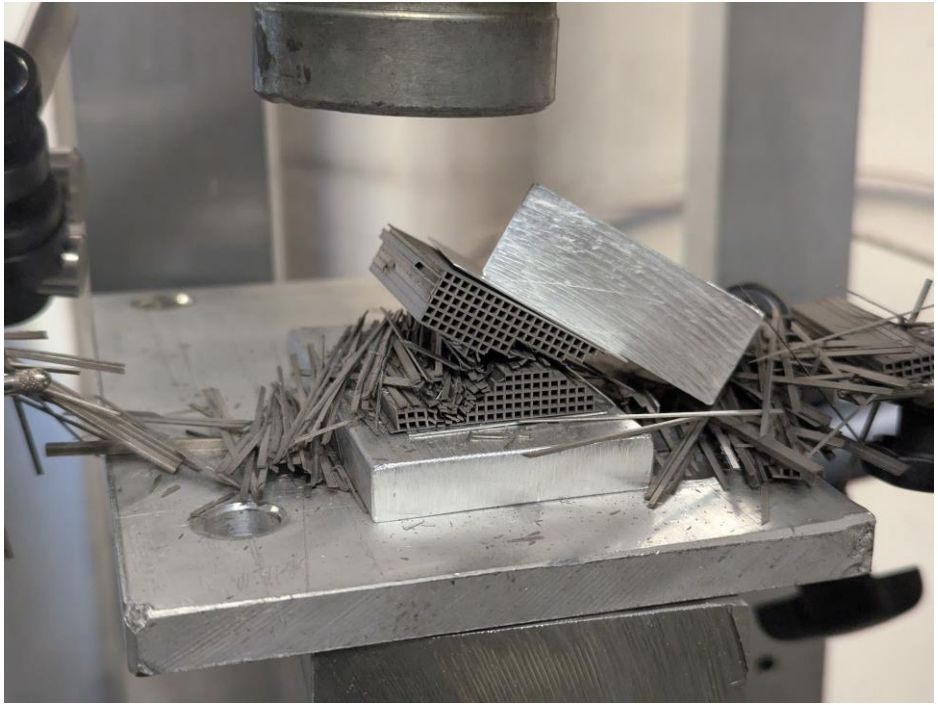
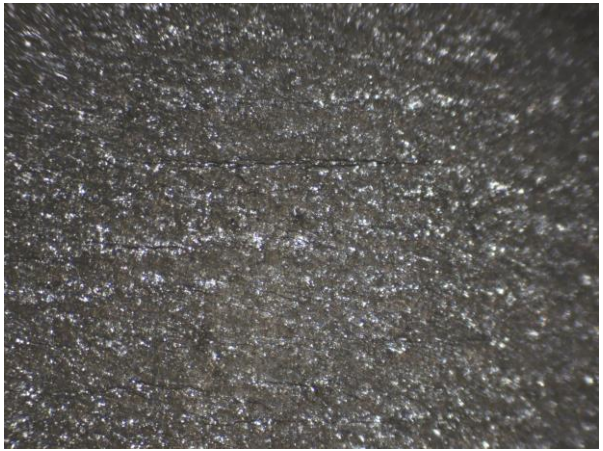
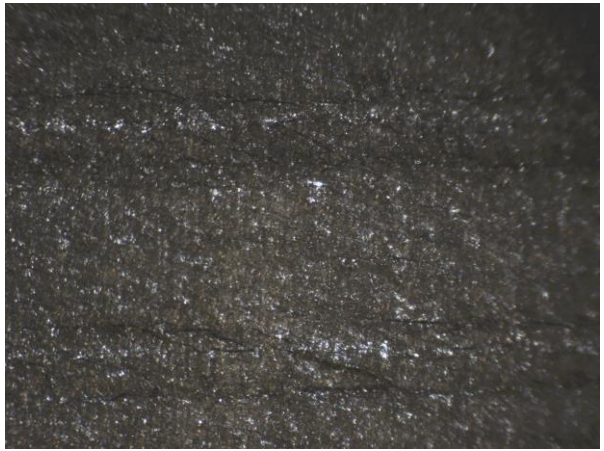


Material Defects

- Absorbers in delivery conditions shown below
- Cracks appear on the entire outside surface of the absorbers


Conclusion

- Load endured by the absorber exceeds the expected load
- Nominal stress is far below the compression test result of additive manufactured, cylindrical test specimens (165 MPa vs. ~800 MPa)
- Why does the absorber fail the way it does?
- What causes the surface cracks in the absorbers? How can they be prevented?
- Where should we move from here? (long term test, precise test with strain measurement, …)

Thank you for your attention!

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Backup slides

Loading Cycle 1: Comparison to FEA