

High Strain-Rate Axisymmetric Compression Testing and Model Fitting for Fine Aggregate Cementitious Material

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Outline

- **Objective to characterize Fine Aggregate Cementitious Material (FACM) and to conduct penetration experiments into this material**
- **Quasi-static tests at ERDC**
- **Confined split Hopkinson pressure bar tests at SNL**
- **Fitting of material data into Geomodel**
- **Summary**



FACM

- **ERDC had a task to investigate strain rate effects in simulating impulsive loading events**
- **FACM has an unconfined compressive strength of 34 MPa (5000 psi) and no coarse aggregate, allowing dynamic testing on SHPB facility**
- **FACM material data → GeoModel → numerical simulations → comparisons with penetration experiment data**

Quasi-static material data

- ERDC/GSL TR-05-16, Laboratory Characterization of Fine Aggregate Cementitious Material

Table 3
Completed FACM Test Matrix

Type of Test	No. of Tests	Test Nos.	Cycles in Test Nos.	Nominal Peak Radial Stress, MPa
Hydrostatic Compression	2	1, 2	2	500
Triaxial Compression	4	37, 38, 39, 40		0
	2	3, 4		5
	2	5, 6	6	10
	2	7, 8	8	20
	2	9, 10	10	50
	2	11, 12	12	100
	2	14, 15	14	200
	2	16, 17		300
	2	18, 19	19	400
UX Strain	2	20, 21	21	500
UX/BX	2	22, 23		200
	2	24, 25		100
UX/CV	1	30		65
	2	27, 29		100
UX/SP	3	26, 31, 32		100/50
DP	5	41, 42, 43, 44, 45		0
RTE	1	35		50
	2	33, 34		65
CTE	1	36		10
Total No. Tests:	43			

UX: uniaxial strain (undrained)

BX: biaxial strain unloading

CV: constant volume

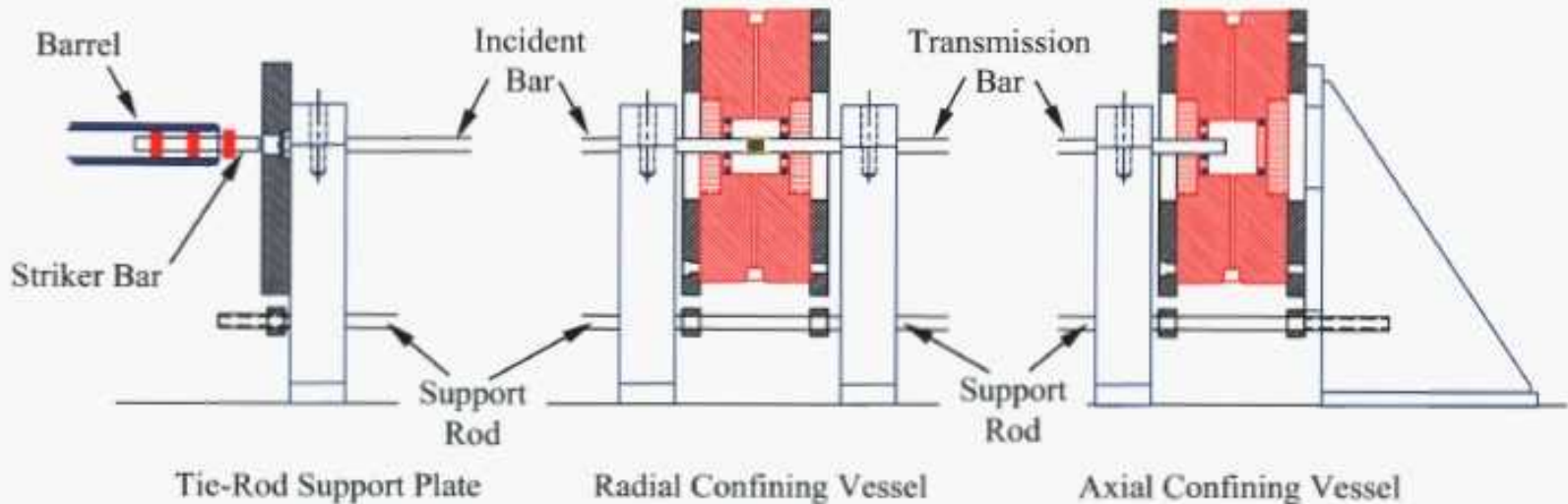
SP: constant strain path

DP: direct pull

RTE: reduced triaxial extension

CTE: conventional triaxial extension

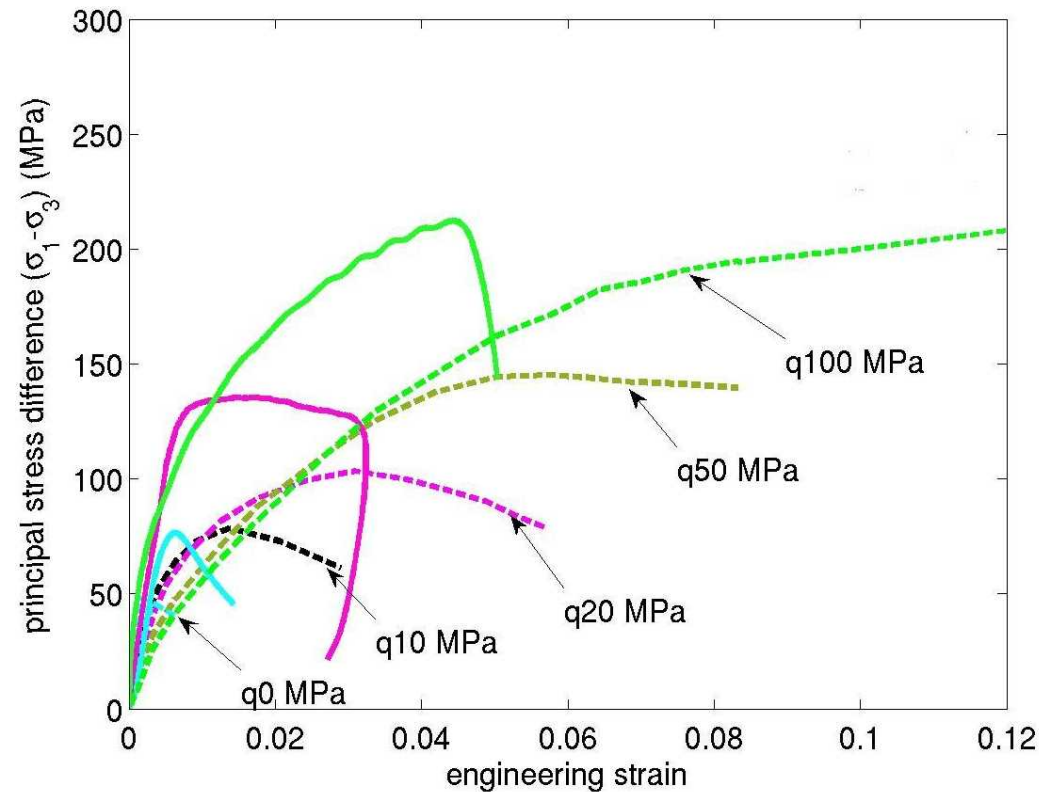
- **Confined SHPB test facility @ SNL**



- **Designed to conduct dynamic axially symmetric compression experiments**
 - isotropic loading followed by pulse/bar wave propagation
- **$\frac{3}{4}$ " and $\frac{1}{2}$ " bar diameters**
- **Strain rates range 100-3000 s⁻¹**
- **Confining pressure limit (current): 200 MPa**



Comparison of dynamic and quasi-static material data



- Dashed lines are for quasi-static data
- Solid lines are for dynamic data
- Strain rates:

180 /s	0 MPa
92 /s	20 MPa
210 /s	100 MPa
- SHPB specimen size:

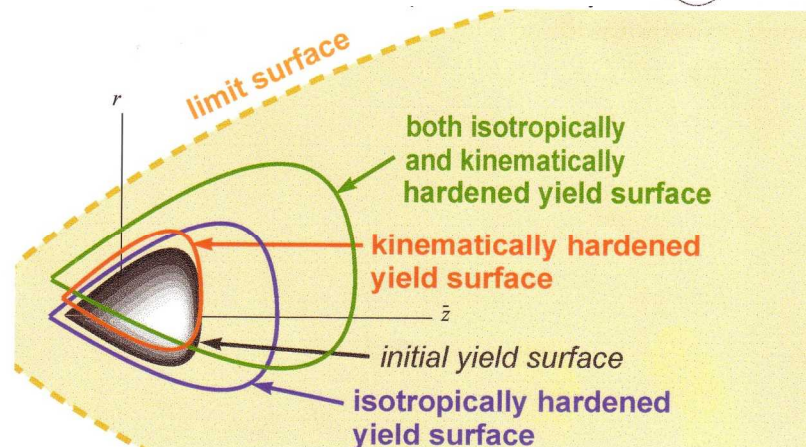
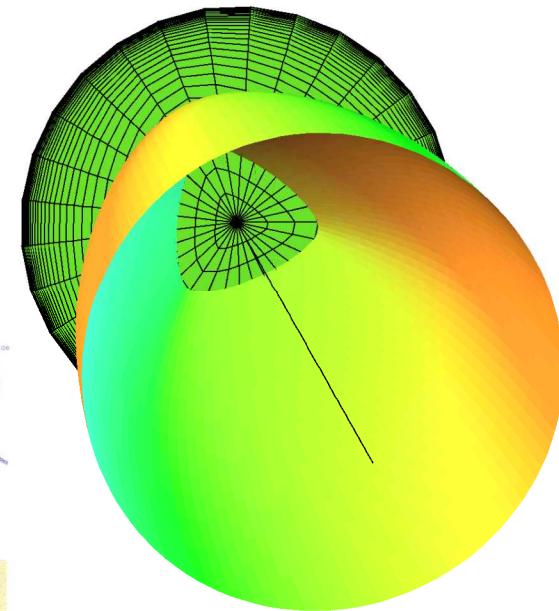
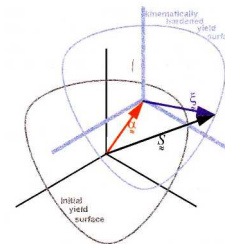
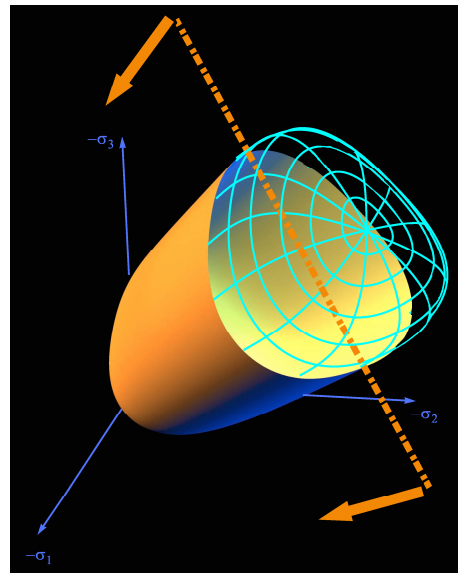
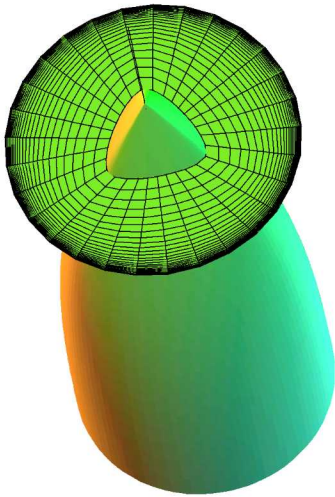
Diameter = 19.4 mm (0.76 in)
Length = 14 - 20 mm (0.55 - 0.79 in)



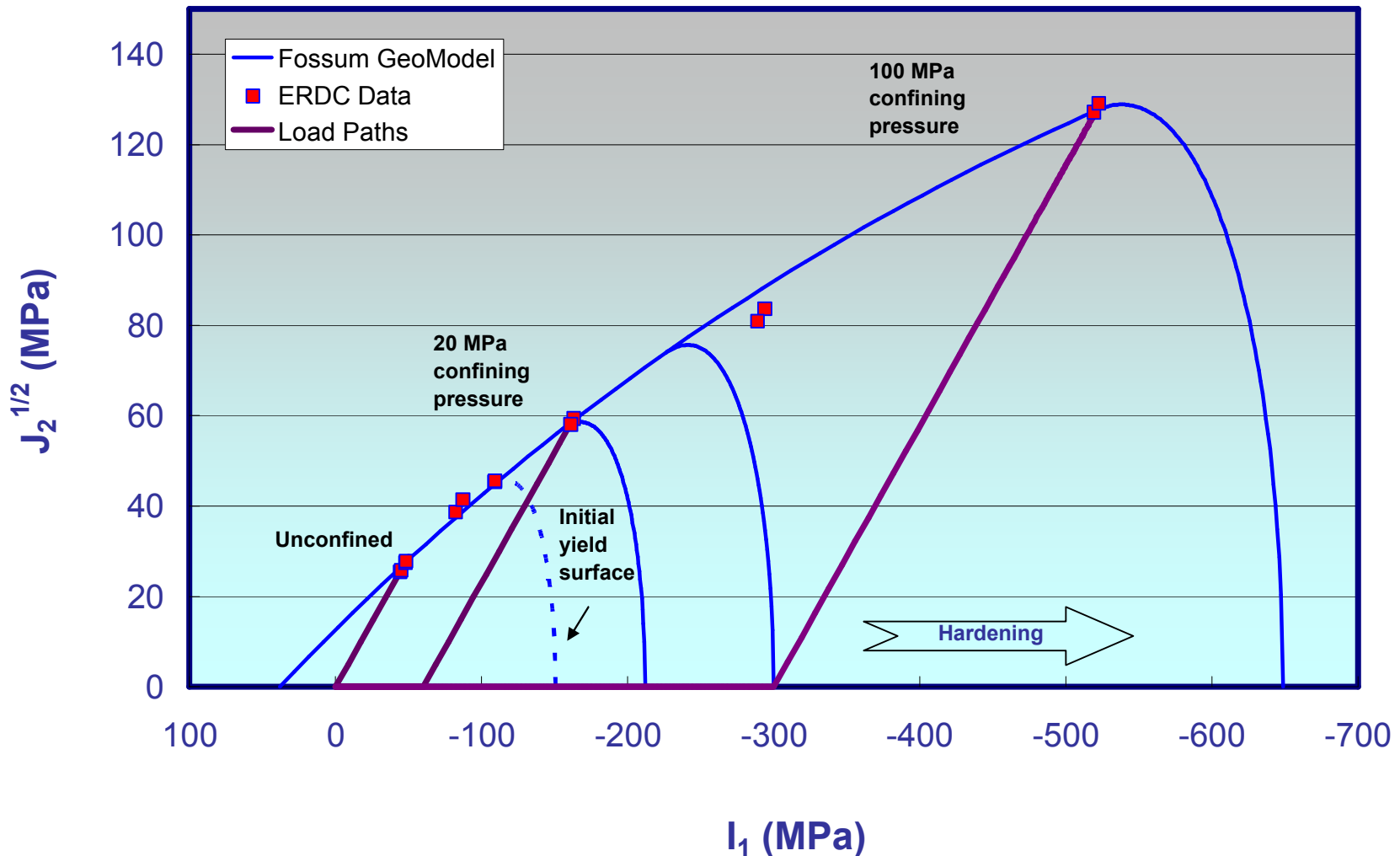
SHPB material data

- **Higher stresses are observed in dynamic data than quasi-static data for similar confining pressure conditions**
- **Limited dynamic data at 0, 10, and 100 MPa at relatively low strain rates are obtained, need more data at other confining pressure conditions and at higher strain rates (> 500 /s)**
- **The duration of SHPB data ought to be extended into higher strain ranges**

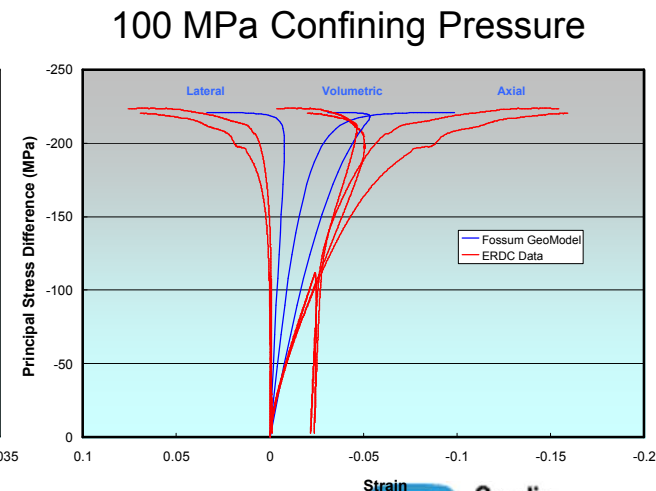
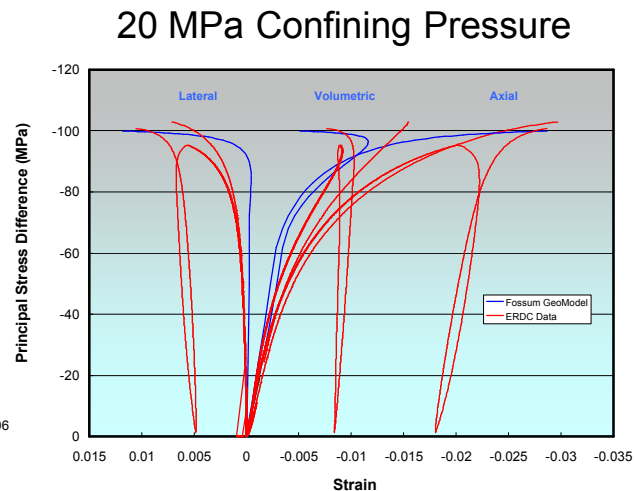
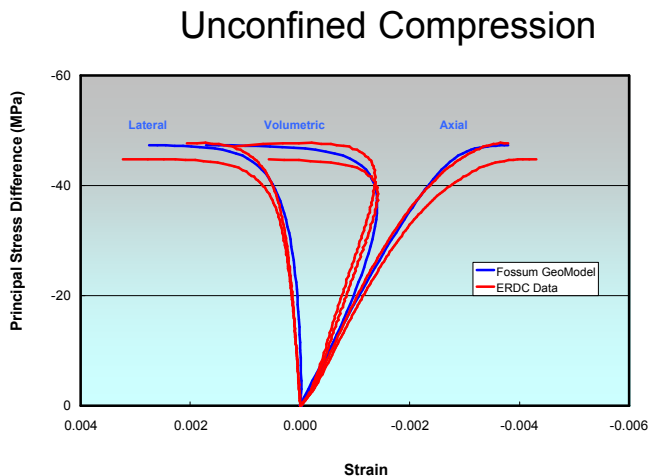
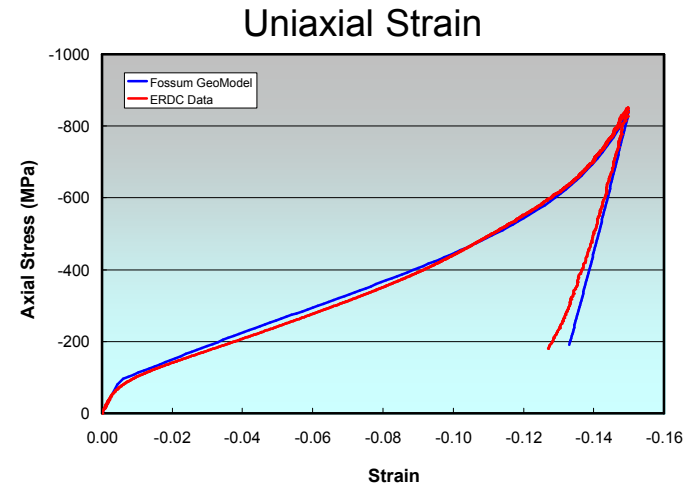
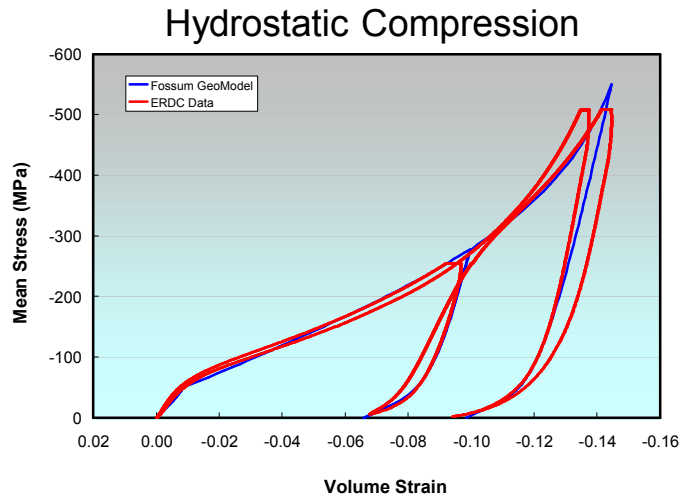
The GeoModel: a rate-sensitive general plasticity model for materials of any porosity



Quasi-static data: yield surface and load paths

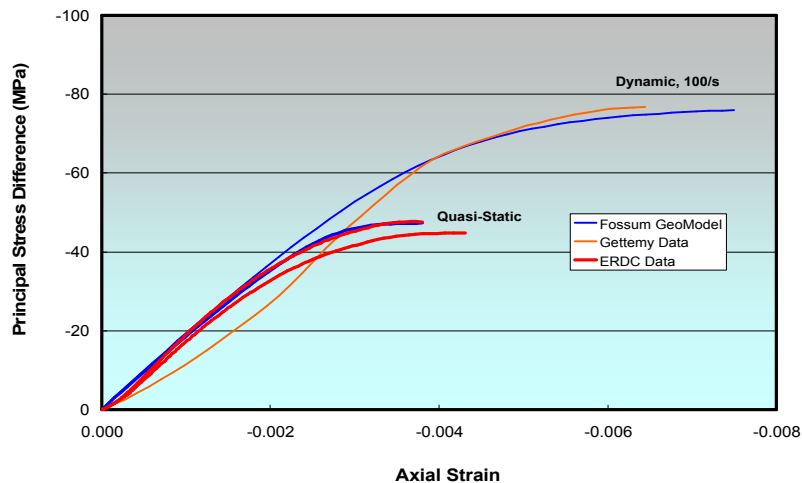


Quasi-static stress-strain GeoModel plots versus measured data

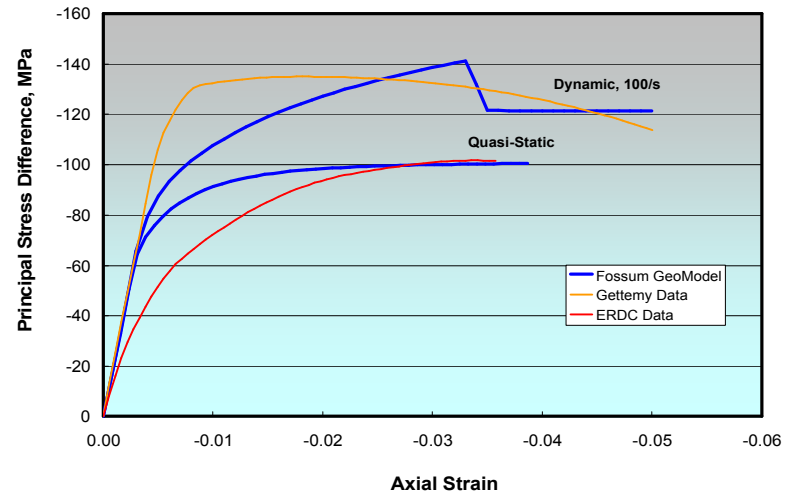


Dynamic stress-strain GeoModel plots versus measured data

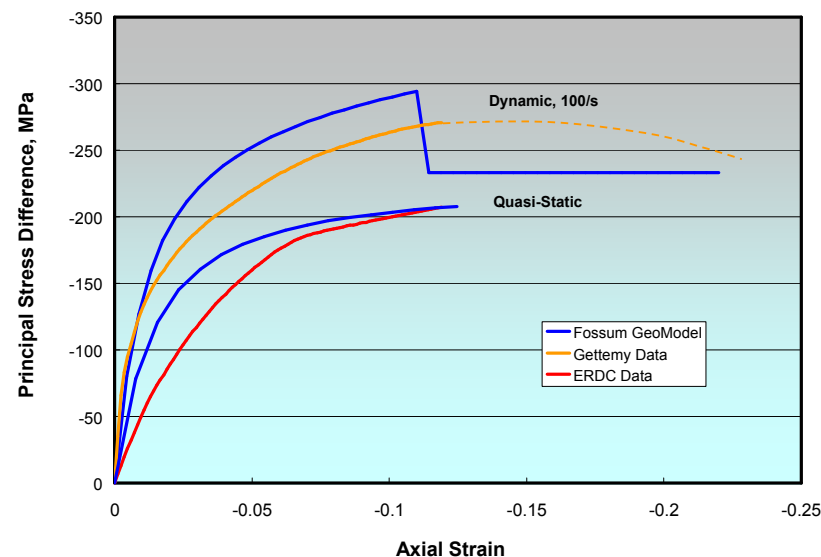
Unconfined Compression



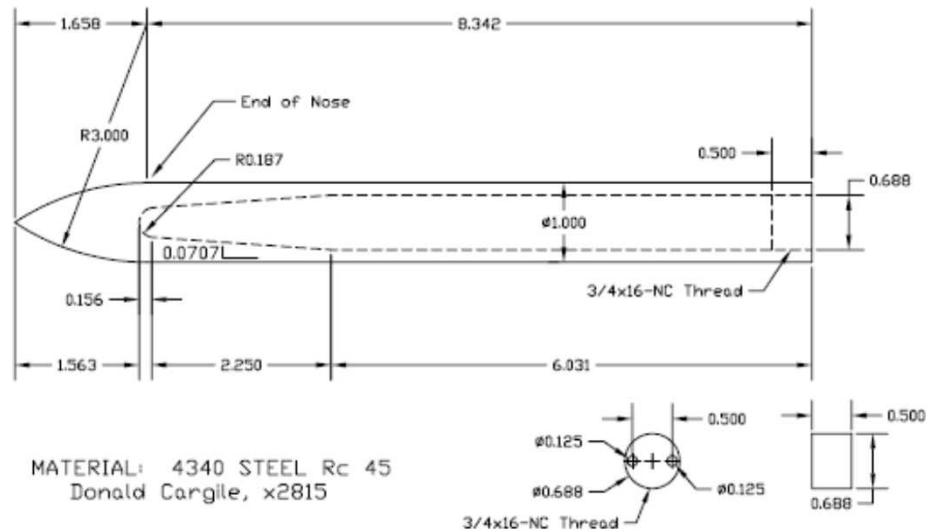
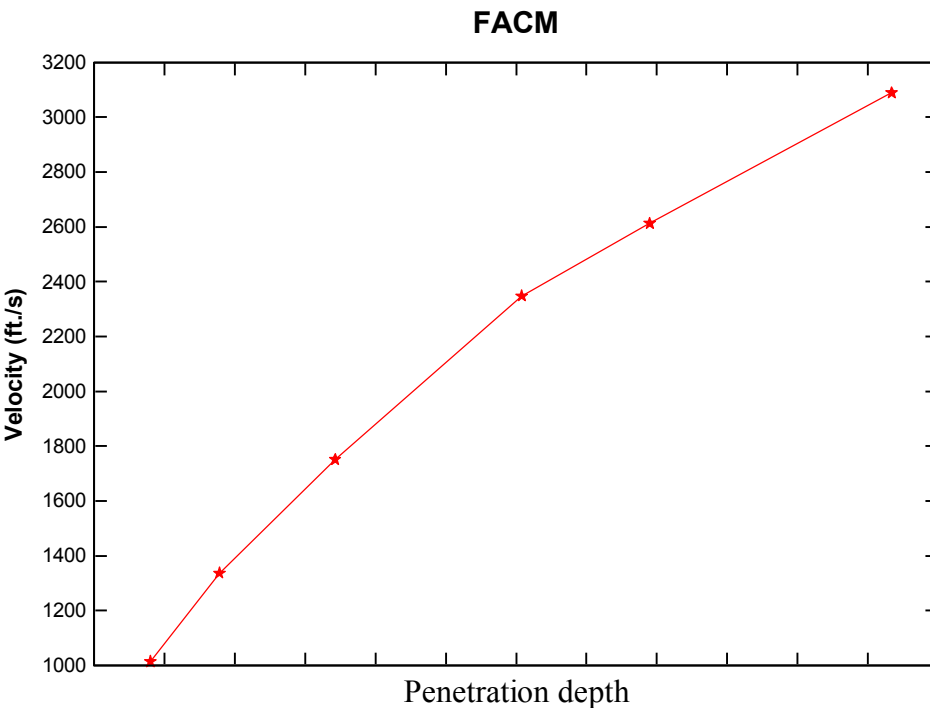
20 MPa Confining Pressure



100 MPa Confining Pressure



ERDC penetration experiments into FACM targets



- ERDC penetration experiments into FACM targets with 1 inch penetrators
- Impact speed ranges from 1000 to 3100 fps
- Code benchmarking, which consists of blind predictions and code evaluations after comparing to experiment data, will start after GeoModel for FACM has completed.



Summary

- 1. Comprehensive quasi-static and limited SHPB data for FACM have been compiled.**
- 2. The GeoModel represents the quasi-static data quite well.**
- 3. The GeoModel can predict the dynamic amplification of the strength, i.e., peak stress for the limited number of SHPB experiments.**
- 4. At the current state of development, the characteristic-time transition in the model is too abrupt in going from dilatation-to-compaction dominated mechanisms, and a smoother transition should be attempted in future enhancements.**
- 5. Additional dynamic experimental data are needed at other confining pressures and higher strain rates.**
- 6. The GeoModel that incorporates the dynamic data for FACM will be used in performing penetration analyses to generate results to compare to penetration data.**