Deformation and Failure Mechanisms of Tissues: Studies at Different Length Scales and Loading Rates

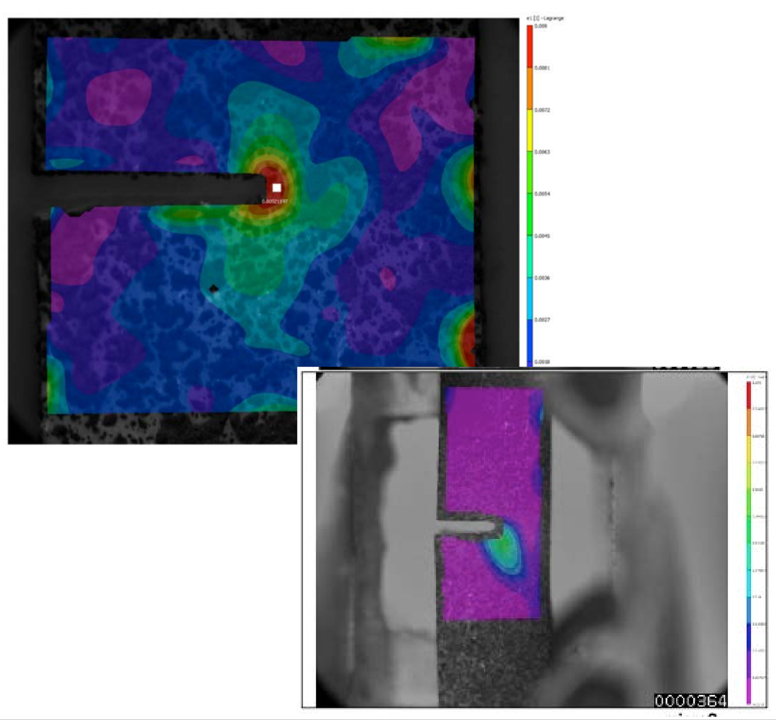
S&T Campaign: Sciences for Lethality and Protection
Kinetic Protection
Soldier Protection

Tusit Weerasooriya
(410) 306-0969
tusit.weerasooriya.civ@mail.mil

open campus

Research Objective

- **Deficiency: The fracture behavior of bones and other tissues are not well understood, especially at high rate**
- **Goal:**
  - **Understand deformation and failure mechanisms of biological tissues subjected to mechanical loading**
  - **Investigate deformation and failure over a wide range of length scales and loading rates**



In situ digital image correlation of the full-field strain behavior

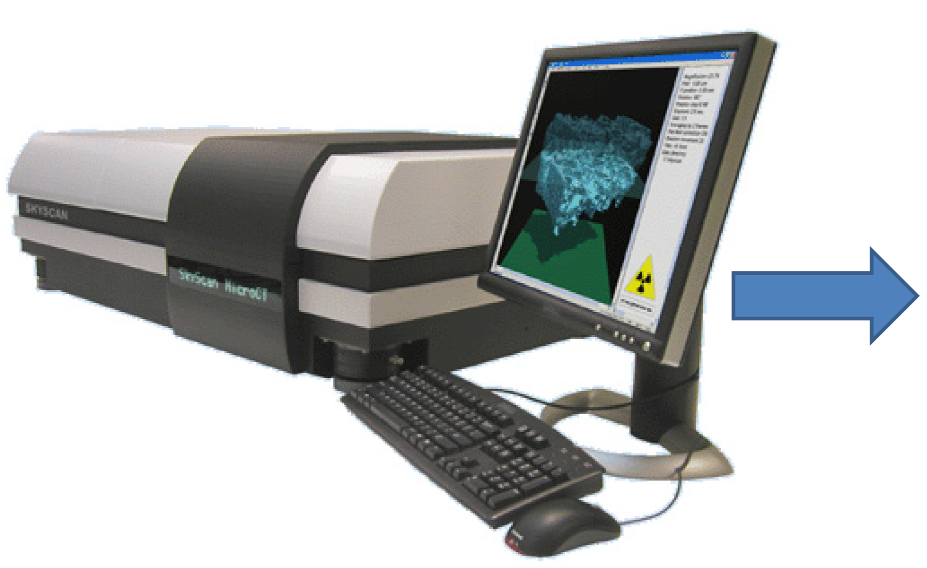
4-pt bend setup for quasi-static and high strain rates

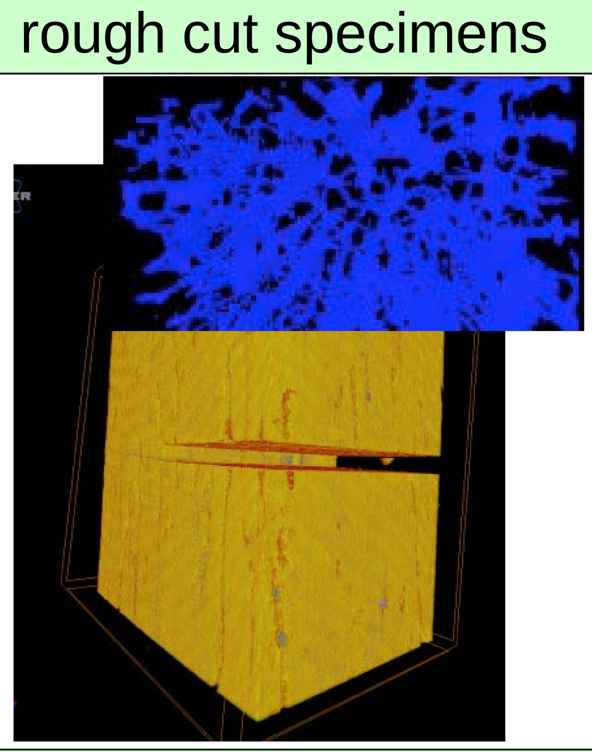
Challenges

- **Anisotropic behavior of bones and other tissues is not well understood**
- **Tissue and bone sample preparation is time consuming**
- **Studies must be conducted to quantify the effect of mechanical loading on the substructural composition of biological tissues**

High-rate experimental setup

Human femur with extracted rough cut specimens

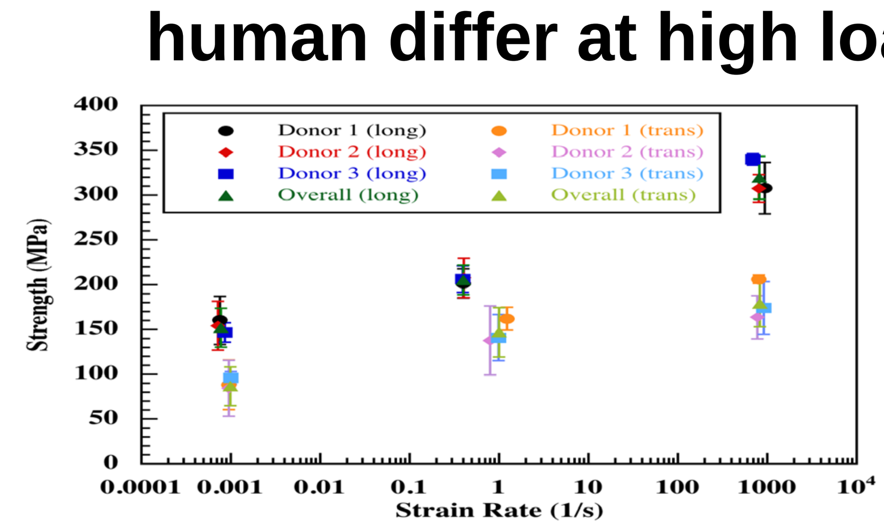




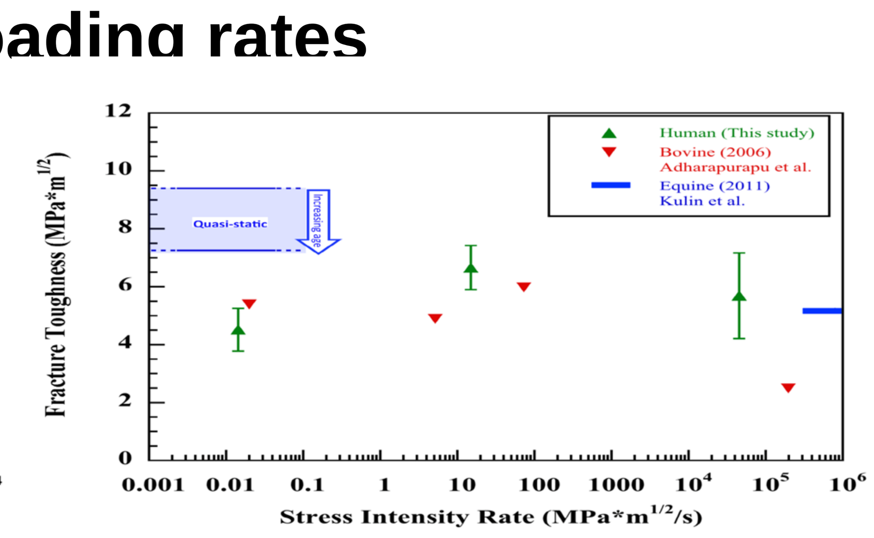
Bruker micro CT
Micro-CT reconstruction of the crack-tip of a fracture specimen

ARL Facilities and Capabilities Available to Support Collaborative Research

- **Experimental capabilities at ARL include**
  - **Quasi-static and high-rate methods to measure the fracture toughness of human cortical bone**
  - **Methods to obtain the compressive response of cortical bone and 3D printed bone simulant materials**
  - **Micro CT imaging capability to look at mineral density, porosity, 3D microstructure and crack growth patterns**
  - **In situ digital image correlation to capture the full-field strain behavior of cortical bone during deformation**
- **Our results show that**
  - **Cortical bone is strain-rate dependent in compression**
  - **Fracture toughness at quasi-static and high rates fall in a similar range, and fracture toughness reaches a peak at intermediate rates**
  - **Critical initiation fracture toughness for animal and human differ at high loading rates**



Compressive failure strength as a function of strain rate



Fracture toughness as a function of loading rate

Complementary Expertise / Facilities / Capabilities Sought in Collaboration

- **Anisotropic constitutive modeling for human cortical bone applicable to quasi-static and high rates**
- **Numerical simulation of cortical and skull bone deformation and fracture at the microstructural scale**
- **A mixed-mode fracture criteria for human cortical bone**
- **Complementary small-scale experiments to study transverse fracture response**
- **Model validation experiments at the macro scale**
- **Studies of mechanical behavior at tissue interfaces**
- **Experimental methods to study connective tissues**
- **Inverse computational methods to extract material response from measured responses of non-uniform materials such as cranial bone**