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Introduction to TRU Waste Model Parameter Determination

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U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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Outline

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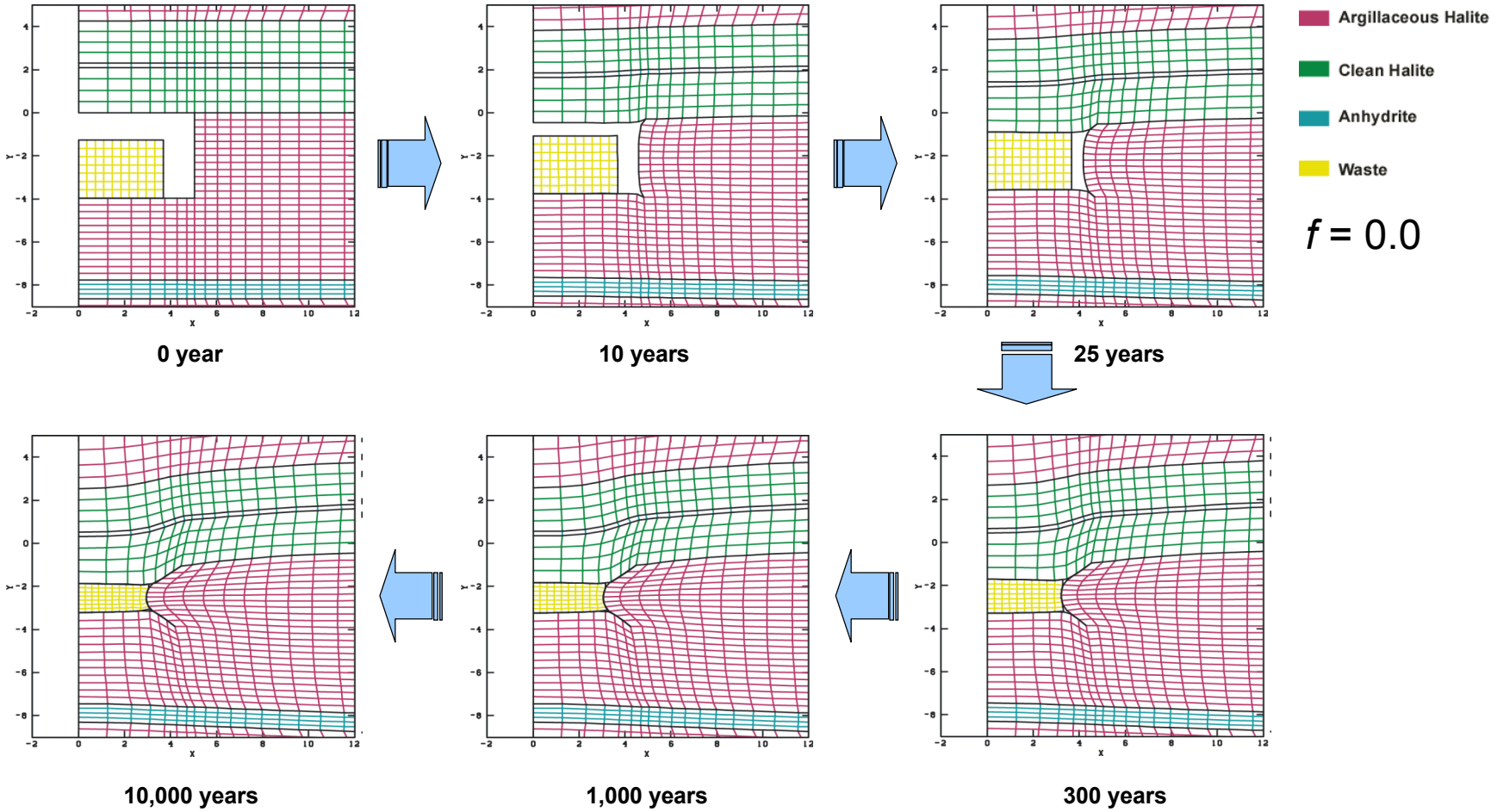
- Porosity surface calculations use Soils and Foams model
- Problems with Soils and Foams model
- Replace existing Soils and Foams model with a different cap plasticity model
- What data is needed to parameterize the new model
- Testing strategy
- Summary

Porosity Surface Calculations

- We use the Soils and Foams volumetric plasticity model implemented in Sandia FEM codes to model the behavior of the waste



Problems with the Soils and Foams Model

- The Soils and Foams model exhibits a negative Poisson's ratio (auxetic materials)
- Pressure versus volumetric strain data set is incomplete
- Composite behavior based on mixture theory
- Inventory different than the BIR, Rev. 1 used by Butcher et al. to develop the model

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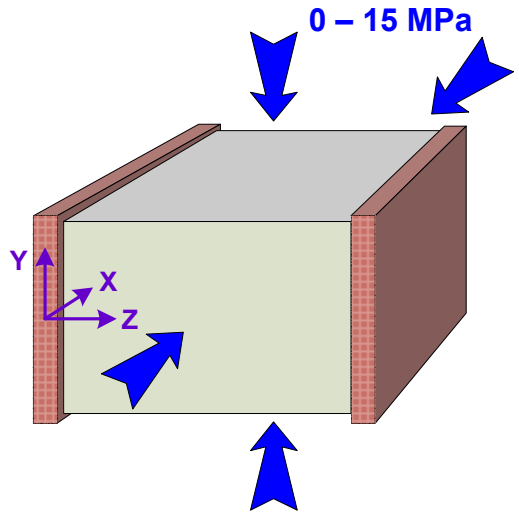
Preliminary Results

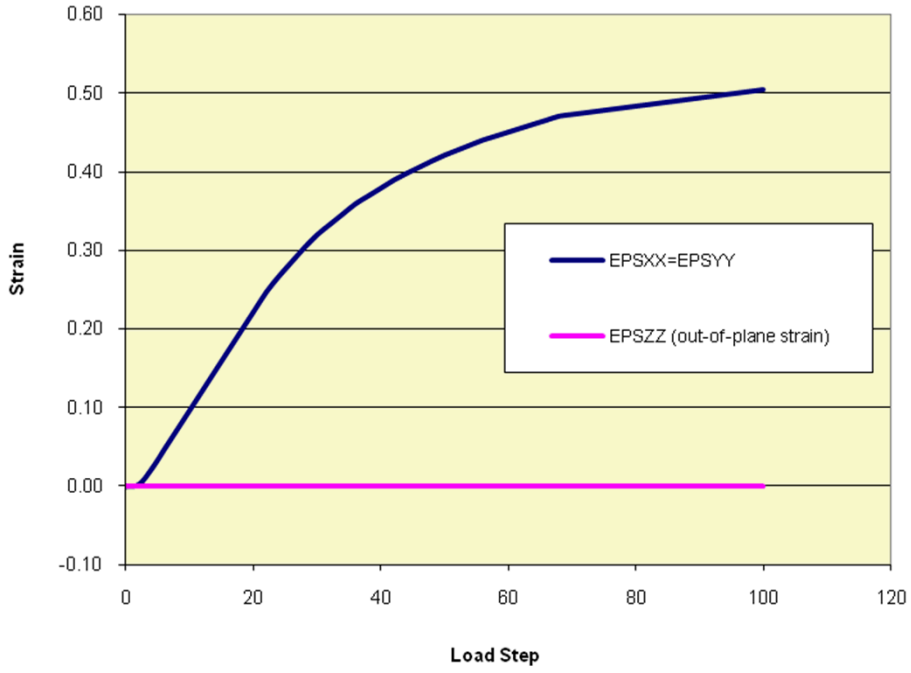


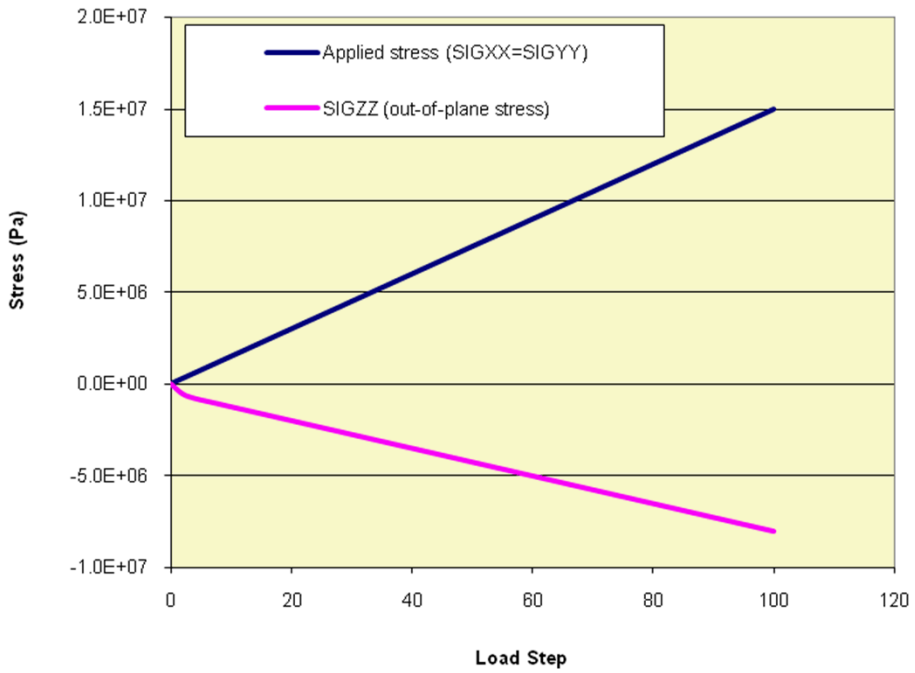
Plane Strain Test Problem:
Calculated Stresses and Strains

Out-of-plane stress is tensile (negative)

Same behavior is seen in room closure calculations

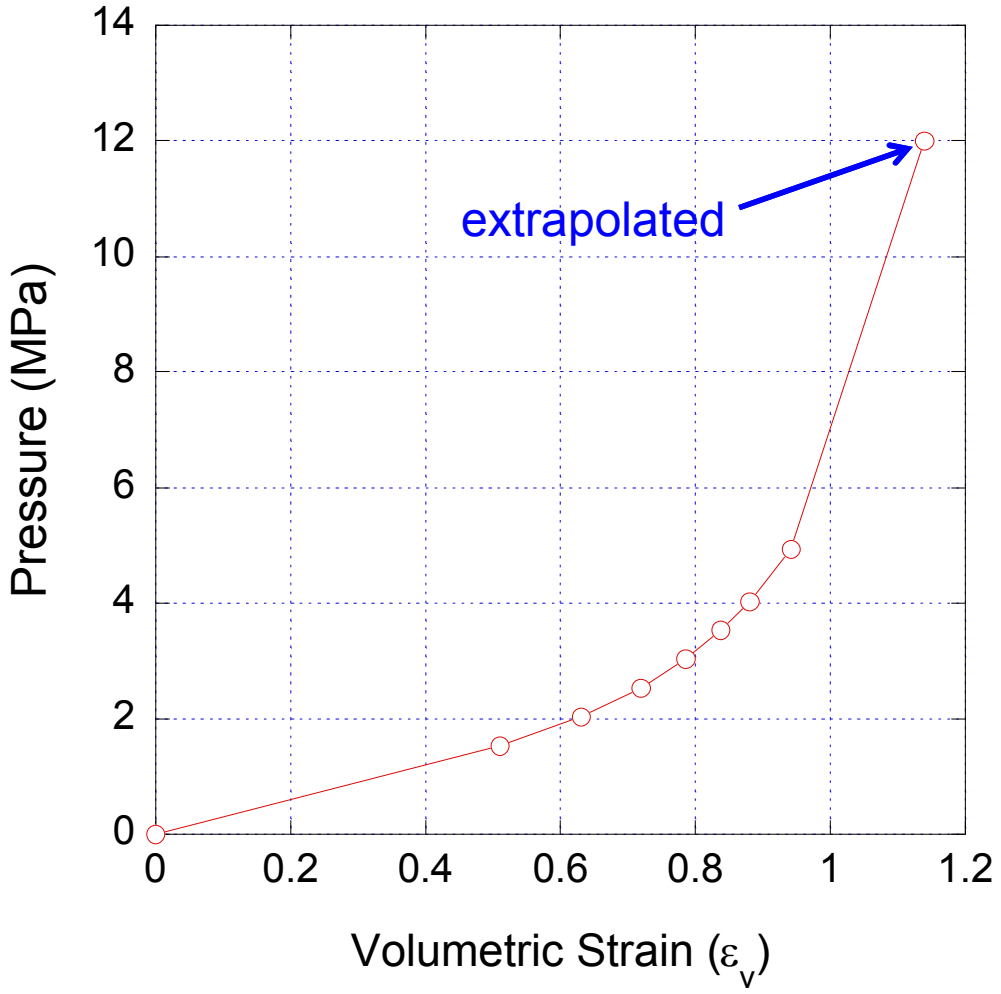
Out-of-plane strain is zero as expected





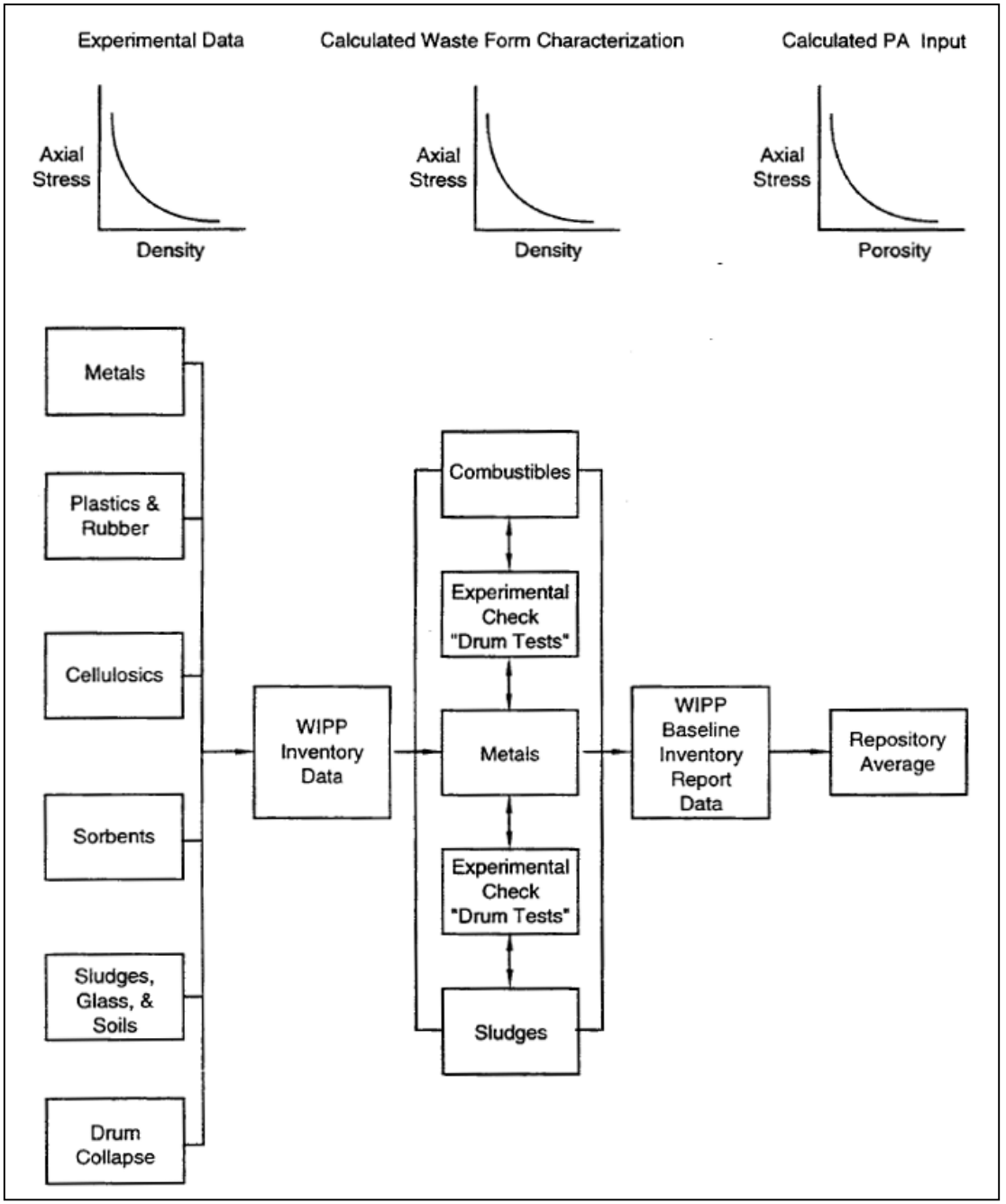
Extrapolated Data Set

- Estimates mean stress and volumetric strain relationship with an extrapolated data set (Weatherby et al. 1991)



Model Development

- Used mixture theory applied to experimental results of a variety of different waste types
  - Die compaction tests
- Used the BIR, Rev 1 estimate



Questions

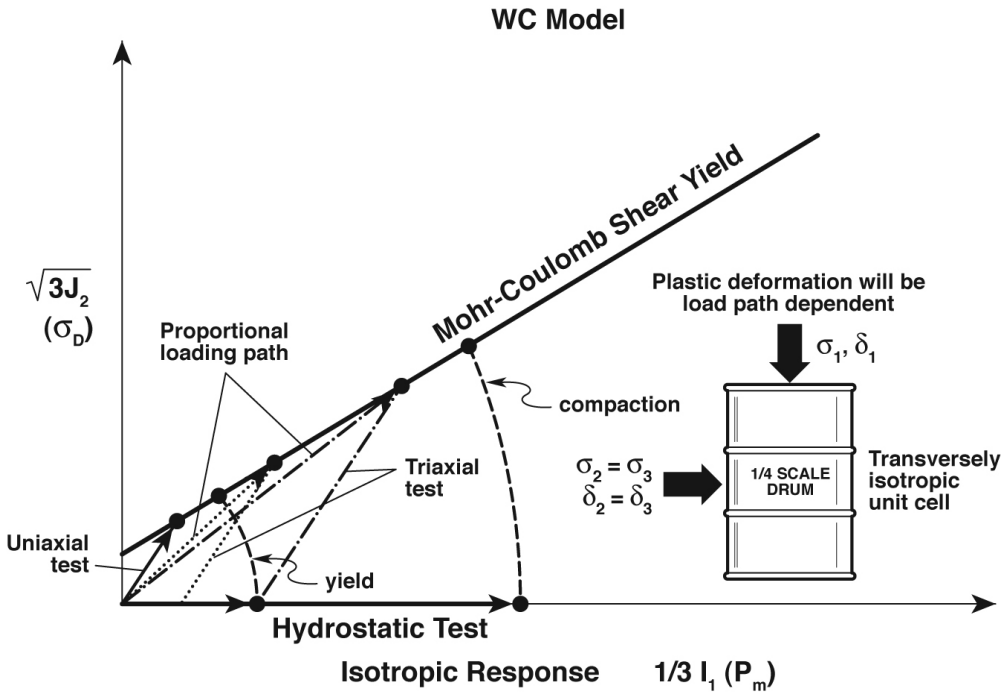
- Is there something wrong with the implementation of the Soils and Foams model in JAS3D or SANTOS (i.e. does it have bugs)?
  - No. It can be shown that the model is behaving according to it's theoretical formulation. A test case used in the qualification of SANTOS and JAS3D shows that it is performing correctly.
- Can the Soils and Foams model parameters be chosen to better fit the drum compression data?
  - No. The model parameters were chosen to honor the available data. There was no data available for determining the shear limit surface.

What Can We Do to Improve the Situation?

- Obtain missing experimental test data and
- Use a different constitutive model for the waste
- The possible choices in JAS3D (listed in order of increasing complexity/features) are:
  - Weidlinger Cap Model (Sandler and Rubin, 1979)
  - Sandia Cap Model (Fossum and Fredrich, 1998)
  - Sandia Geomodel (Fossum and Brannon, 2004)
- Other cap models have been implemented in Adagio

Experimental Data Requirements

- To uniquely define a cap model under all possible stress paths, five types of stress path tests are required:
  - Hydrostatic compression
  - Uniaxial compression
  - Triaxial compression
  - Triaxial extension
  - Direct tension
- Because of the nature of the material, having essentially zero tensile strength, only the first three are necessary



Current Data Sets

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Fresh Waste	Degraded Waste
Butcher et al. (1991) • Die compacted scaled waste (quasi-uniaxial strain) • Uniaxial compression of full-scale waste packages. • Only axial deformation was measured. Wawersik (2001) • ¼-scale waste packages • Uniaxial compression • Confined (with backfill) compression seven-pack arrangements	Hansen et al. (1997) • 50% and 100% with and without MgO • Die compaction (primarily to create consolidated samples) • Uniaxial compression • Triaxial compression (two pressures) Broome et al. (2014) • 50% and 100% without MgO • Hydrostatic compression • Triaxial compression

Testing Strategy

- Surrogate 50% and 100% degraded wastes testing is complete
- Full-scale testing of containers with fresh waste is not possible for all needed loading paths and would be very expensive
- Use ¼-scale tests to simulate response of waste packages along needed loading paths
  - Use full-scale tests along selected load paths for up-scaling validation

Summary

- A more complete cap model is capable of giving a better approximation to the behavior of fresh and degraded waste forms than the current Soils and Foams Model
- Additional test data is required to fully implement a complete cap model
- Model differences may not radically affect the predictions of the overall performance of WIPP (Callahan 2004), however it will correct an obvious defect created by application of a simplified model and a sparse data set

Odd Math

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USA 2, Ghana 1 → USA 3

Questions?

- Scott will answer all your questions

Inventory Comparison

Weight Fraction (%)

Waste Composition	Butcher et al. (1991)	Hansen et al. (1997)	CRA-2004 PABC	CRA-2009 PABC	CRA-2014
Metals	22	52	41	47	49
Cellulosics	30	7	8	8	5
Rubber and Plastics	15	9	9	10	10
Sorbents	7	4	5	6	7
Sludges	26	28	37	30	28

Cap Models

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- Uses a shear limit surface (e.g. Drucker-Prager, Mohr-Coulomb, etc.).
- It uses an elliptical shaped cap with flow rule (generally associated flow rule). This allows inelastic deviatoric and volume strains for stress states on the cap.
- Depending on shear surface and flow rule, model can predict material dilation when the stress reaches the limit state.