Producing fractures with a 3D-printer for flow experiments – The price to pay for the easy way out

Klaus-Peter Kröhn and Michael Kröhn

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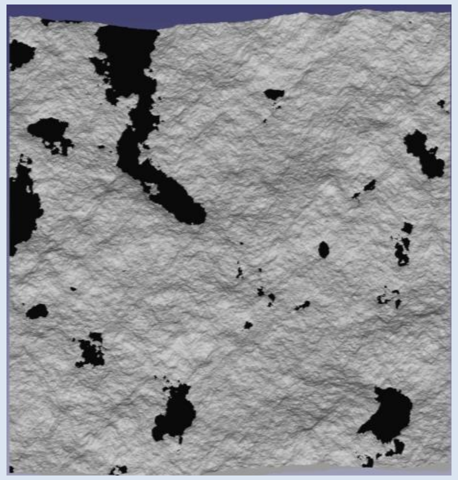
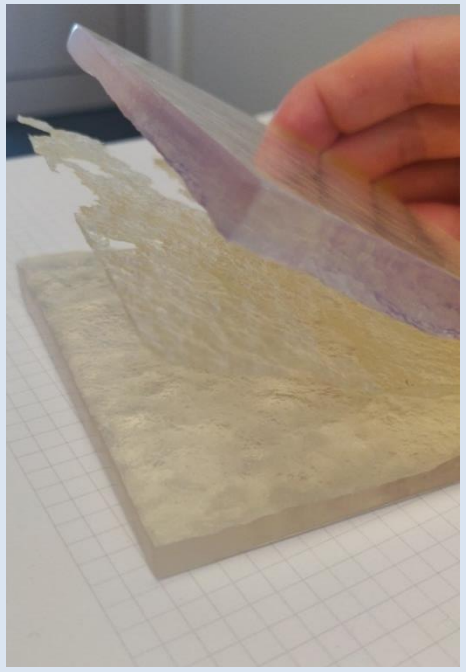
Printing fractures for flow and transport tests



Data for the negative of a fracture; contact areas in black



Printed fracture (negative in the middle)

Problems with dimensional accuracy

Printing fidelity

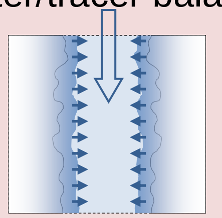
→ minimum printable fracture aperture

→ repeatability

Water uptake of the resin

→ swelling

→ water/tracer balance



Proposal of standardised simple tests

Measurements on test cubes with a side length 1 cm
- weight (nominal accuracy e.g. 1 mg) and
- size (caliper, nominal accuracy e.g. 10 µm)

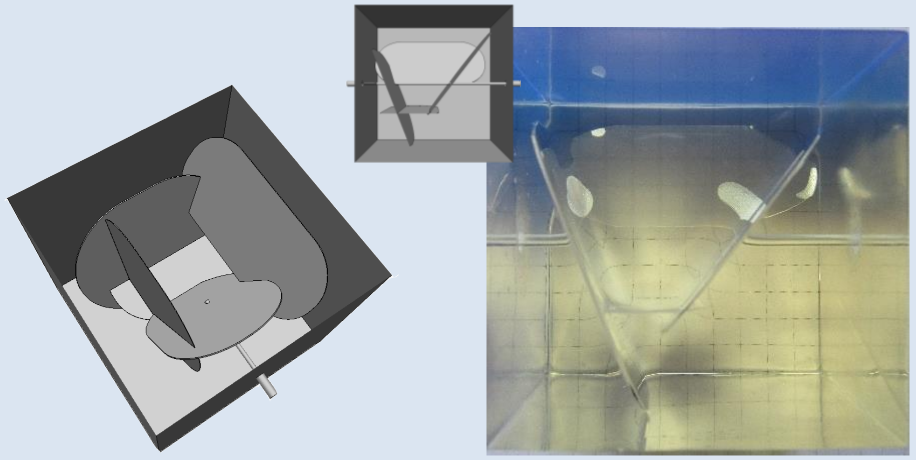
using
- distilled water
- salt solution

performed
- initially at dry state and
- over time in contact with the fluid

Tests are easy to perform
- to ensure comparability of results
- to enable set-up of a data base

Pre-tests

Printable fracture aperture



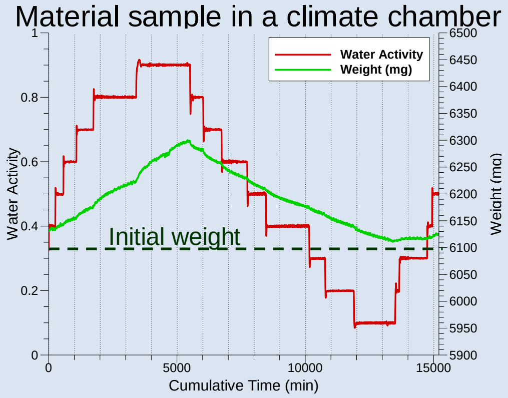
Test cube (side lenght 10 cm) with 5 fractures (aperture 200 to 600 µm); design drawings (left and middle) and printed cube (right)

Comparison of CAD-files and printed samples

Commissioned measurements, preliminary results:
- comparisons of a CAD-file of a realistic fracture surface with printed samples
- deviations from the CAD-file do not appear to be negligible
- remeasurements required

Uptake of water vapour

Material sample in a climate chamber



Relative humidity (red) and resulting sample weight (green)

→ significant water storage

Uptake of coloured water

Previously transpararent cubes
- side length 1 cm
- after 53 days
- sawn up into two halfs

→ imbued completely

Acknowledgements

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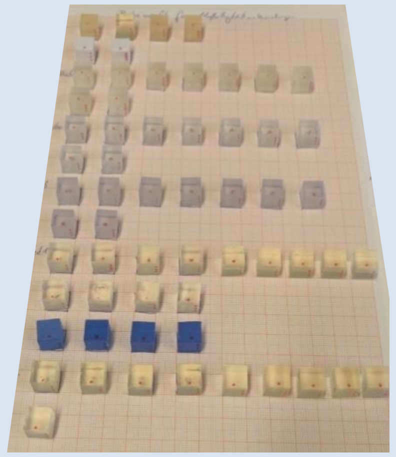
First simple water uptake tests

Compilation of test bodies
- 7 different materials
  + 5 postprocessing variants on one material
- 4 different printing principles



Rotating shaker; one bottle per batch

Results after 3 days of testing
- uptake seems to follow the characteristics of a diffusive process
- uptake between 0.4 % and 14.1% by weight
- linear expansion between 0.06 % and 5.20 %
- significant uptake reduction by postprocessing

Conclusions

(1) Fractures, as a rule of thumb, require an aperture of at least ten times of the printing resolution that is claimed by the manufacturer.
(2) Transparent 3D-prints are usually done with resins.
(3) Printed plastic materials are generally prone to water uptake.
(4) Contact time of 3D-prints with water should be minimised if dimensional accuracy is of importance.
(5) Fracture flow tests in printed samples need to be performed as quickly as possible.
(6) Tracers must be chosen carefully to avoid losses to the printed material.
(7) Further testing is advisable

Dimensional accuracy might also depend on

conditions at printing
- temperature
- layer thickness
- printer firmware

conditions after printing
- aging
- light

Contact :
Klaus-Peter Kröhn
Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH
Klaus-Peter.Kroehn@grs.de · Tel. : +49 (0) 531/8012-218

www.grs.de