Field Vane Test (FVT)

1. In situ test developed to measure undrained shear strength (s_u) of fine-grained soils

2. Calibrated against back analysis of embankment failures, i.e., stability problems

3. Widely used as a frame of reference for other in situ tests and laboratory tests for interpretation of s_u

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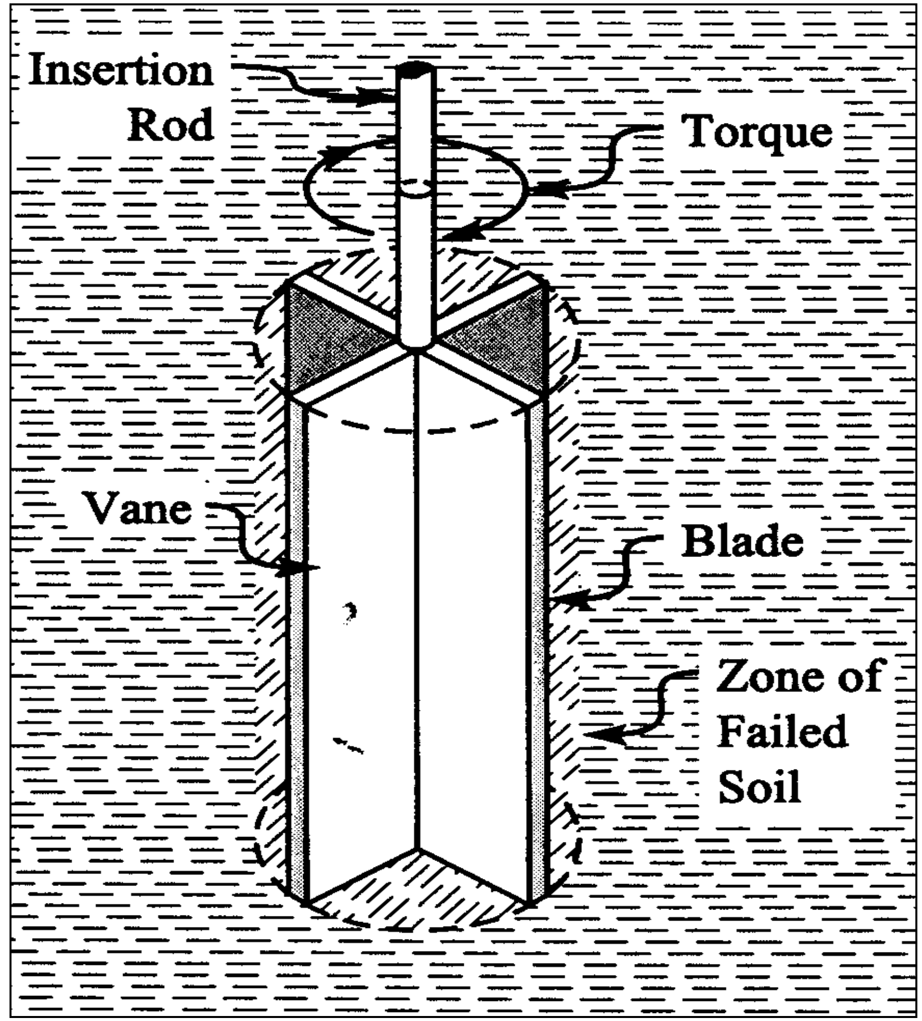
FVT - Equipment and Mechanics

1. Push thin bladed vane into soil, rotate and measure torque

2. Usual geometry: rectangular with 4 blades, sized to match expected strength of soil, H/D = 2

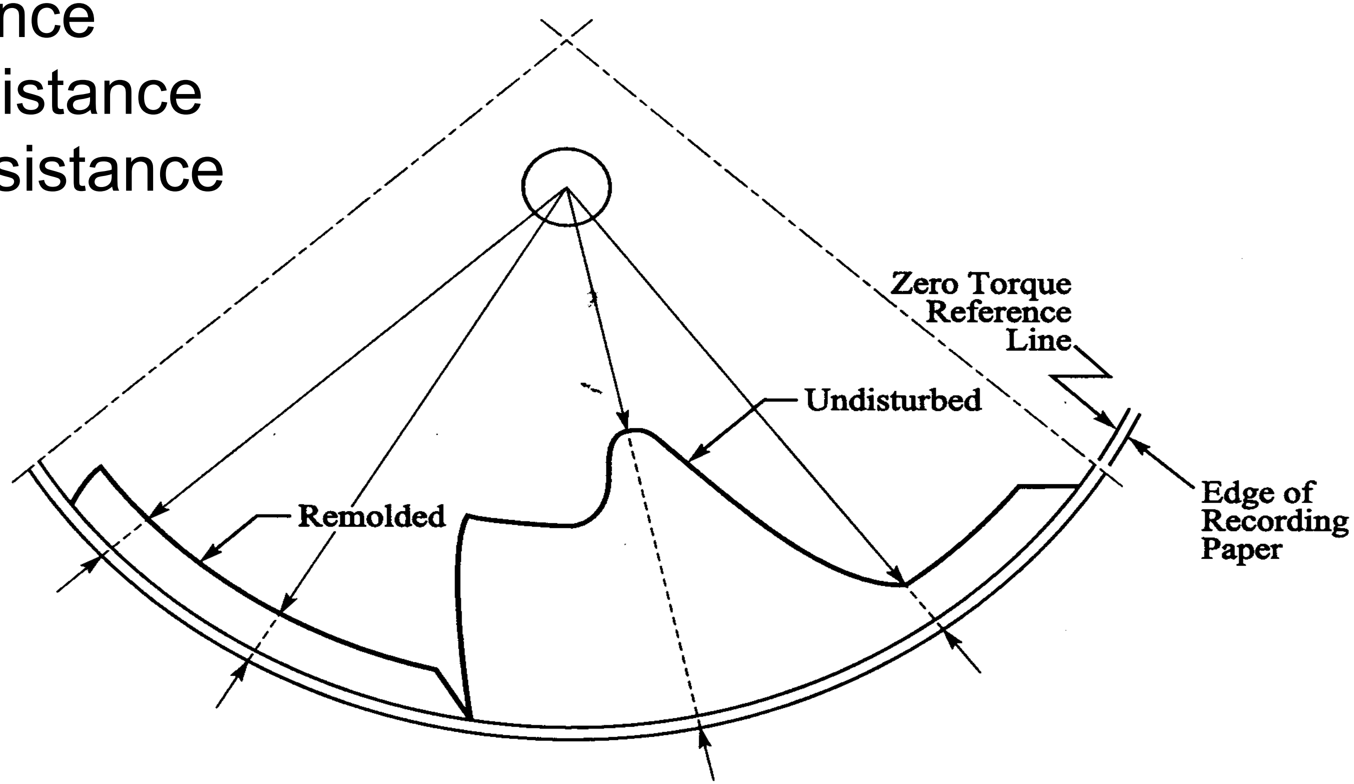


Nilcon Vane Borer

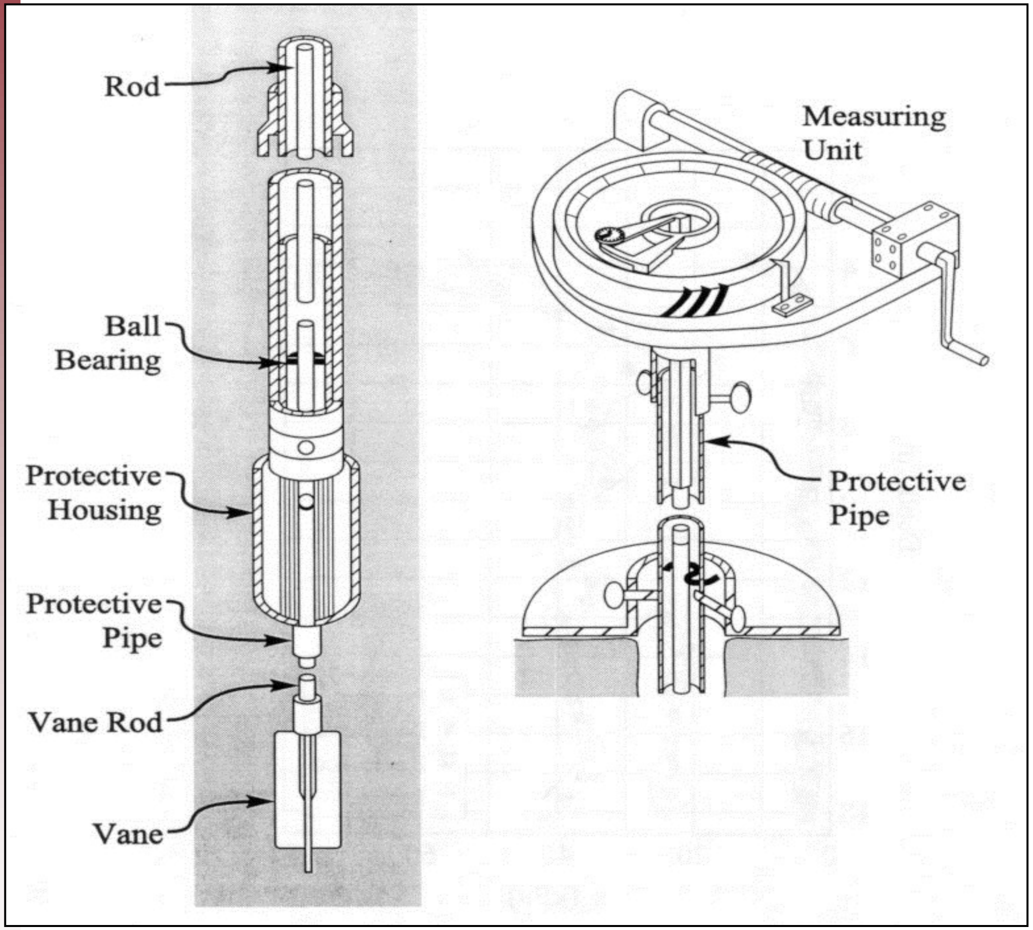
Nilcon Vane test tracing

Scribe on wax paper with trace that includes:

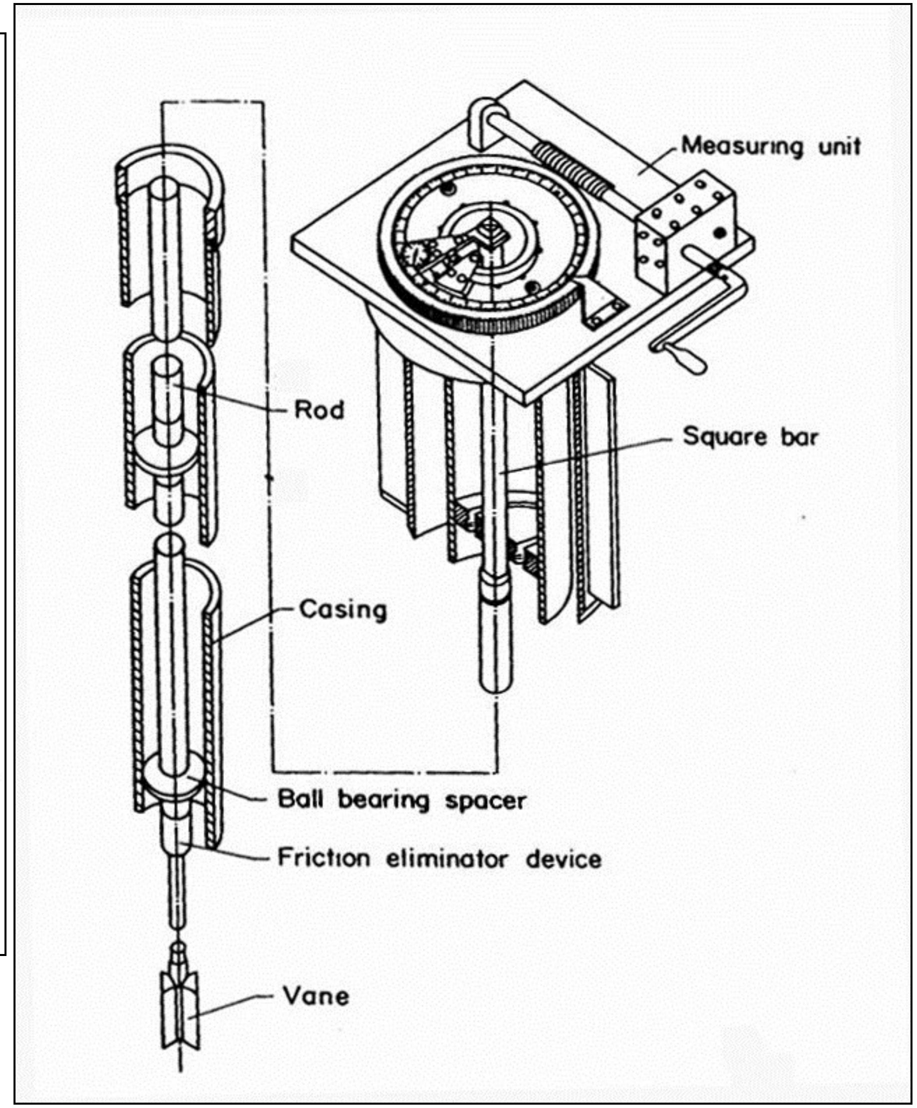
- rod friction (via slip coupling)
- peak resistance
- softened resistance
- remolded resistance



Geonor Vane



Acker Drill Co. Vane



GeoMil Electric Vane Tester

- Computer control and data acquisition
- 0.1 to 20 degrees per second
- real time plotting of torque vs rotation

Pictures from GeoMil

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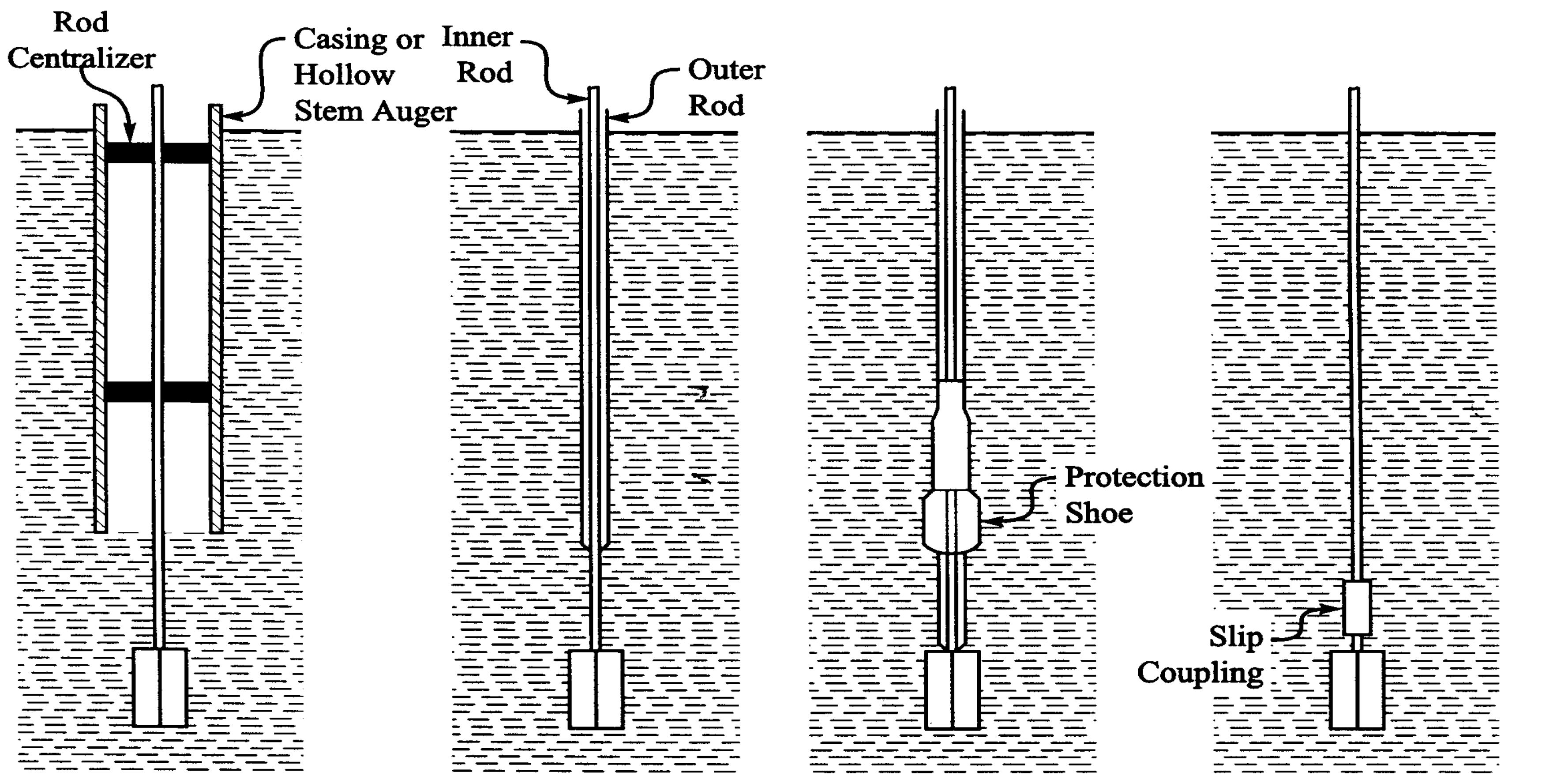
FVT – Deployment Methods



(a) Unprotected Vane through a Cased Borehole

(b) Unprotected Vane with Protected Rods

(c) Protected Vane and Rods

(d) Unprotected Vane and Rods with Slip Coupling

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FVT – Test Variables

1. Installation
2. Consolidation Time
3. Shear Rate
4. Progressive Failure
5. Vane size
6. Vane Shape

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FVT – Test Procedure

1. ASTM D2573 "*Standard Test Method for Field Vane Shear Test in Cohesive Soil*"
2. Rectangular vane w/ H/D = 2
3. Test at ≥ 5 diameters from base of borehole
4. Wait time after insertion? → 1 to 5 min
5. Rotate ≤ 0.1°/s = 6°/min, t_f ~ 2 – 5 min
6. After failure rotate ~ 10 times to measure s_{ur}
7. Test interval ≥ 2 ft

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FVT Standards and Guidelines

Examples of some differences (after Lunne 2006)

Parameters	ASTM[1]	BS[2]	NGF[3]	SGF[4]	CEN[5]
Vane blade diameter (mm)	38.1 / 50.8 63.5 / 92.1	50 / 75	55 / 65	40 – 100	40 – 100
Thickness of blade (mm)	1.6 / 3.0	??	2.0	0.8 – 3.0 / avg. ≤ 2.0	0.8 – 3.0
Procedure depth of insertion	5x hole dia.	3x hole dia.	0.5 m below shoe	5x hole dia.	5x hole dia. or 0.5 m
Rate of rotation	6°/min	6-12°/min	12°/min	not specified	6 - 12°/min
Time to failure	2 to 5 min	5 min	1 to 3 min	2 to 4 min	not specified
s_{ur} - min # revolutions	5 - 10	not given	25	20	≥ 10
Delay time	< 5 min	-	< 5 min?	2 - 5 min	2 – 5 min
Interval between tests	> 0.76 m	0.5 m	0.5 - 1.0 m?	> 0.5 m	≥ 0.5 m

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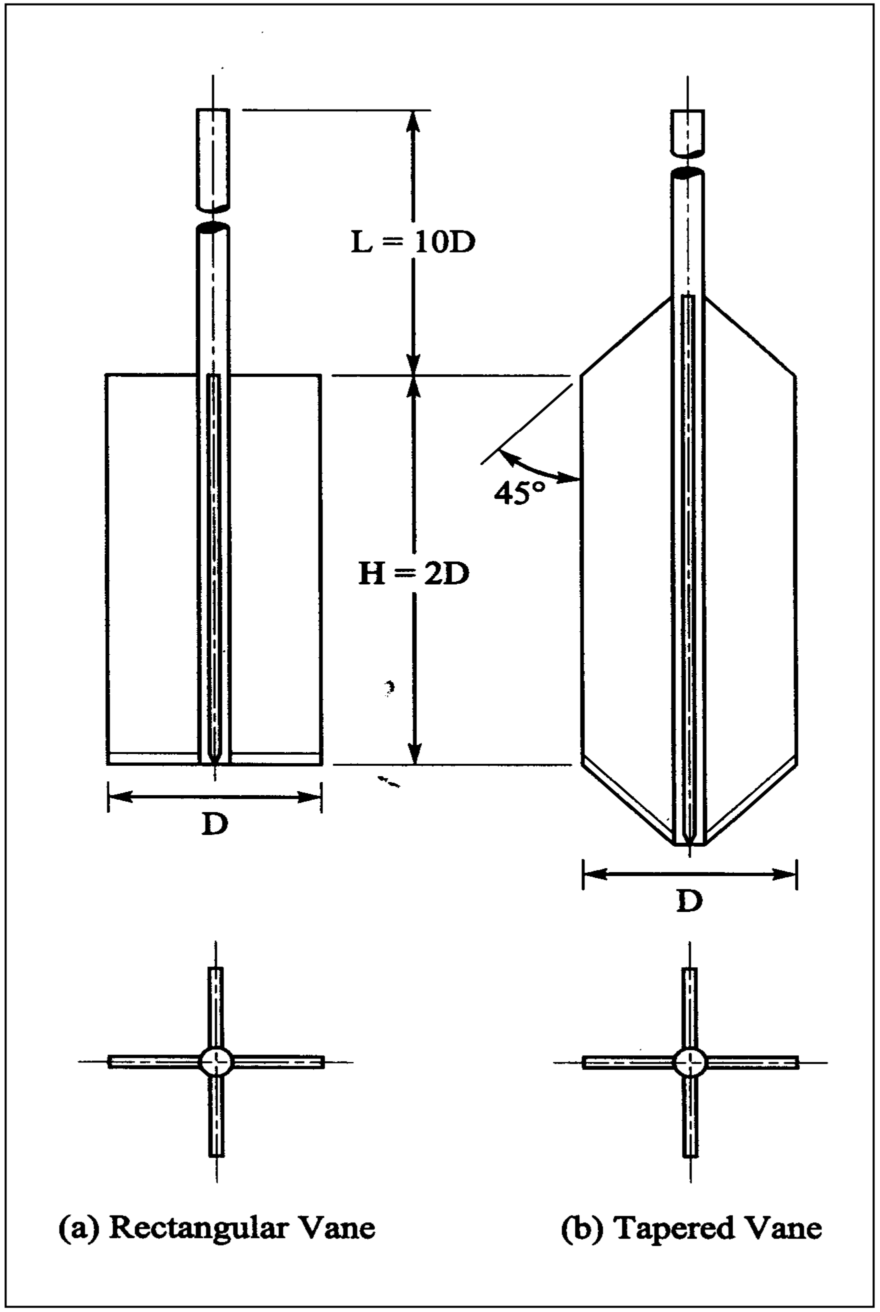
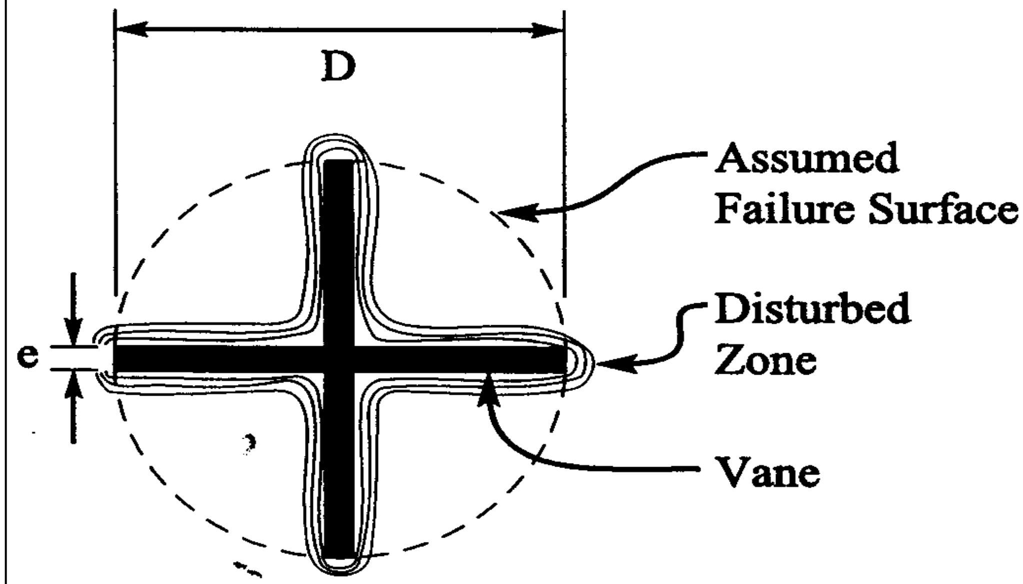
Common vane shapes



FVT – Installation Disturbance

1. Depends on vane dimensions and soil properties
2. Use Perimeter Ratio $\alpha = 4e/\pi D$
3. Want low α, therefore   D or ↓ e
4. Typical commercial vanes α = 4 to 8%



Perimeter Ratio:
$\alpha = 4e/\pi D$

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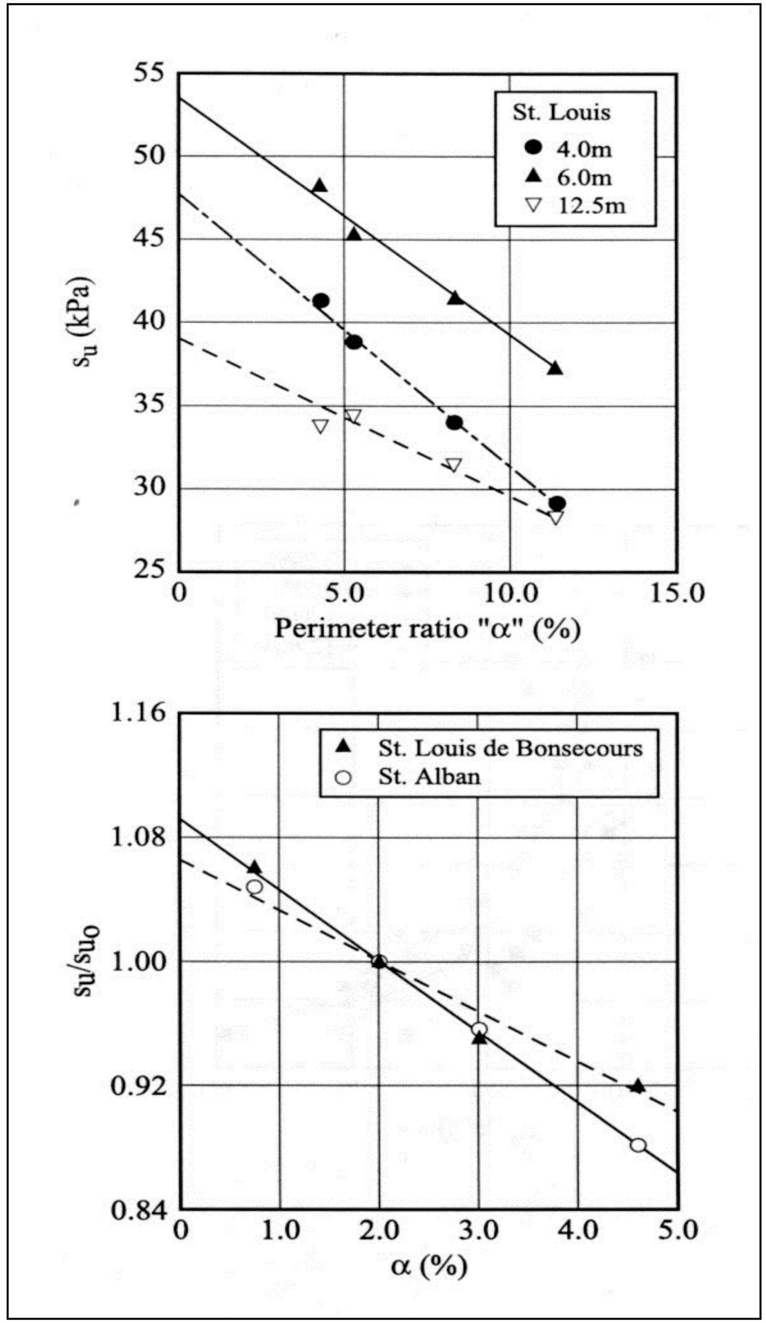
Influence of Perimeter Ratio

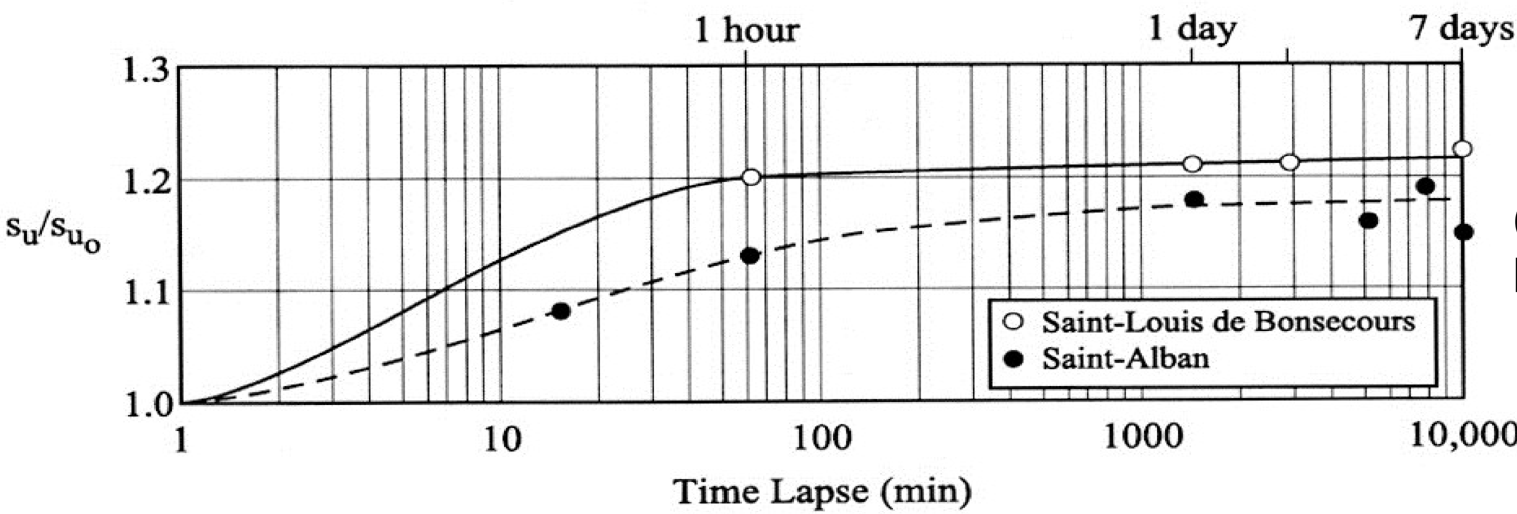
(after LaRochelle et al. 1973)



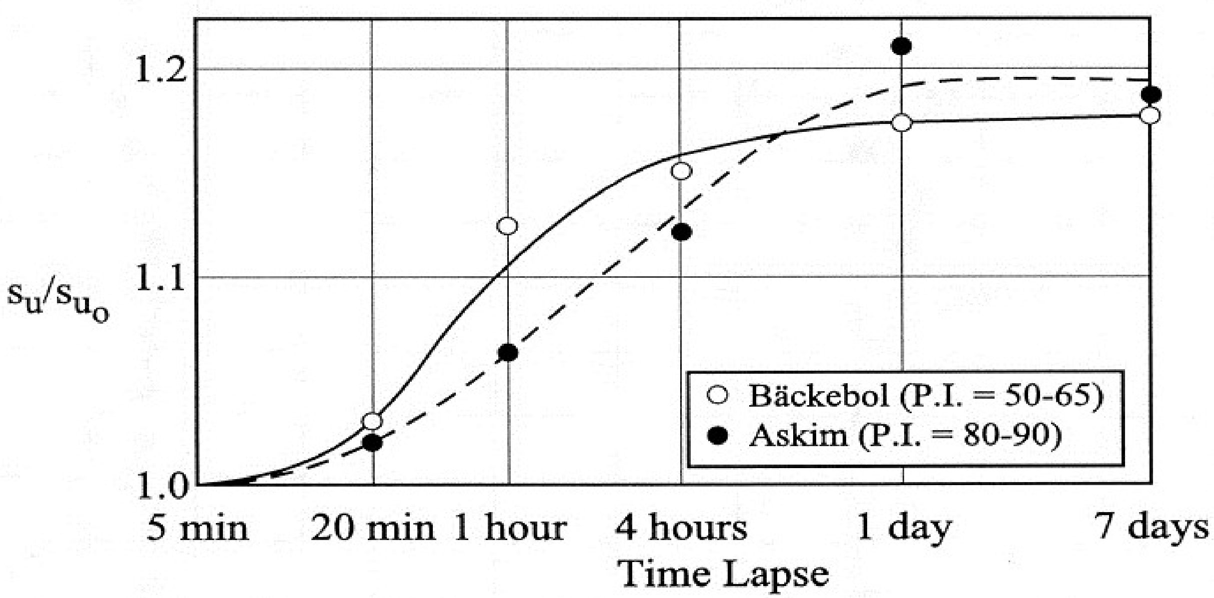
FVT – Consolidation Time

1. Generate excess pore pressures during deployment – depends on OCR
2. What to do?
3. Usually 1 to 5 min after installation

Influence of Consolidation time



(after Roy and Leblanc 1988)



(after Torstensson 1977)

FVT – Rate of Shearing

1. Strain rate effects
2. $V = r\omega$
3. Therefore must consider r and ω
4. Effect is function of soil type

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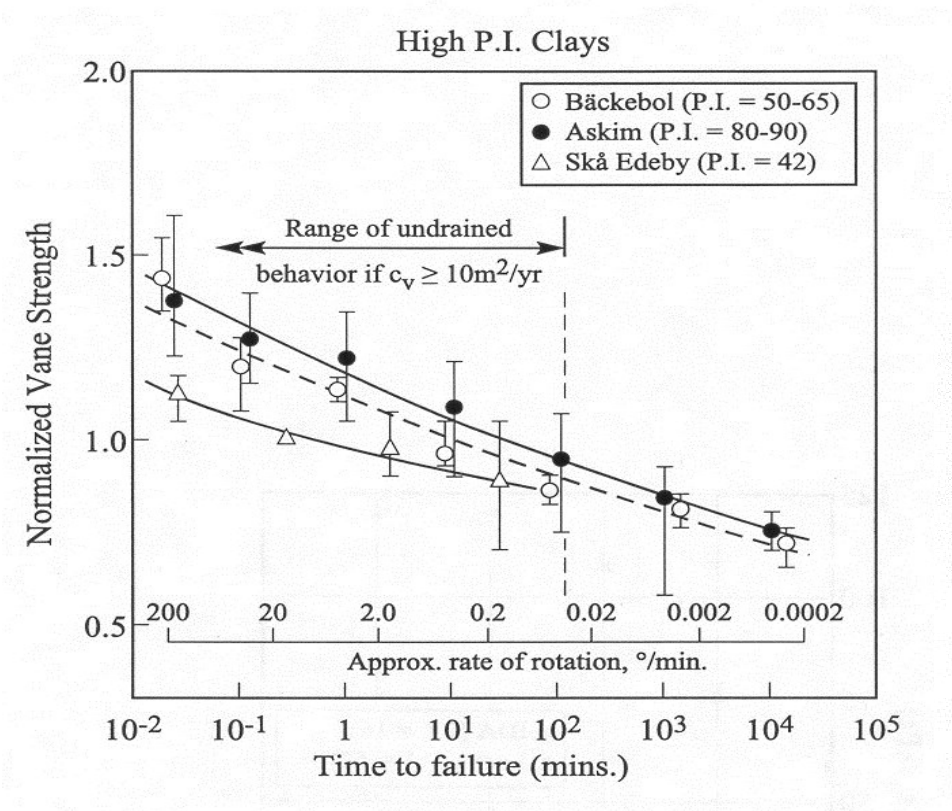
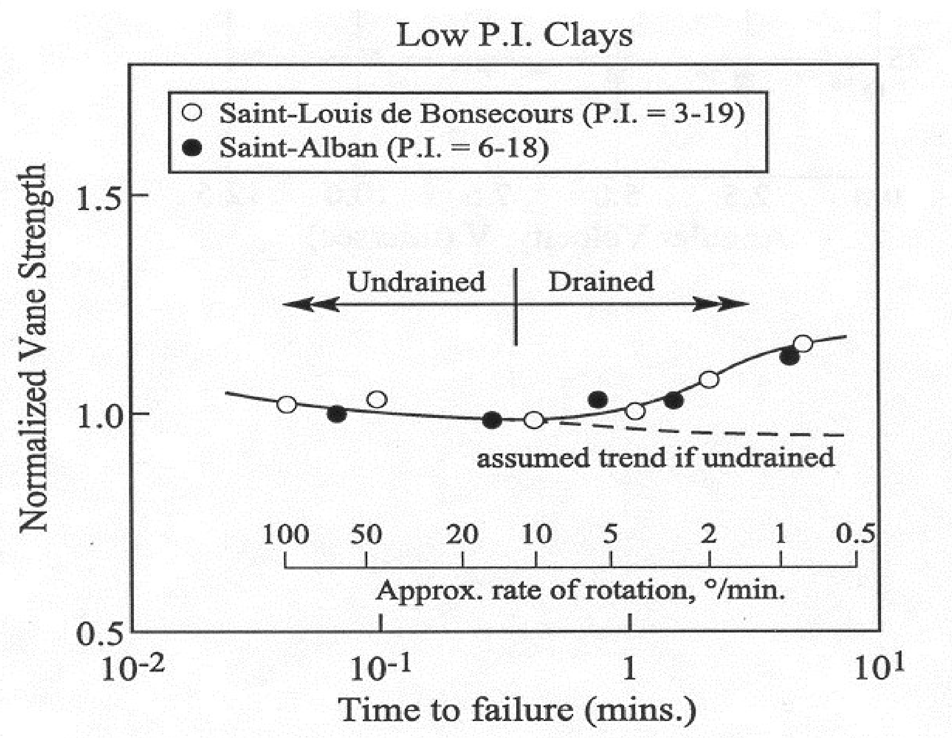
Influence of Rate of Shearing





(after Chandler 1988)

FVT – Interpretation of Data

1. Measured data: vane geometry and torque
2. Typical assumptions (from Flaate 1966)
   - undrained shear
   - no disturbance
   - small area ratio
   - no progressive failure
   - isotropic conditions

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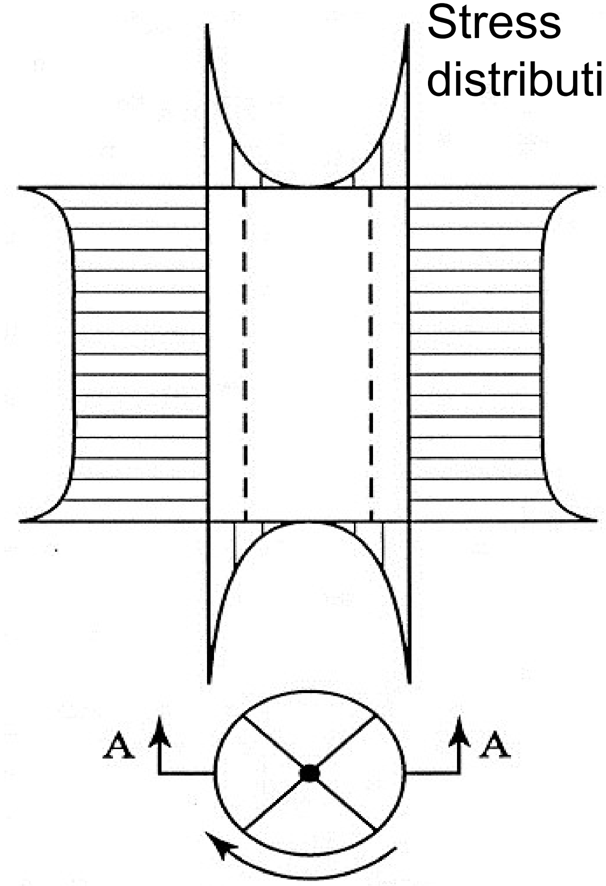
FVT – Calculations

$$T = s_u(\pi DH)(D/2) + 2s_u(\pi D^2/4)(D/a)$$



where

T = torque

s_u = undrained shear strength

D = diameter of vane

H = height of vane

a = shape factor

Contribution of top and bottom surfaces is relatively minor

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FVT – Calculations (cont)

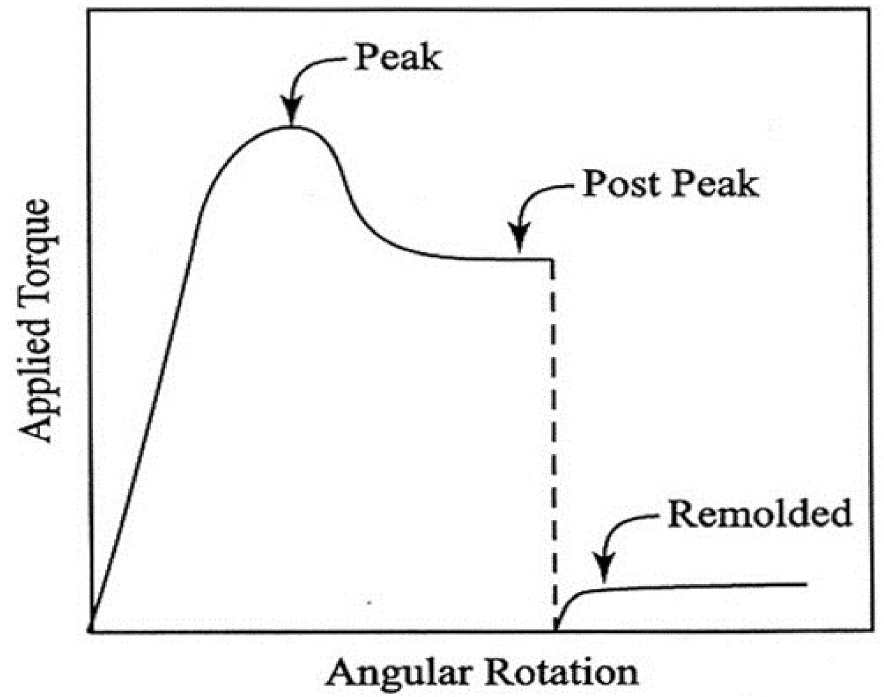
Typically use H/D = 2 and assume a = 3, therefore

$$s_u = 6T/7\pi D^3$$

FVT – Remolded Strength

1. Measure remolded shear strength = s_{ur}
2. Compute sensitivity S_t as

$$s_t = s_u/s_{ur}$$



- Remains the best in situ geotechnical tool to measure S_t

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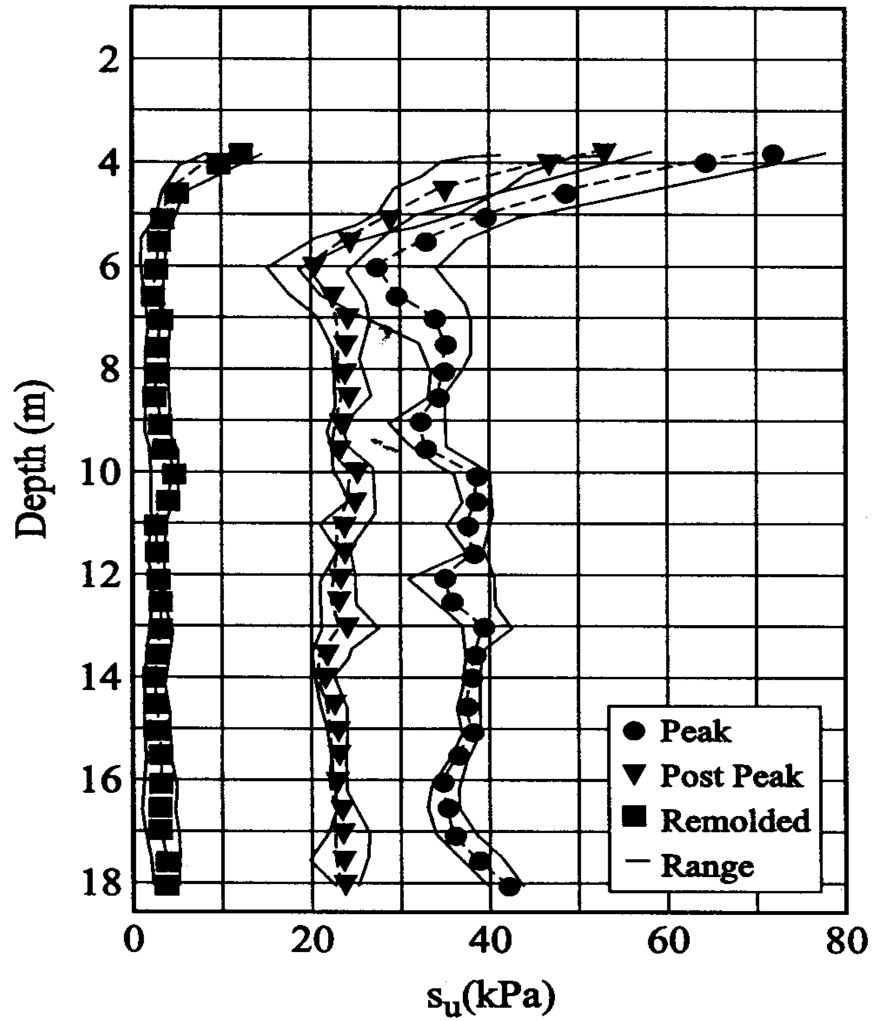
Example Field Vane profiles at UMass Amherst National Geotechnical Experimentation Site

- A lacustrine Varved clay deposit with an upper desiccated crust



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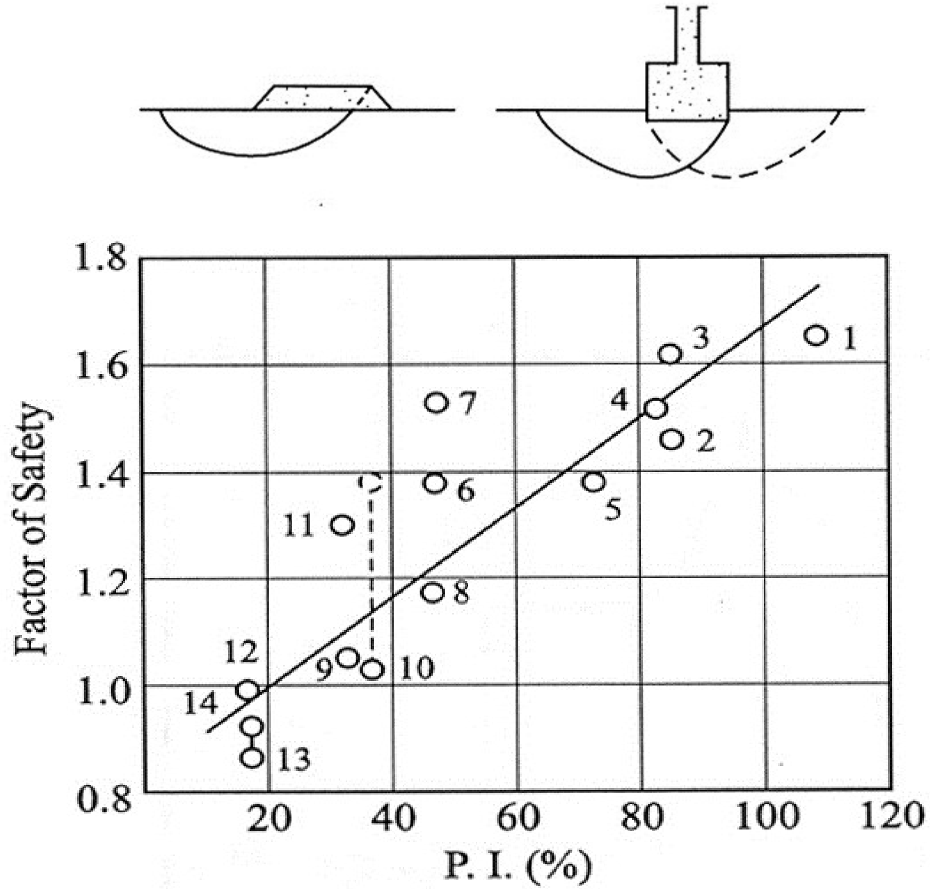
FVT – Correction Factors

Bjerrum (1972) suggested s_u(FVT) needs to be corrected for stability analysis

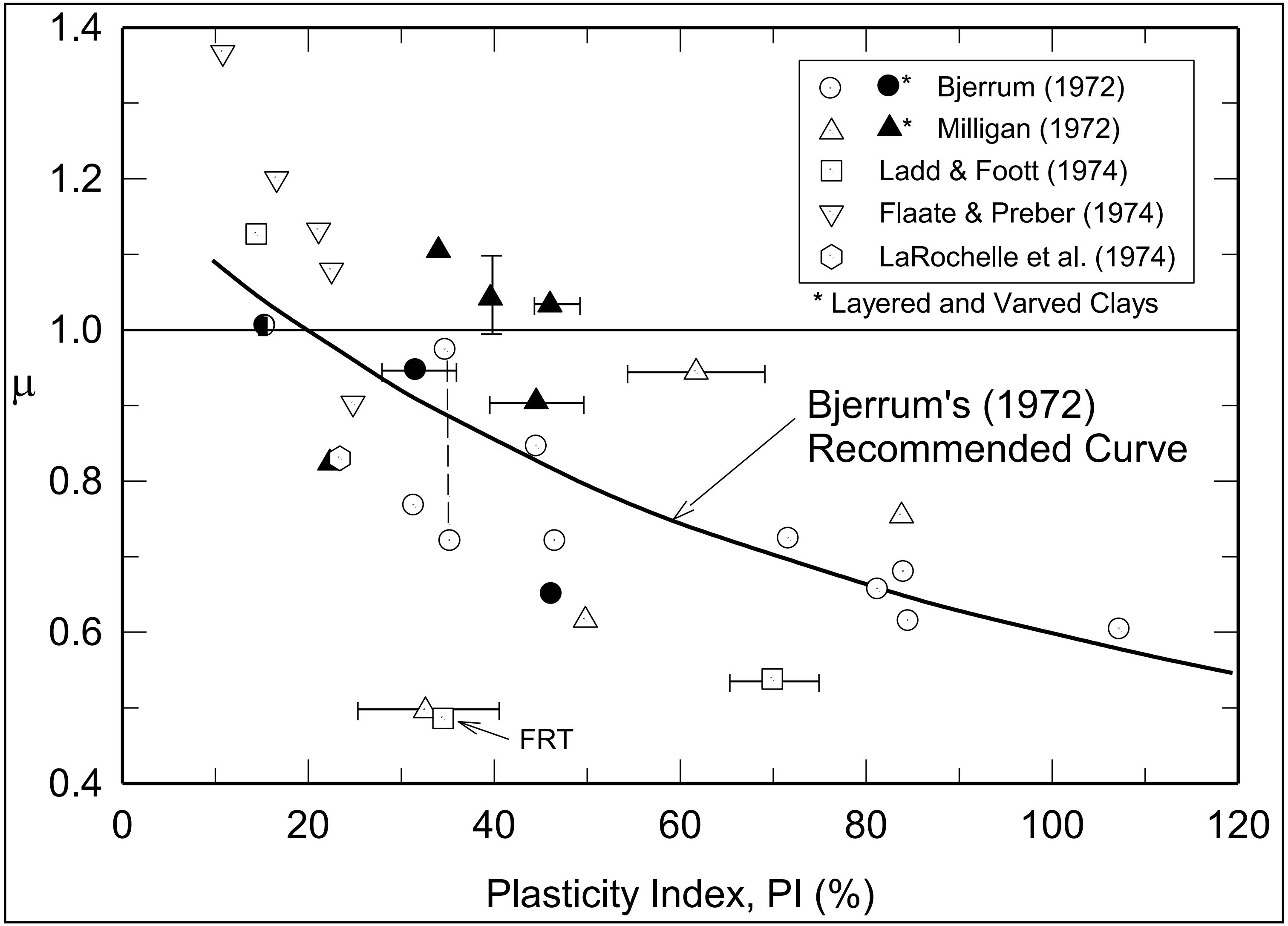
$$s_u = \mu s_{u(FVT)}$$

where μ = 1/FS based on stability of embankments. To compensate for disturbance, strain rate, anisotropy and progressive failure



[after Bjerrum 1972]

Embankment failures → $s_u(ave) = \mu s_u(FV)$



[from Ladd and DeGroot 2003]

Mesri (1975) Interpretation of Bjerrum (1972, 1973)

Bjerrum (1972, 1973) developed relationships:

- $s_u(FVT)/\sigma'_{v0}$ vs PI for "young" (OCR = 1) clays
- $s_u(FVT)/\sigma'_{v0}$ vs PI and σ'_p/σ'_{v0} for "aged" (OCR > 1) clays

and

- $s_u(mob) = \mu s_{u(FVT)}$ with $\mu = f(PI)$

Mesri (1975) combined first set of data into:

- $s_u(FVT)/\sigma'_p$ vs PI

then coupled with second set of data to find:

- $s_u(mob) = 0.22\sigma'_p$ independent of PI

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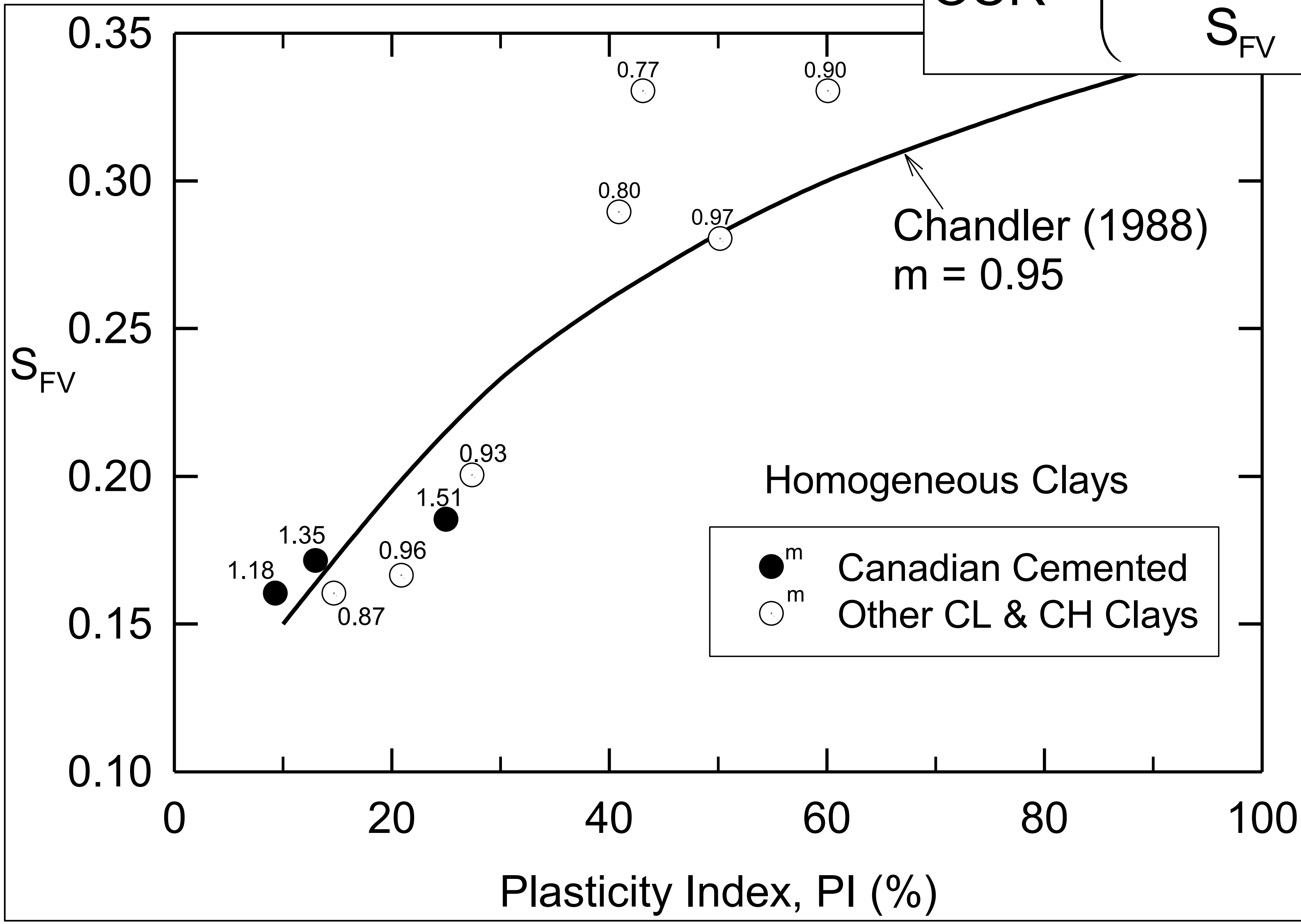
Interpretation of Stress History

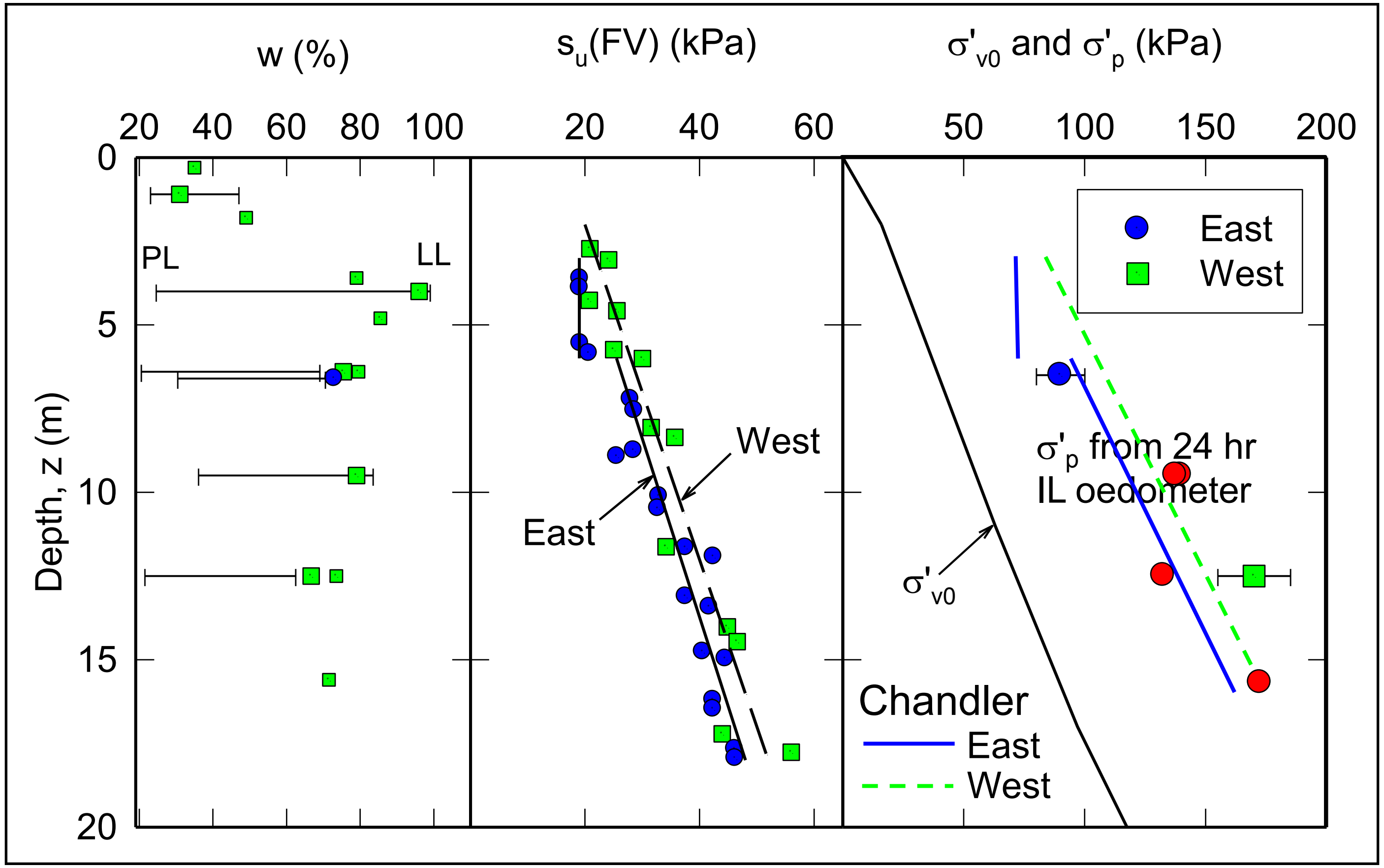
– linkage between s_u and OCR

$$OCR = \left(\frac{s_u(FV)/\sigma'_{v0}}{S_{FV}} \right)^{1/m=1.05}$$



Example: estimation of stress history (σ'_p)

- Preload fills for abutments of two river bridges, Northern Ontario



- Applied Chandler (1988), S_{FV} = 0.28 for PI = 50%
- CRS tests

[from Ladd and DeGroot 2003]

FVT – Recommendations

1. Rectangular vane with constant cross section, H/D = 2
2. Calibrated torque head, gear driven
3. Insert slowly and begin test within 1 min.
4. Peak, post-peak, & remolded strength
5. Report geometry of vane used + gear system
6. Use Bjerrum's correction factor for stability problems only

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