Experimental Investigation of the Flow Properties of Layered Coal-rock Analogues

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3D printing is a valuable tool to investigate coal behaviour under depletion conditions

- Coal is a compressible rock that gets deformed during reservoir depletion due to changes in reservoir pressure and stresses.
- Coals are heterogeneous and the zones of interest for gas production (high fracture density) are often friable.
- 3D printed (3DP) rocks can create a repeatable analogue by minimizing specimen variability.
- Very few studies aimed to replicate coal properties using synthetic rocks or 3D printing technology.
- This study investigates a series of 3DP coal seam gas packages under various flow conditions to determine the impact of fracture network and interburden rock on the dynamics of permeability.
- The 3DP coal analogue is treated with sodium silicate and carbon dioxide to reduce porosity and permeability. Seven cylindrical specimens are analysed including: the intact 3DP coal analogue, the intact interburden analogue, the unidirectionally and multi-directionally fractured coal analogues, and packages of coal-interburden-coal with different fracture systems.
- These specimens are subjected to isotropic triaxial flow tests to compare the properties of natural and synthetic rocks.

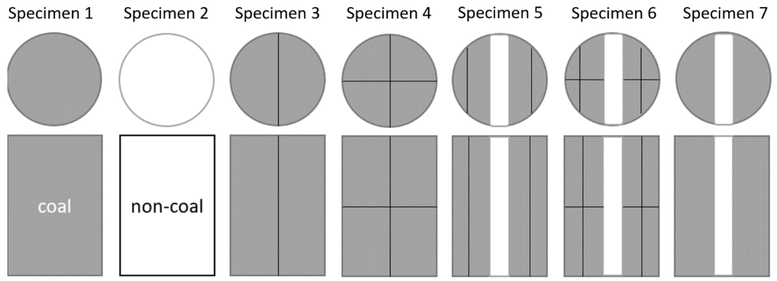
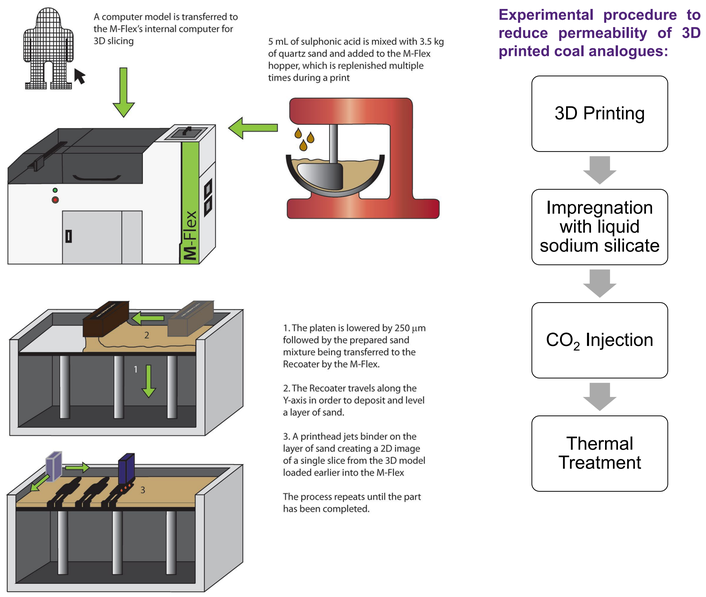


Figure 1: Schematic of tested specimens (grey: coal analogue, white: interburden analogue).

3D printing of coal analogues



Experimental procedure to reduce permeability of 3D printed coal analogues:

Figure 2: Summary of 3D Printing process using sand grains and furan binder (Hodder et al. 2018).

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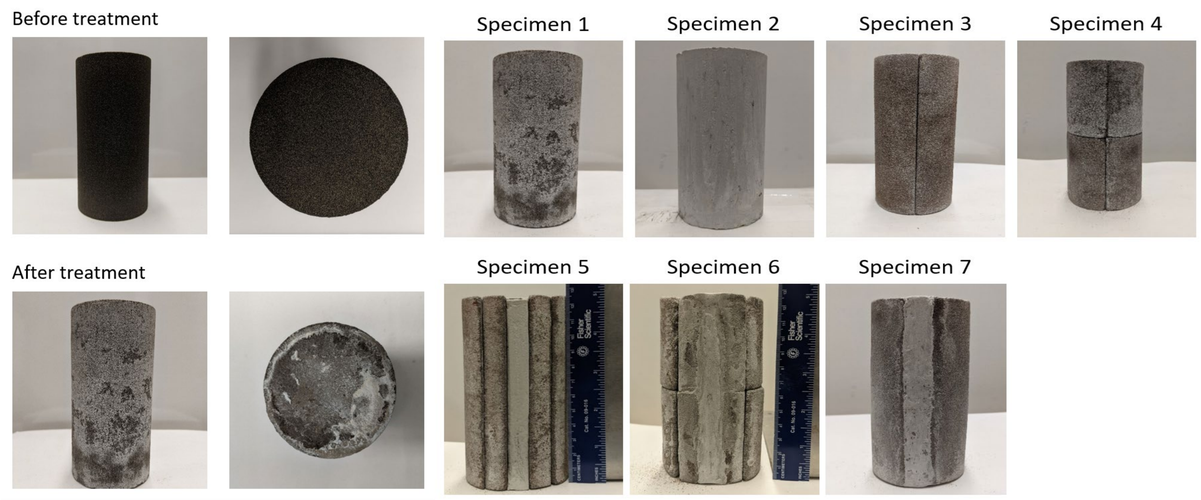

Figure 3: Photographs of synthetic rocks and histogram of permeability before and after treatment with sodium silicate and carbon dioxide.

Results

3DP Samples with multi-directional fractures exhibit lower fracture compressibility than ones with unidirectional fractures.

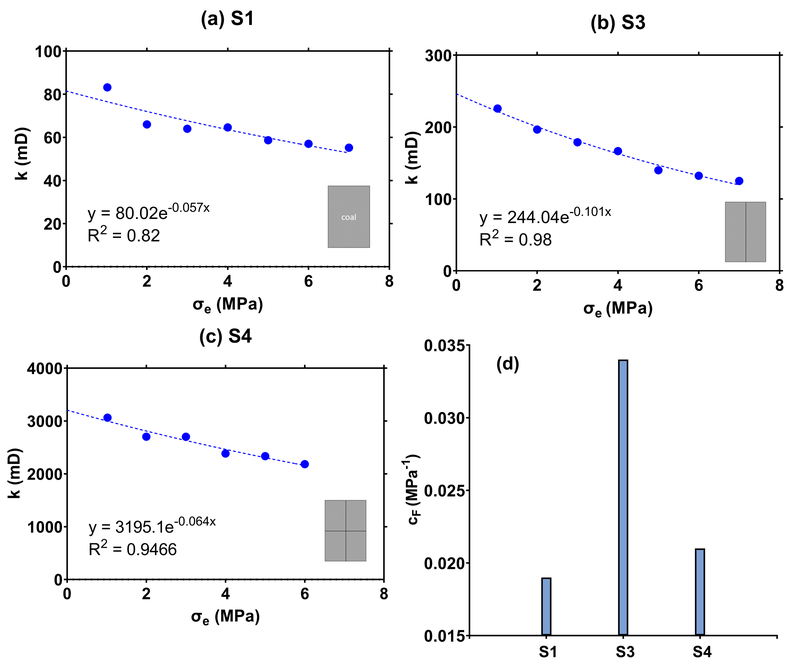

Figure 4: Permeability vs. effective stress, and pore compressibility of S1, S3 and S4.

Specimens with higher fracture intensity exhibited higher bulk compressibility.

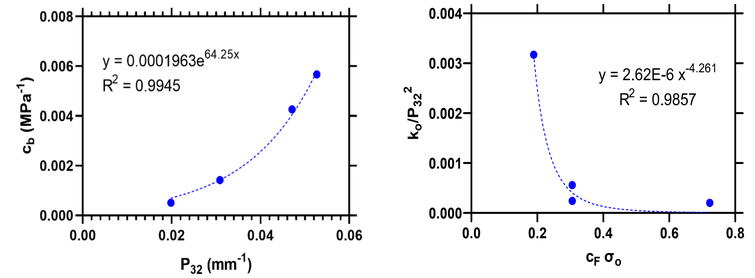

Figure 5: Average bulk compressibility versus fracture intensity of S3-S6 (fractured specimens), and relationship between proposed dimensionless groups.

Similar properties of coal and 3D printed analogues

Fracture compressibility	**Elastic modulus**
Fracture permeability	**Fracture aperture**
Fracture intensity	**Bulk compressibility**

Conclusions

- 3D printed coal analogues can be a valuable strategy to validate numerical models
- Post-treatment of 3D printed rocks reduces permeability of coal matrix analogues
- The fracture network influences the compressibility of fractured specimens
- Bulk compressibility increases exponentially with fracture network intensity

Acknowledgements

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