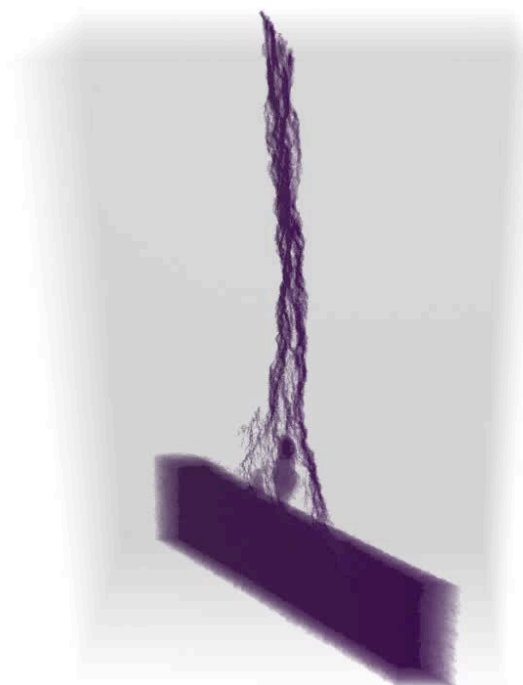
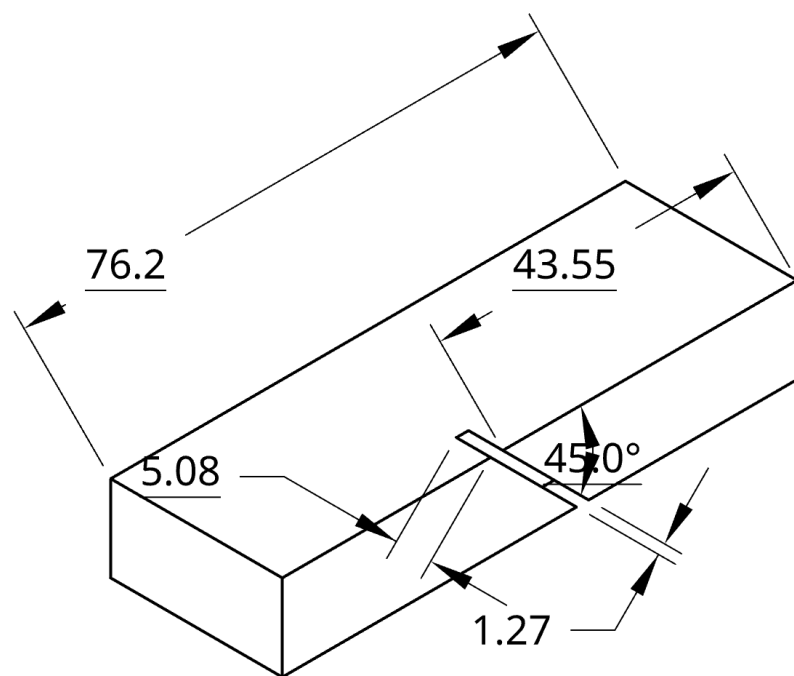


Induced Fracture Geometry in Layered Media under Mixed Mode I and III Loading Conditions

Liyang Jiang, Hongkyu Yoon, Antonio Bobet, Laura J. Pyrak-Nolte



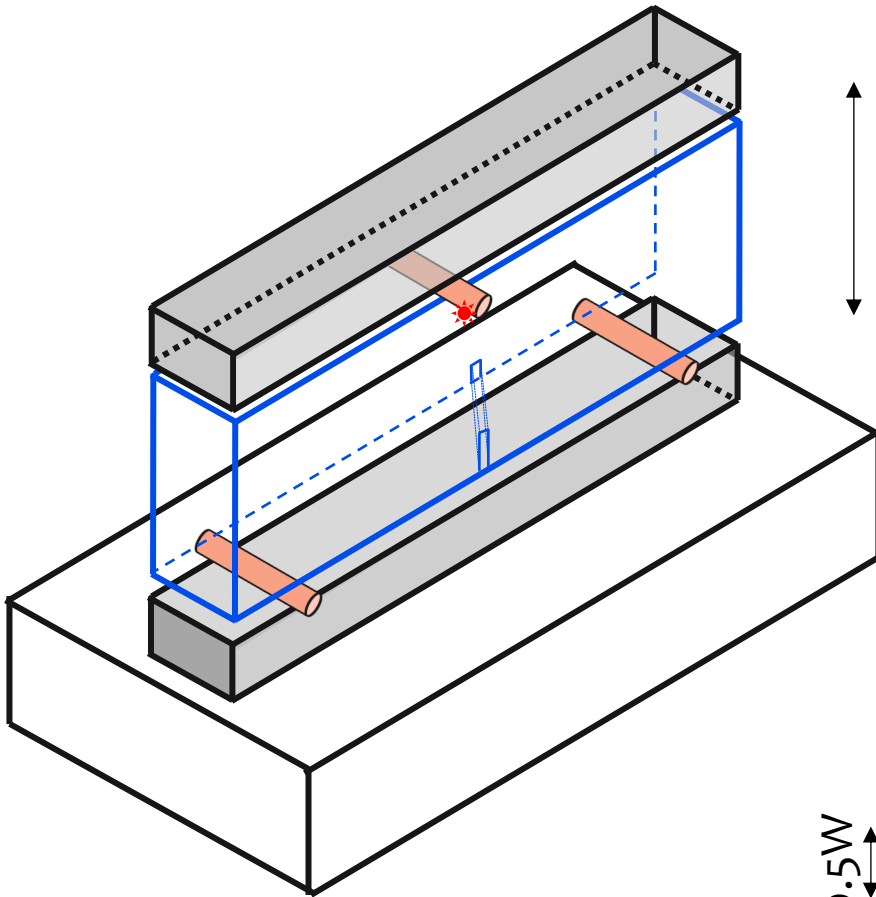
PURDUE
UNIVERSITY®



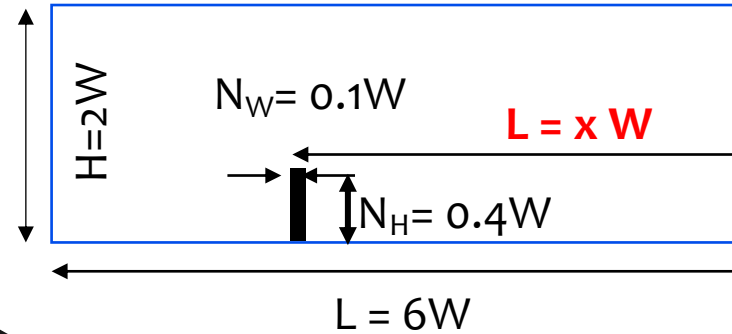
AGU FALL MEETING
New Orleans, LA & Online Everywhere
13-17 December 2021

Mixed Mode I and III Loading in Three Point Bending (3PB) Tests

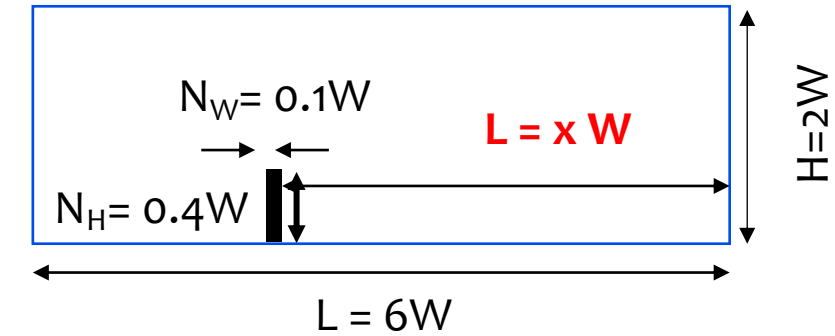
Mode I & III (Mixed Mode)
Off Center Notch - Angle



Front View

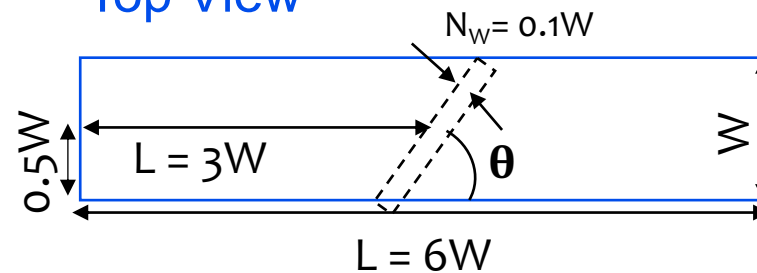


Back View

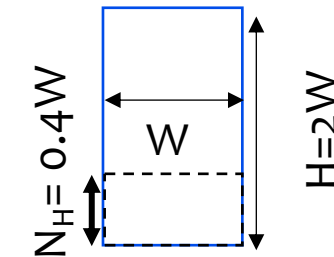


Where x depends on θ

Top View



Side View



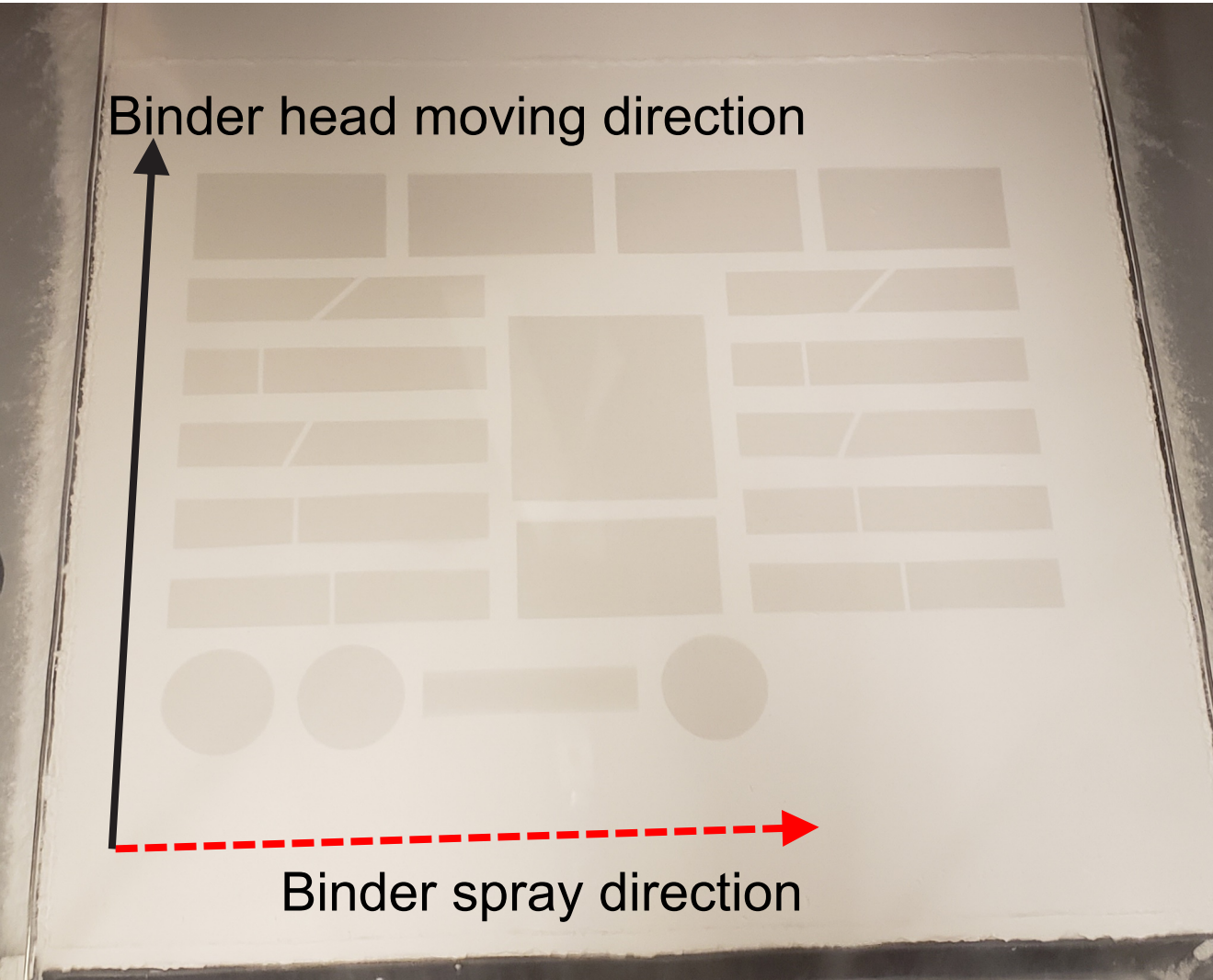
$W = 12.7 \text{ mm}$
 $H = 25.4 \text{ mm}$
 $L = 76.2 \text{ mm}$

Notch is rotated about center with an angle, $\theta = 20^\circ, 30^\circ, 45^\circ, 60^\circ$



Orientation in the Printing Bed

Printing Directions for Samples

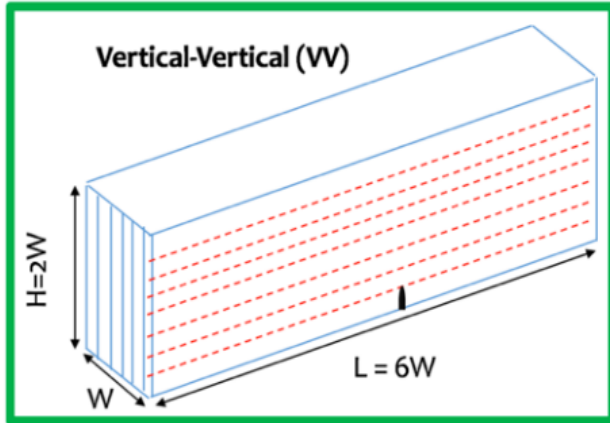


Samples after Printing

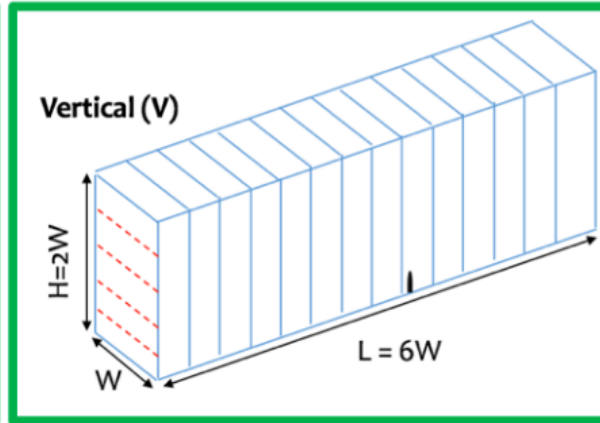


Sample Printing Design

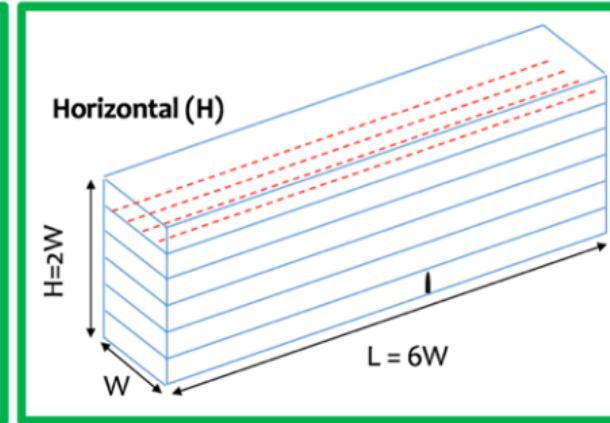
Divider



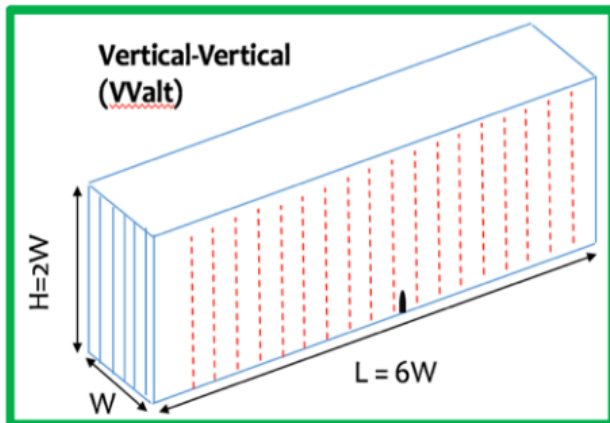
Short-Transverse



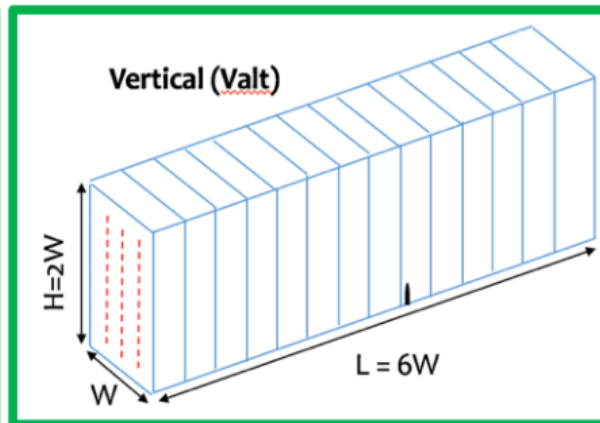
Arrester



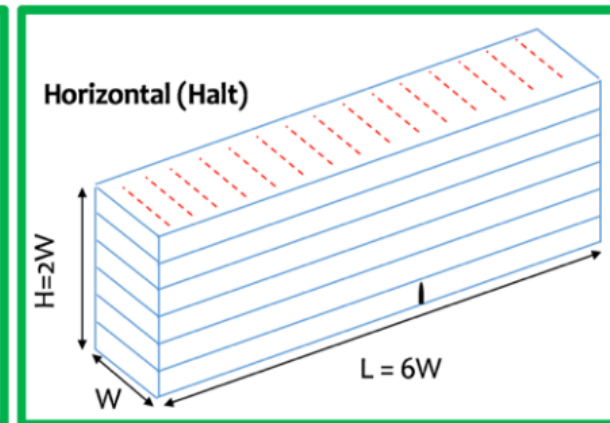
Divider



Short-Transverse

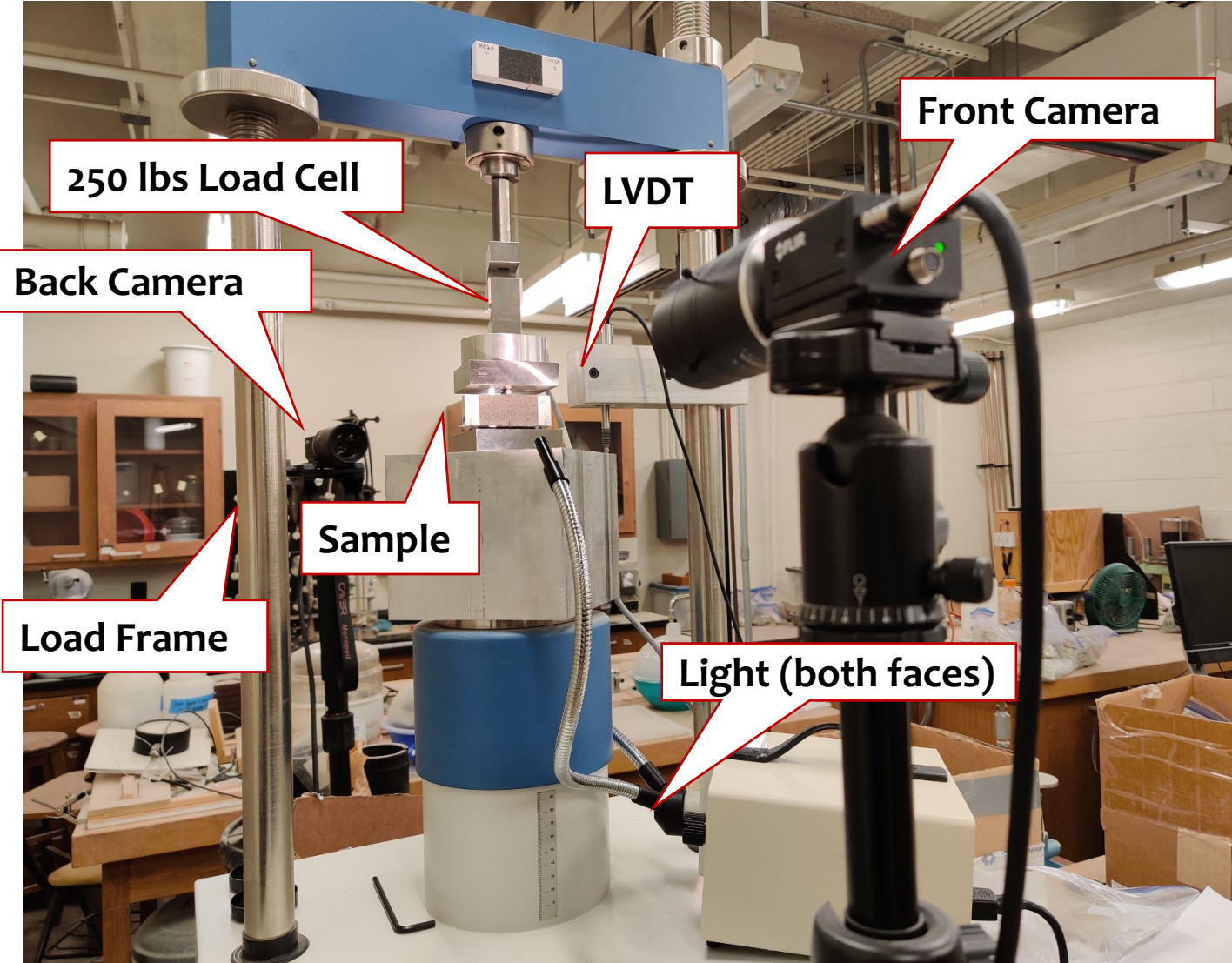


Arrester

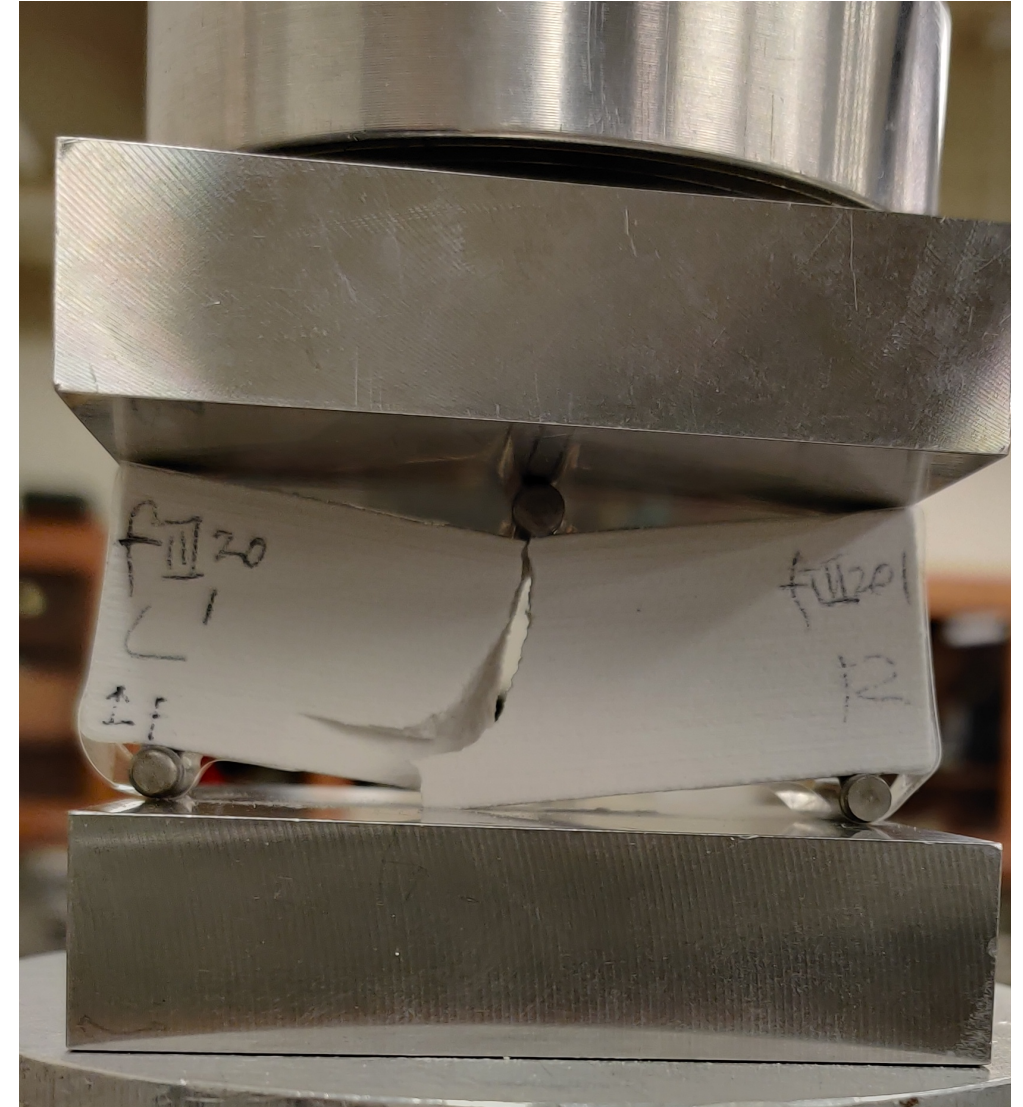


orientation of the bassanite layers (blue lines)
orientation of the gypsum texture (red lines)

Three Point Bending (3PB) Tests



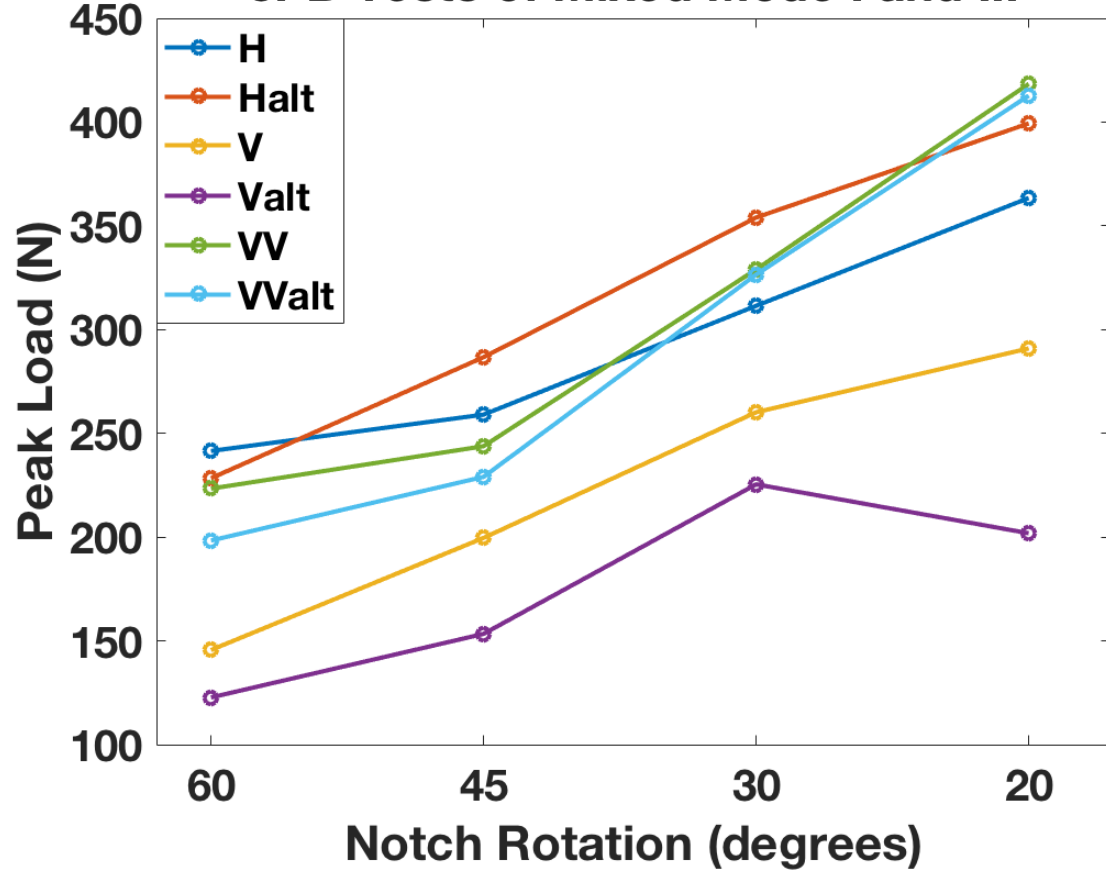
Experimental Setup



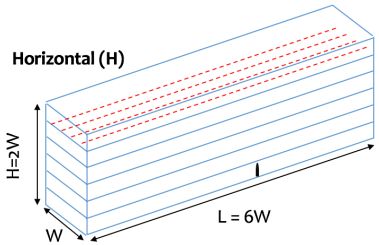
Sample after Failure

Mixed I and III – Failure Load—Fracture Toughness

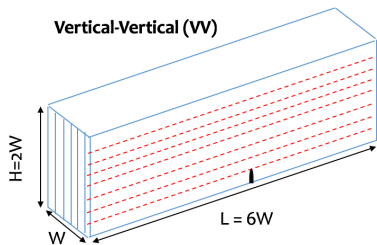
3PB Tests of Mixed Mode I and III



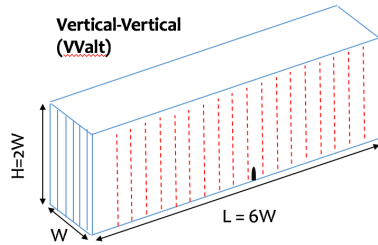
Bottom View of Cracked H Sample



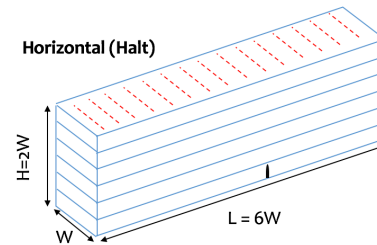
Arrestor (H)



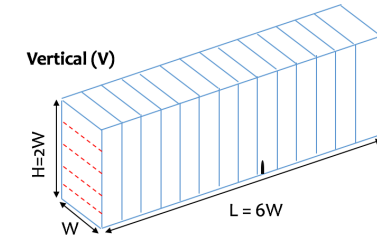
Divider (VV)



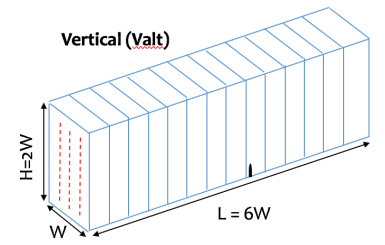
Divider (VValt)



Arrestor (Halt)

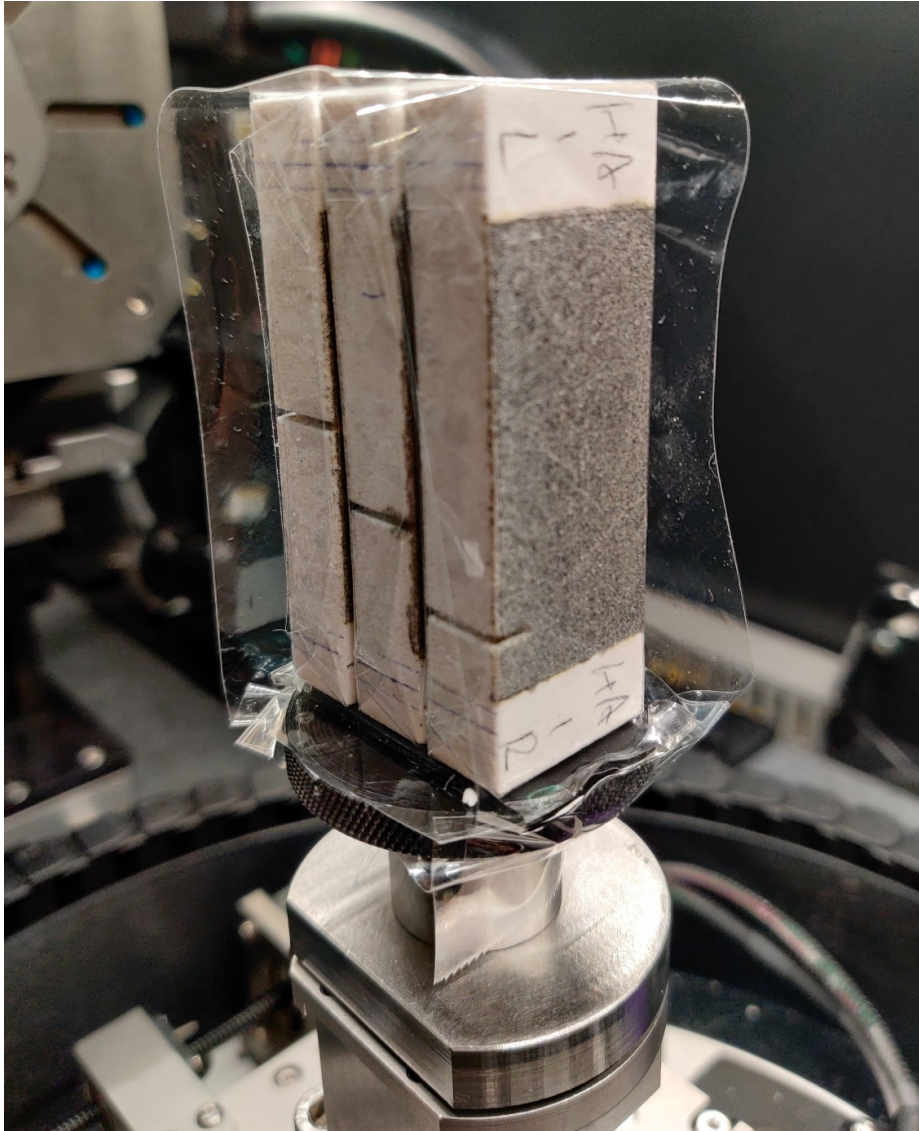


Short-Transverse (V)



Short-Transverse (Valt)

3D X-ray CT Tomography of Induced Fractures



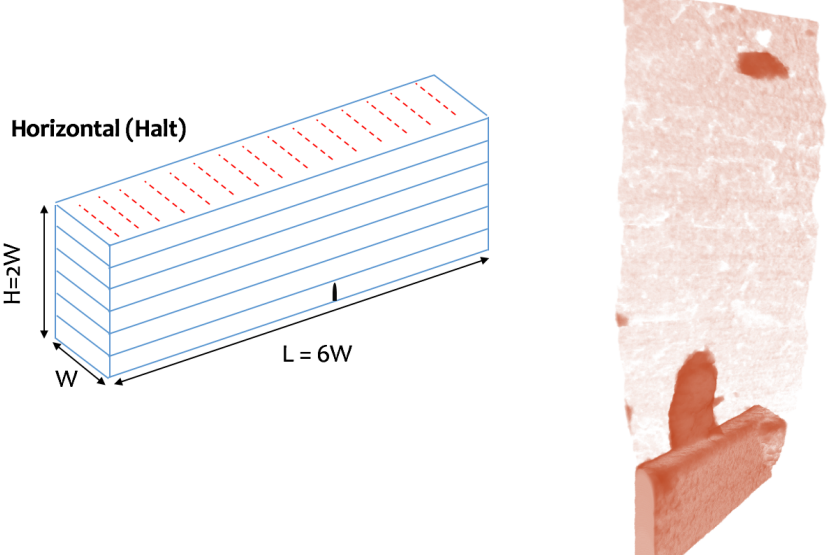
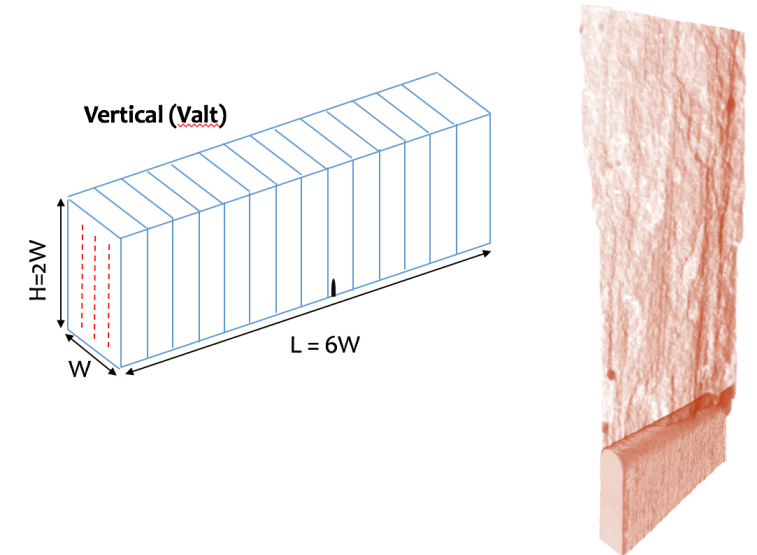
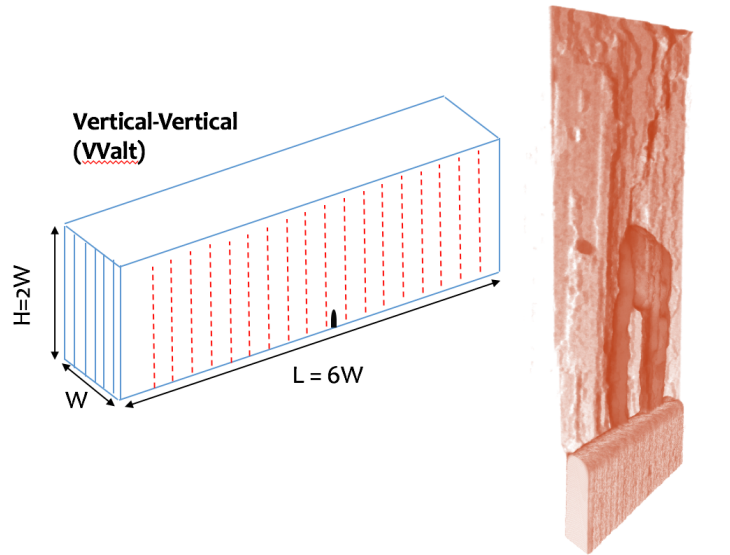
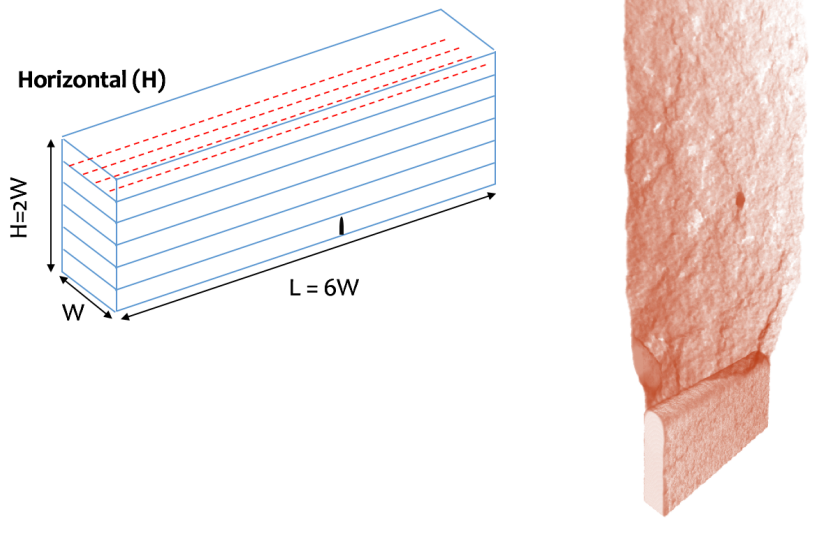
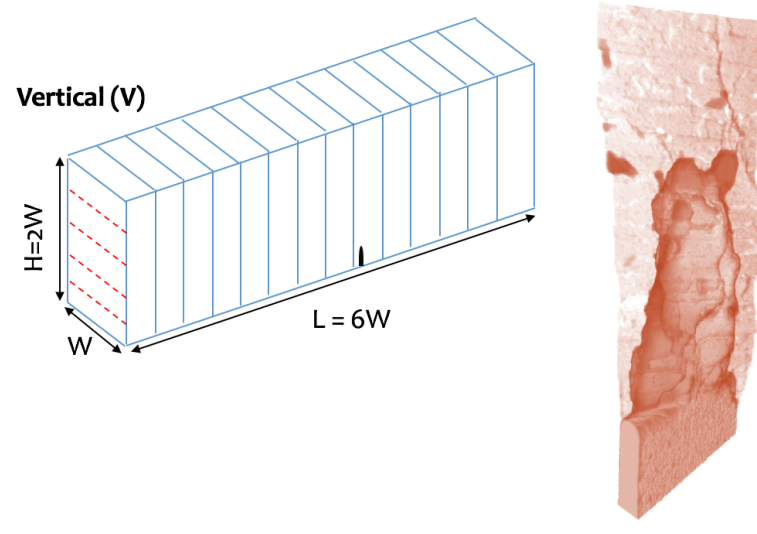
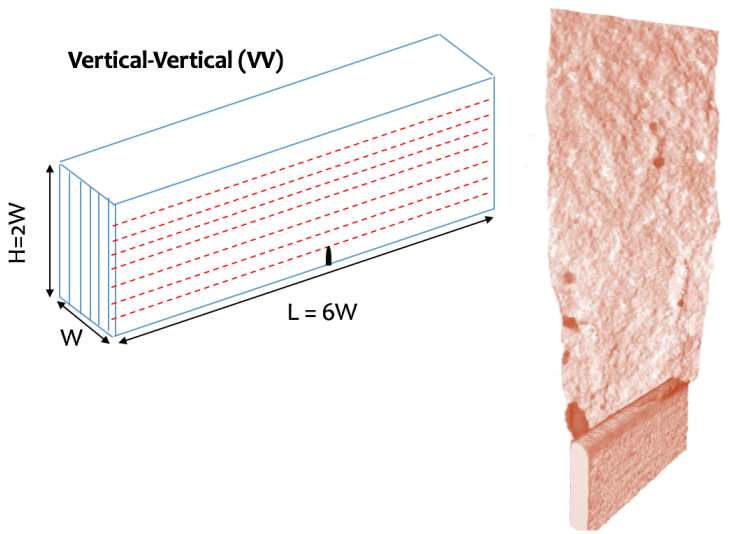
Three samples on stage inside Xray machine

A screenshot of the 'Image Control' software interface. The interface has a menu bar with 'Annotation', 'Info', 'Axes', 'Thermal', and 'Reference'. The 'Info' menu is selected. The main area displays various parameters for the CT tomography scan, including imaging mode, camera settings, source information, and exposure time. There are input fields for several parameters like source setting, source-RA distance, detector-RA distance, pixel size, and exposure time. At the bottom, there are 'Edit' and 'Update' buttons.

| Image Control | | | |
|--|----------------------------|----------------------|---------|
| Annotation Info Axes Thermal Reference | | | |
| Imaging Mode: | Tomography | Source Information | |
| Camera Binning: | 1 | Power: | 9.99 |
| Camera Temperature: | -59 C | Voltage: | 149.83 |
| File Data Type: | USHORT | Target Current: | 66.66 |
| Display Data Type: | FLOAT | Tube Current: | 168.19 |
| Image Size: | 2048 x 2048 | Centering X: | 165.82 |
| File Size: | 25608.000 MB | Centering Y: | 129.14 |
| Source Filter: | Air | Vacuum Level: | 7.23 |
| Source Setting: | 150 kV 67 uA | Focus Current: | 2382.12 |
| Source-RA distance: | 200.0123 mm | Hours on target: | 13.12 |
| Detector-RA distance: | 75.0014 mm | Target turn #: | 574 |
| Pixel size: | 24.9798 um | Filament: | 7.287 |
| Optical Magnification: | 0.39305 : "0.4X" | Cold Cathode Status: | Off |
| Exposure Time: | 4.0000 sec | | |
| Camera Readout: | Fast (2.5 MHz) | | |
| Heated Sample Temp: | NA | | |
| Date and Time: | 09/04/2021 02:09:22.114 | | |
| Frames/Image: | NA | | |
| Exp/Frame: | NA | | |

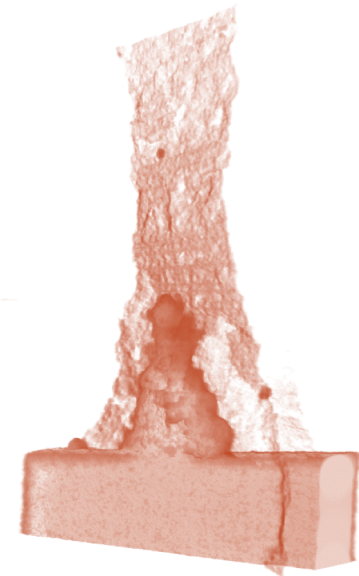
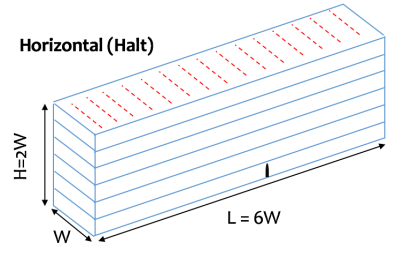
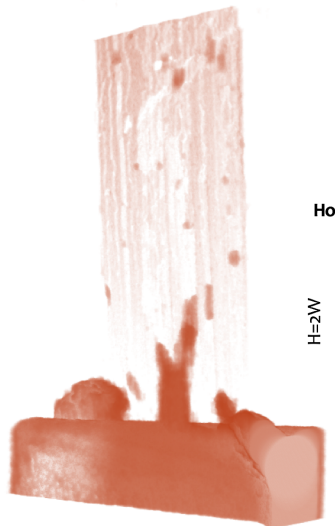
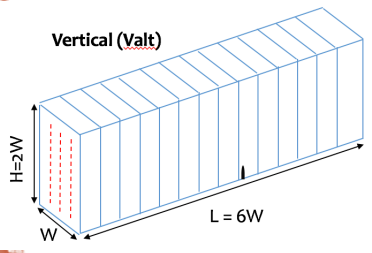
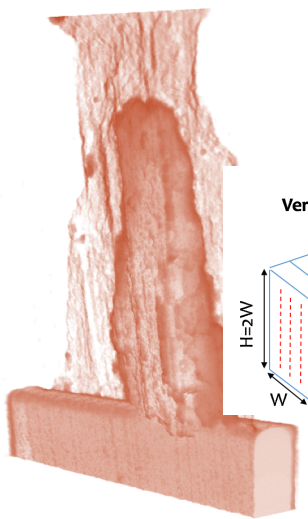
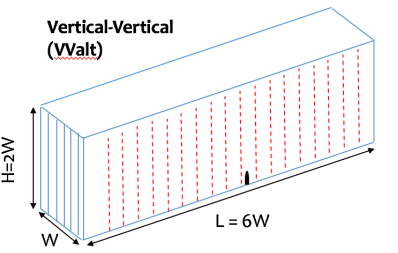
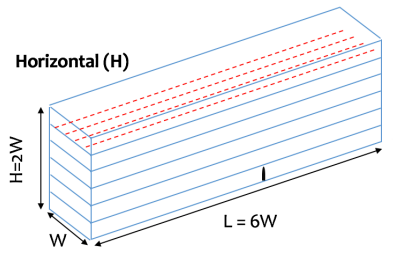
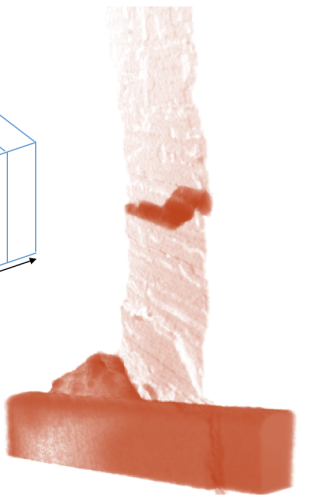
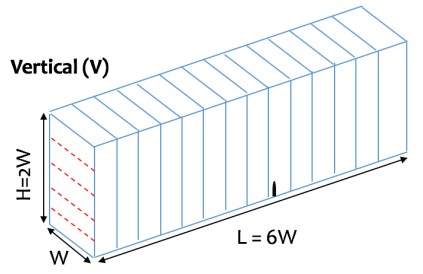
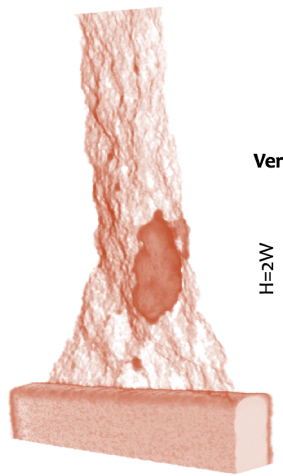
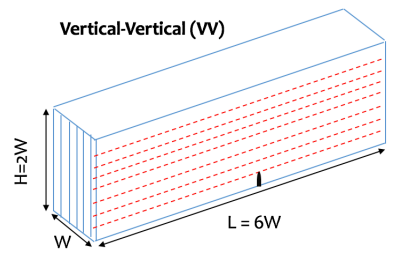
CT tomography parameters

Segmented Fractures (Notch Rotates 60 degrees)



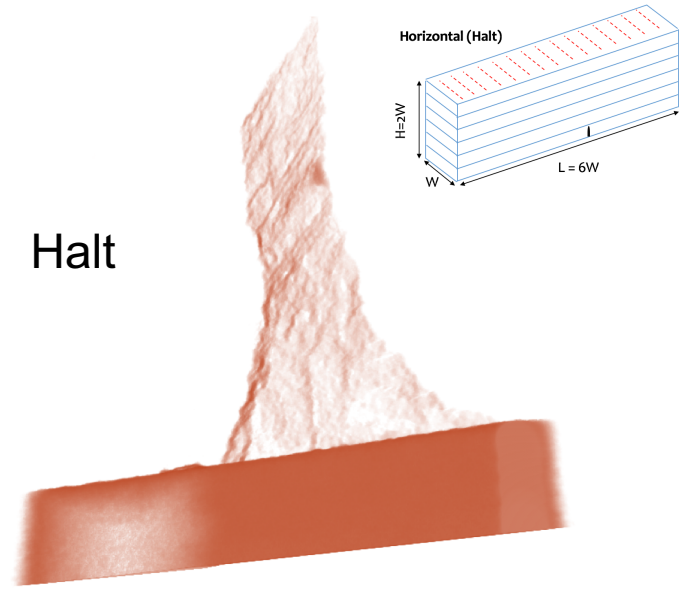
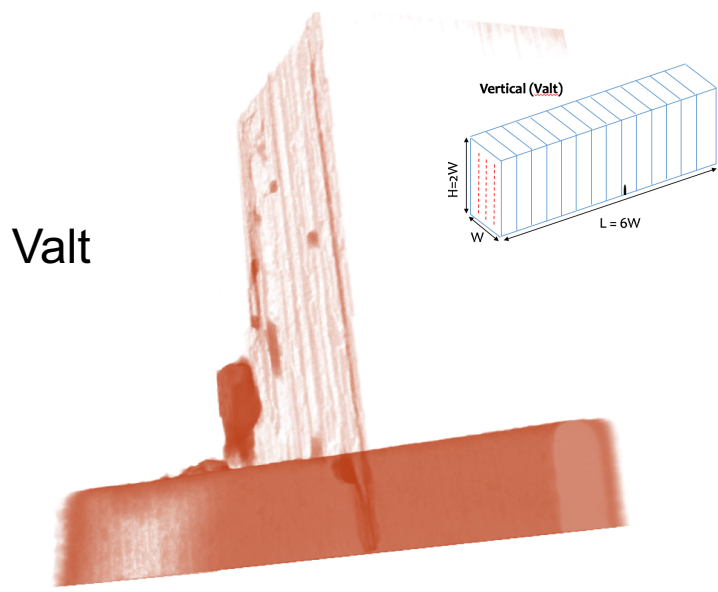
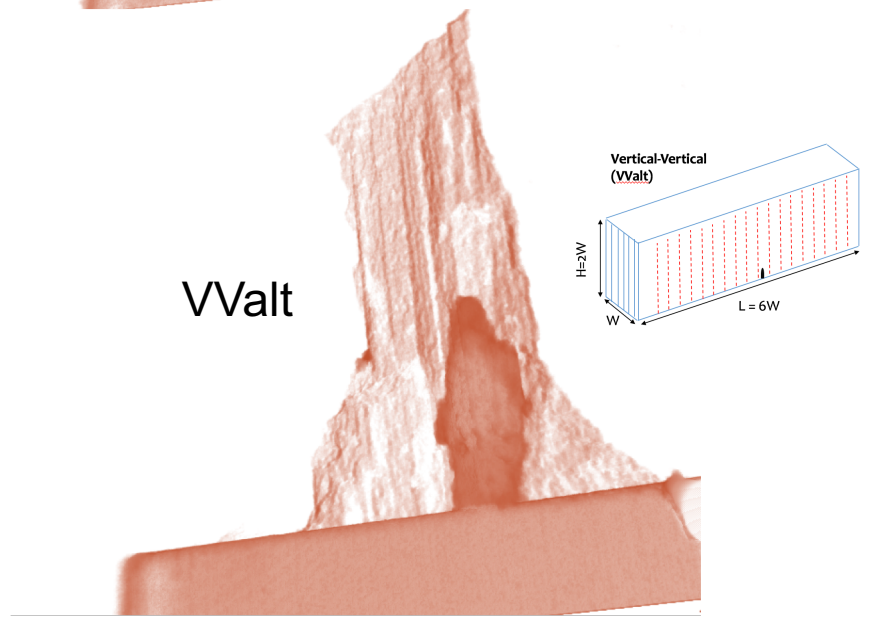
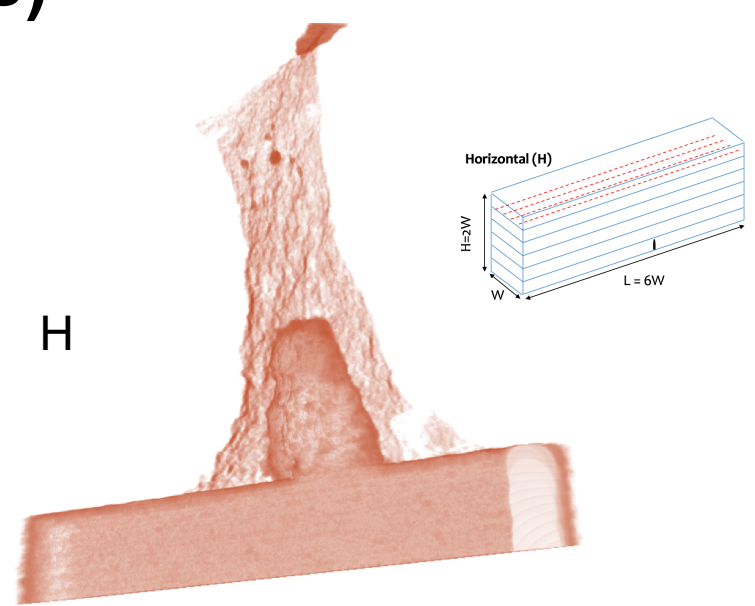
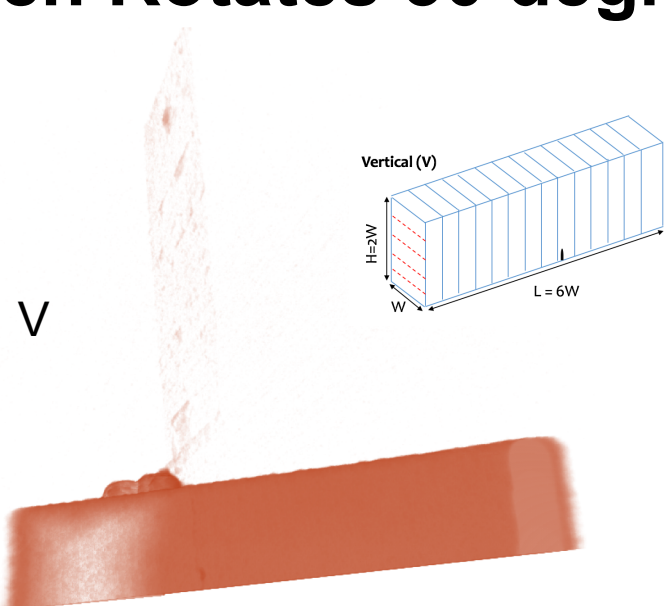
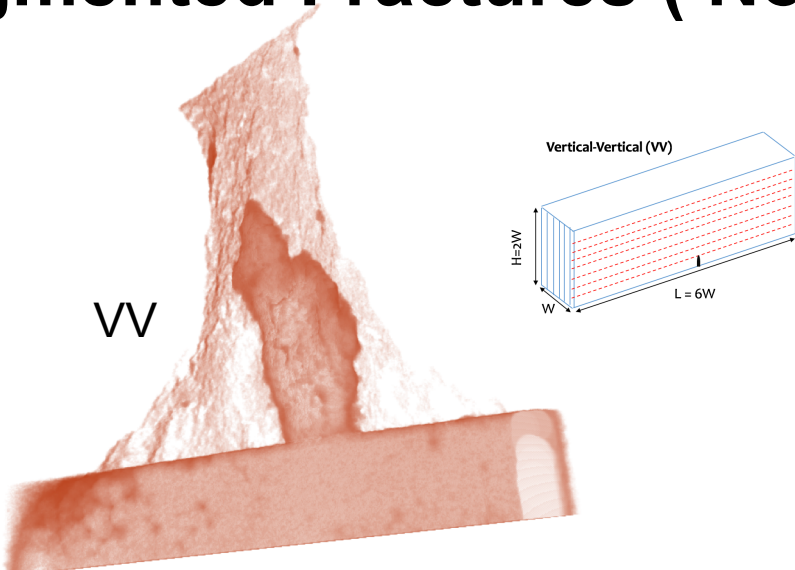
Notch height 5.08 mm

Segmented Fractures (Notch Rotates 45 degrees)



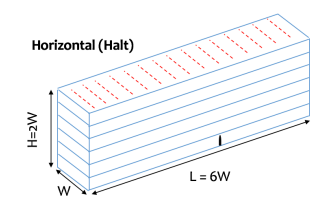
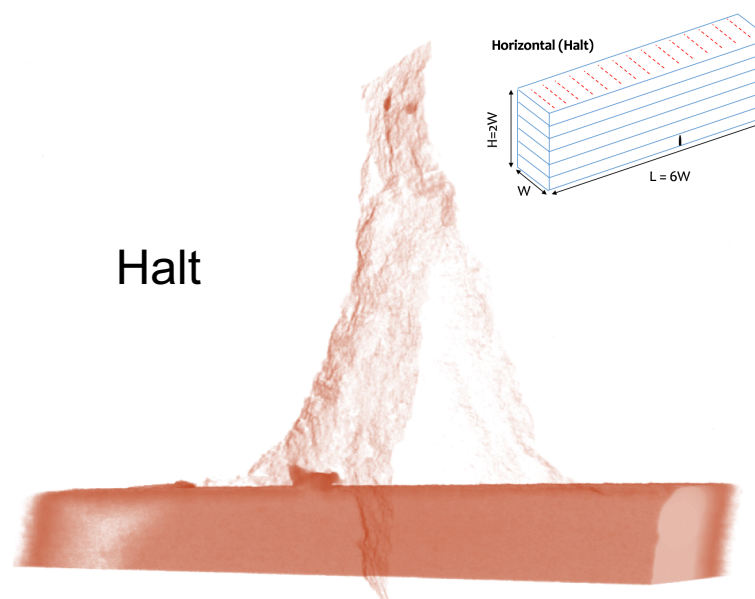
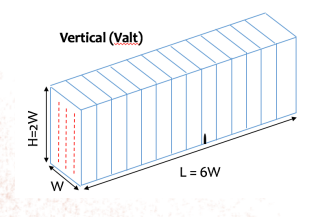
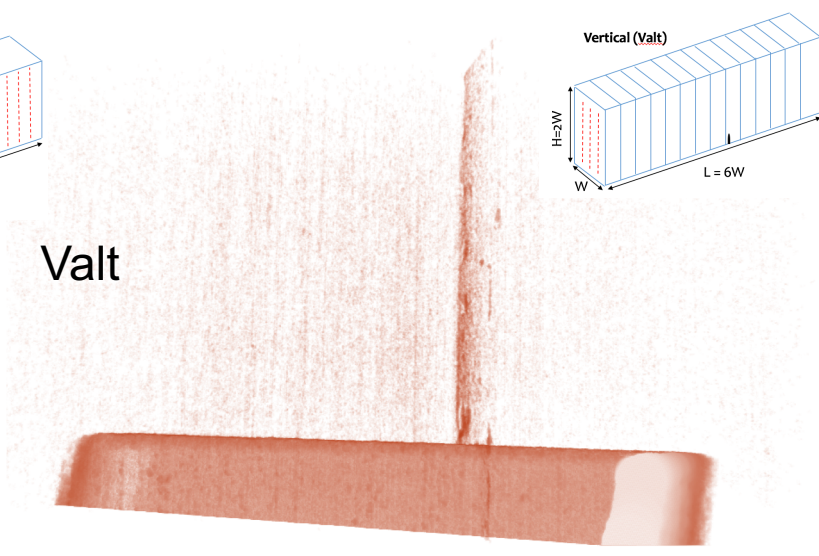
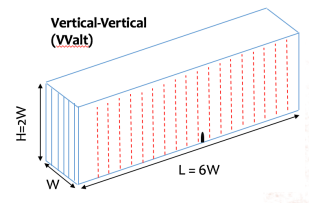
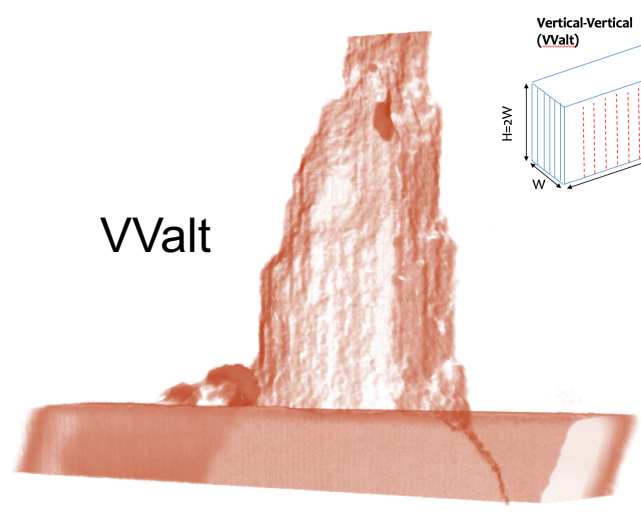
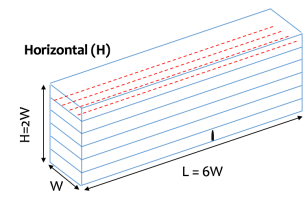
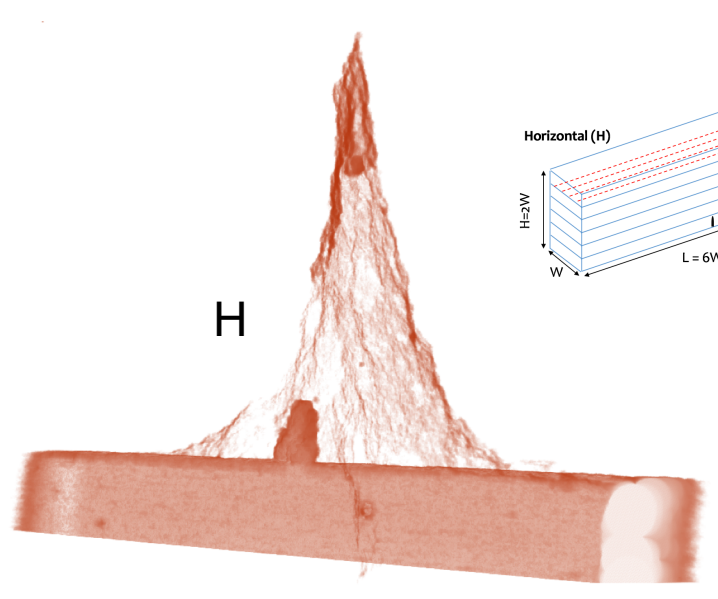
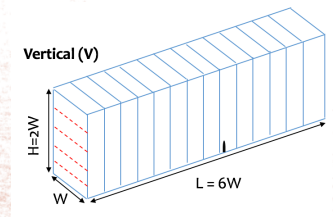
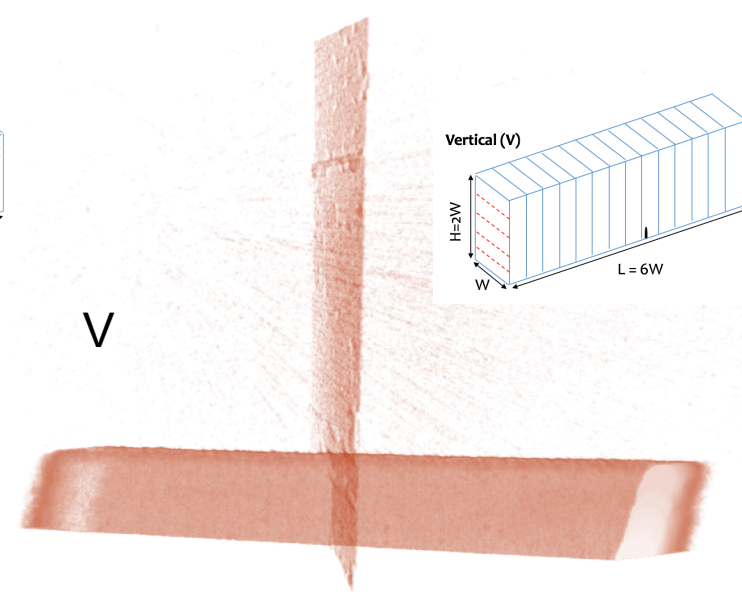
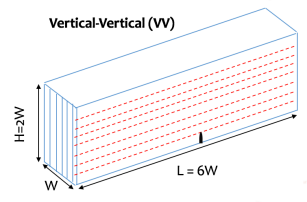
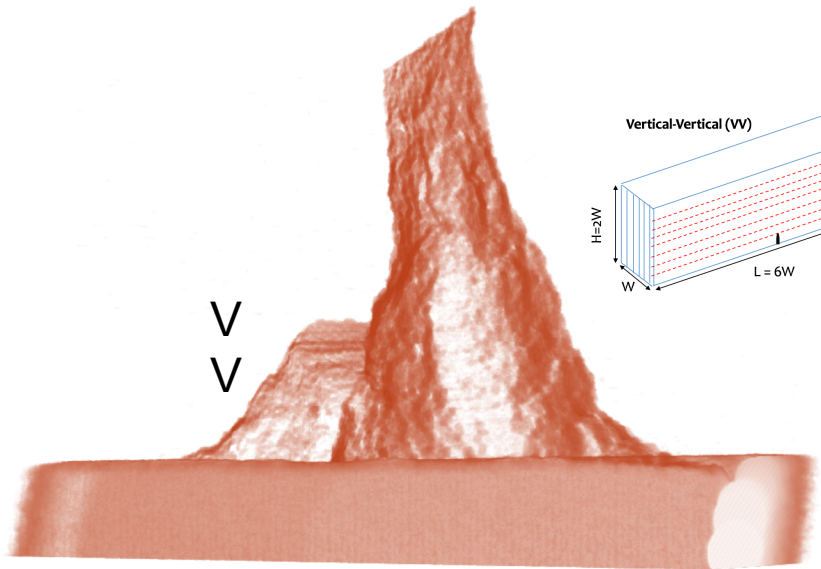
Notch height 5.08 mm

Segmented Fractures (Notch Rotates 30 degrees)



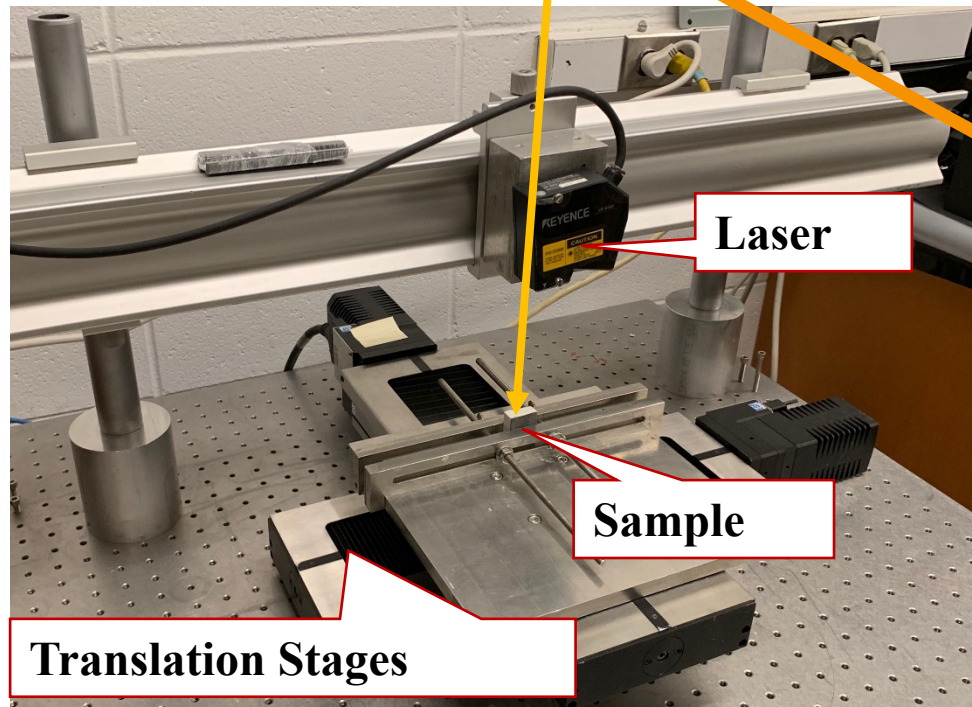
Notch height 5.08 mm

Segmented Fractures (Notch Rotates 20 degrees)

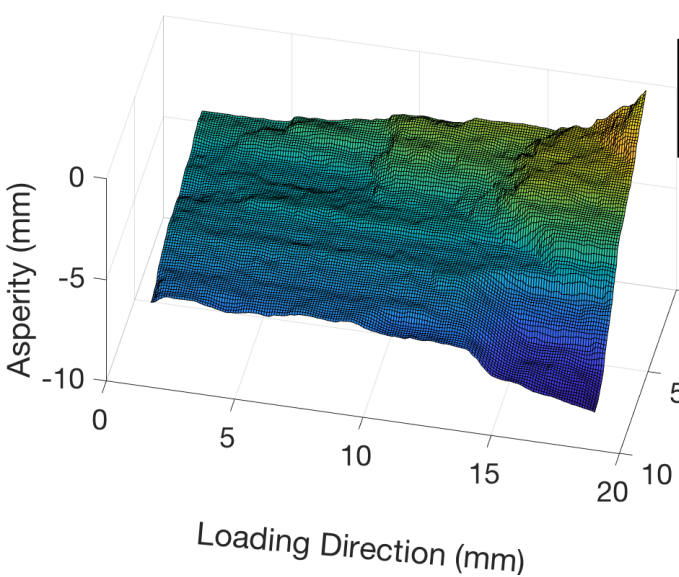


Notch height 5.08 mm

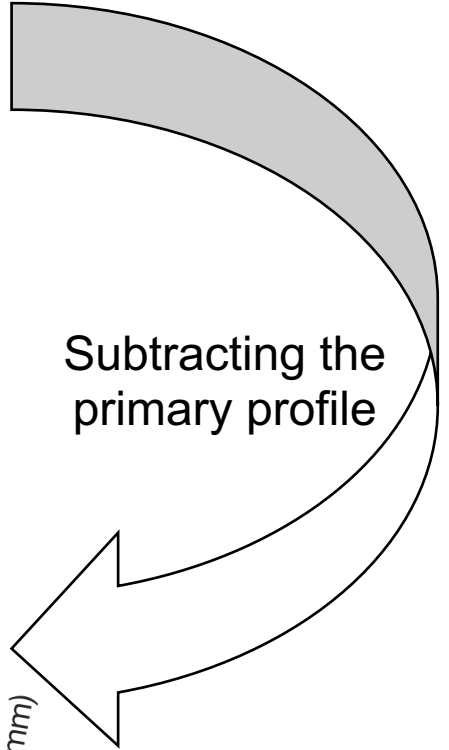
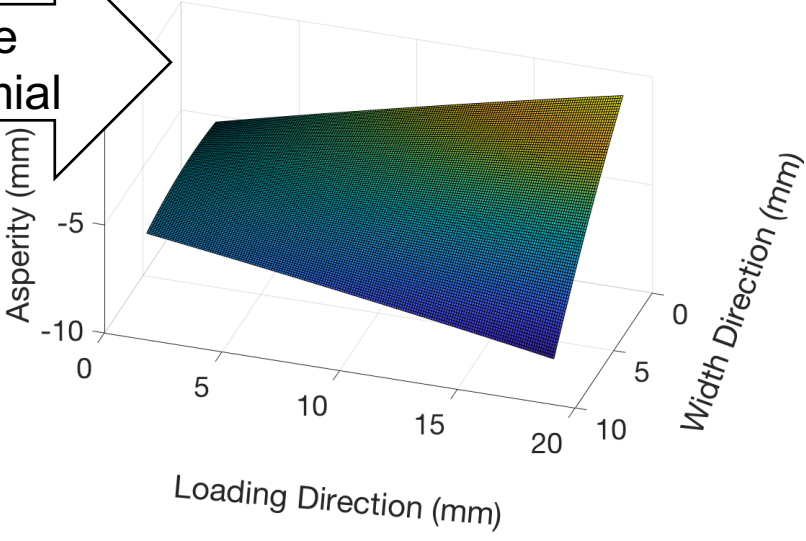
Surface Roughness Measurements: Laser Profilometry



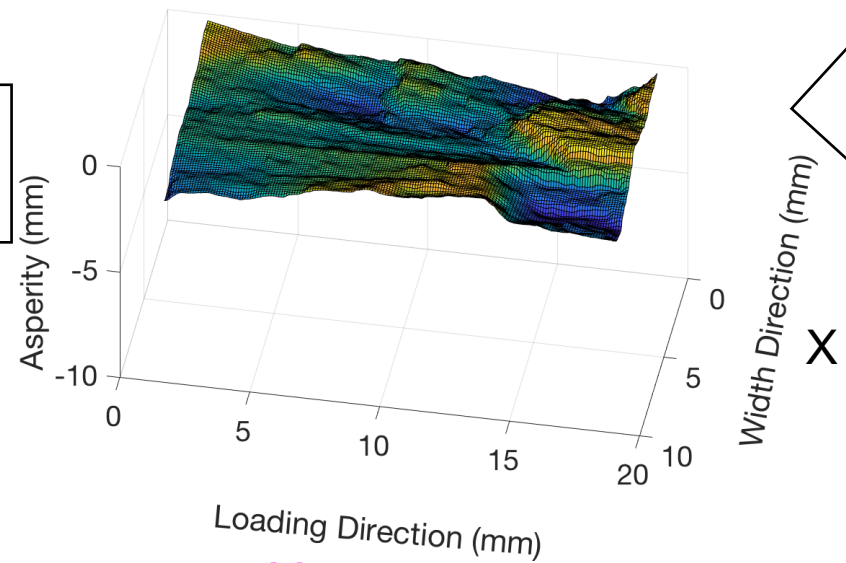
Micro-Slope Analysis with General Twist Removing



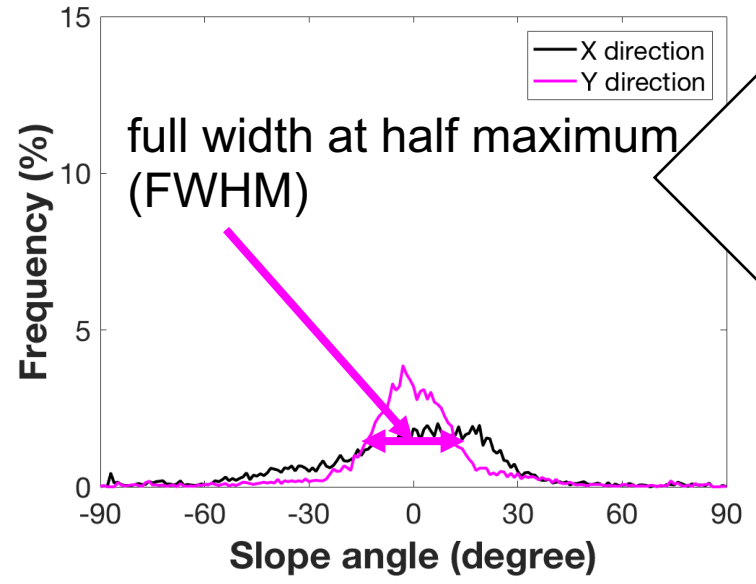
Fit the scanned surface with a 2nd order polynomial



Subtracting the primary profile

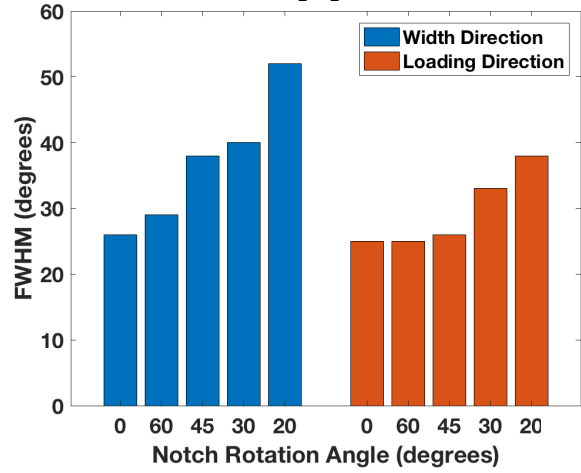


Micro slope distribution from roughness profile

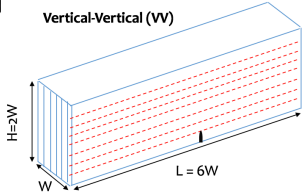


Full Width Half Maximum (FWHM) of Surface Micro Slope Distribution

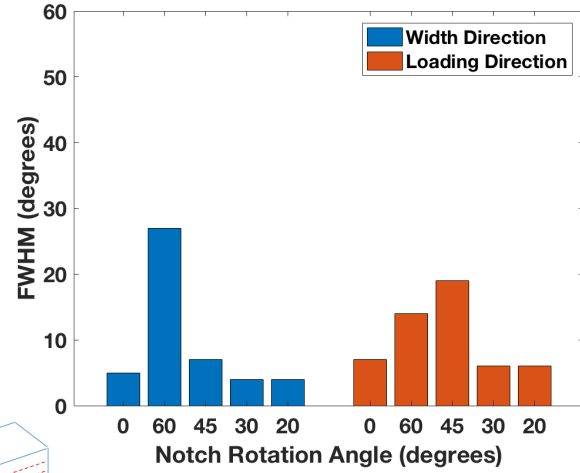
VV



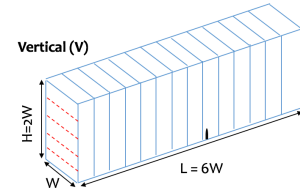
Vertical-Vertical (VV)



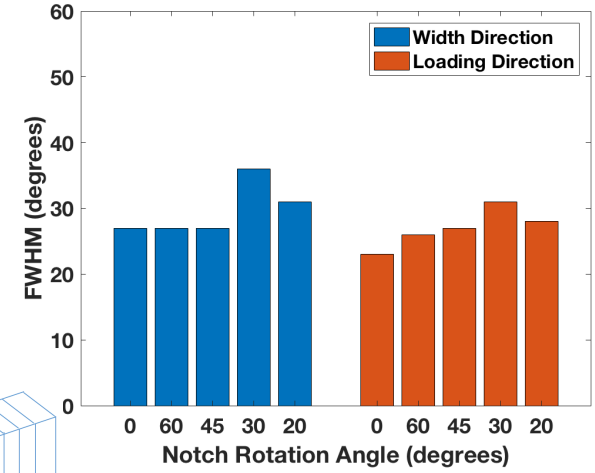
V



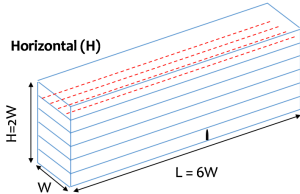
Vertical (V)



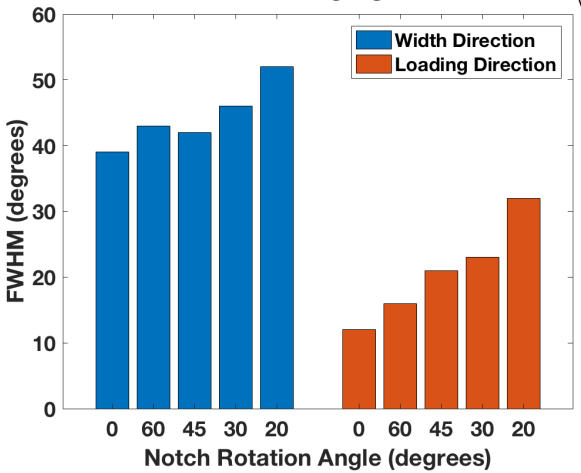
H



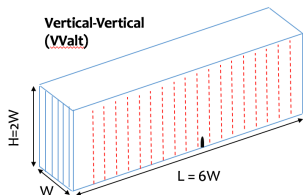
Horizontal (H)



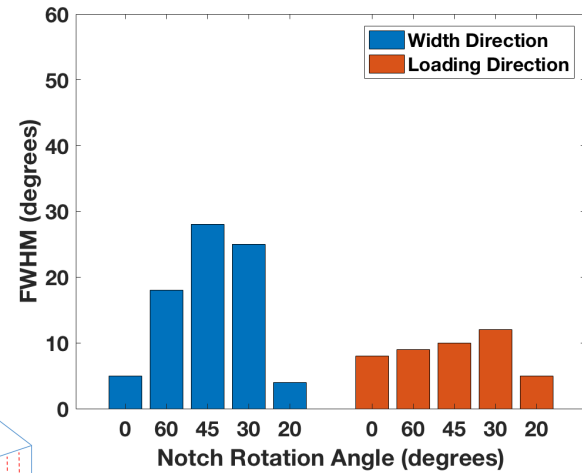
VValt



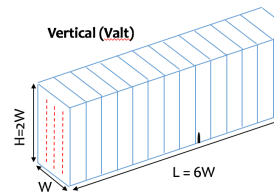
Vertical-Vertical (VValt)



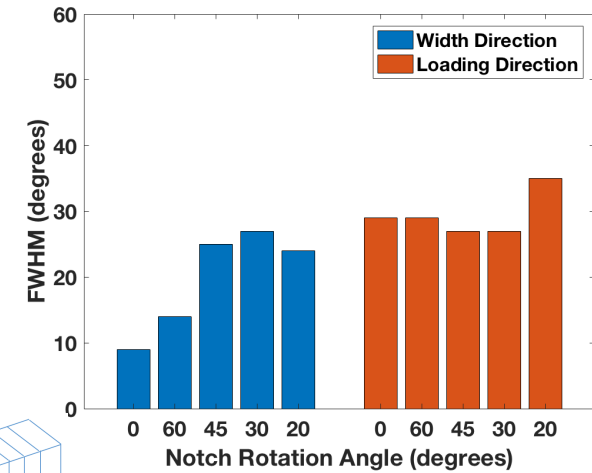
Valt



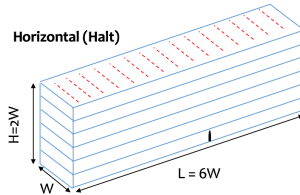
Vertical (Valt)



Halt



Horizontal (Halt)



Conclusions

- The direction of layering and in-layer mineral fabric affected the fracture path, toughness, and roughness.
- As the fracture propagated, the fracture surface rotated, tended to become planar and parallel to the loading i.e. becoming a Mode I failure plane.
- Micro-Slope distribution changed when Mode III applied.
- When the mineral fabric or layer directions were parallel to the loading, the induced fracture tended to be planar.

~Thank you for your attention~

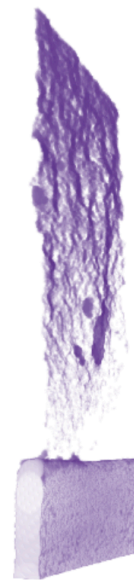
Questions?

Liyang Jiang
jiang352@purdue.edu

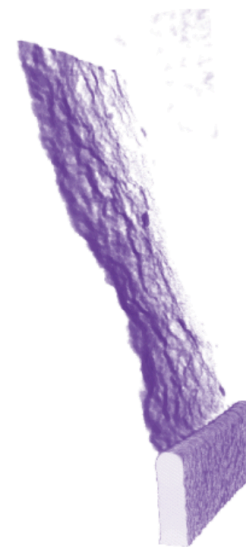
Advisement of Damage Mechanics Challenge on Brittle-Ductile Material

https://purr.purdue.edu/groups/damage_mechanicschallenge

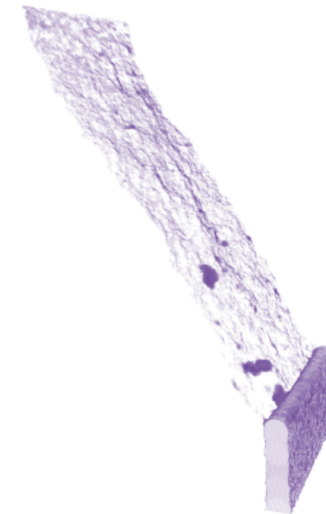
DMC



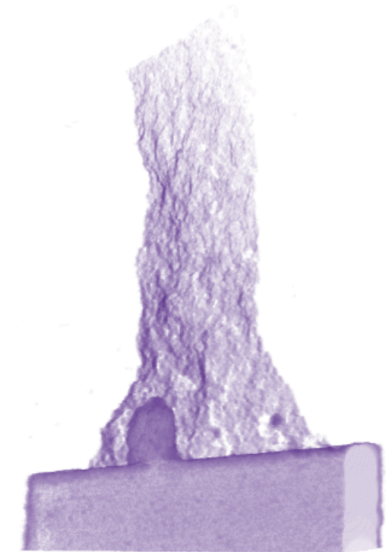
Mode I
Type C



Mode I & II
Type B



Mode I & II
Type A



Mode I & III
45 degrees angle

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