FOUNDATIONS ON SHRINKING AND SWELLING SOILS

(Prediction of Movement, Construction Issues)

by

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ACKNOWLEDGEMENTS

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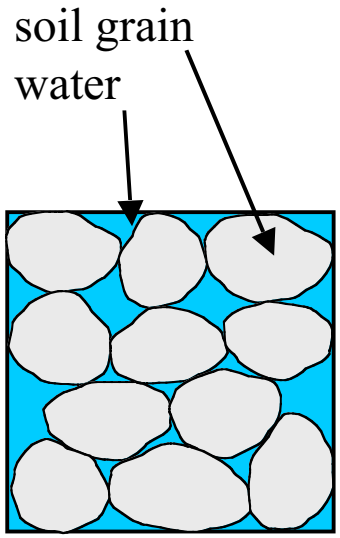
  Doug Dayton

OUTLINE

- FUNDAMENTAL BEHAVIOR
- SHRINK TEST – WATER CONTENT METHOD
- CASE STUDY
- SMART FOUNDATION

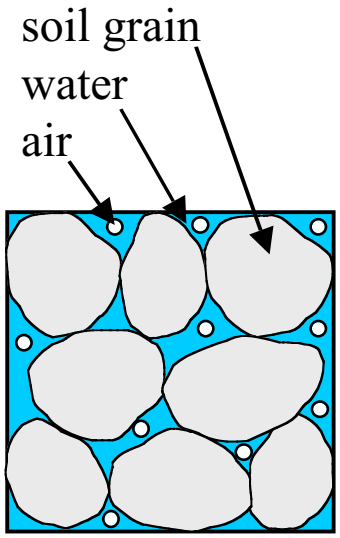


Saturated

$u_w \neq 0$

$u_a = 0$

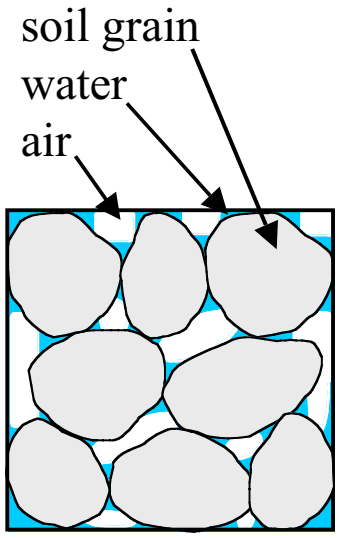
$\sigma' = \sigma - u_w$



Occluded Air

$u_w = u_a$

$\sigma' = \sigma - u_w$



Continuous Air

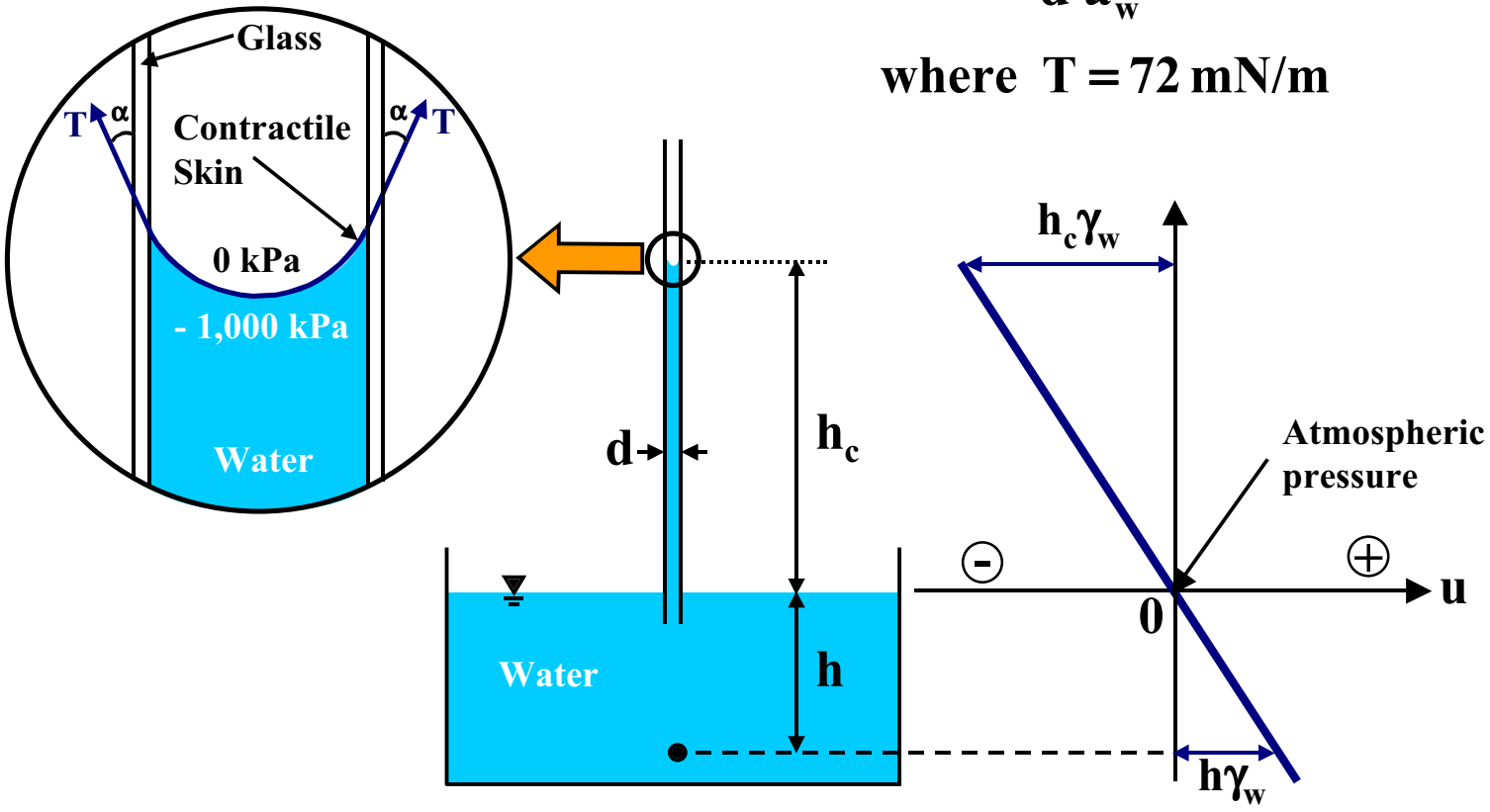
$u_w \neq 0$

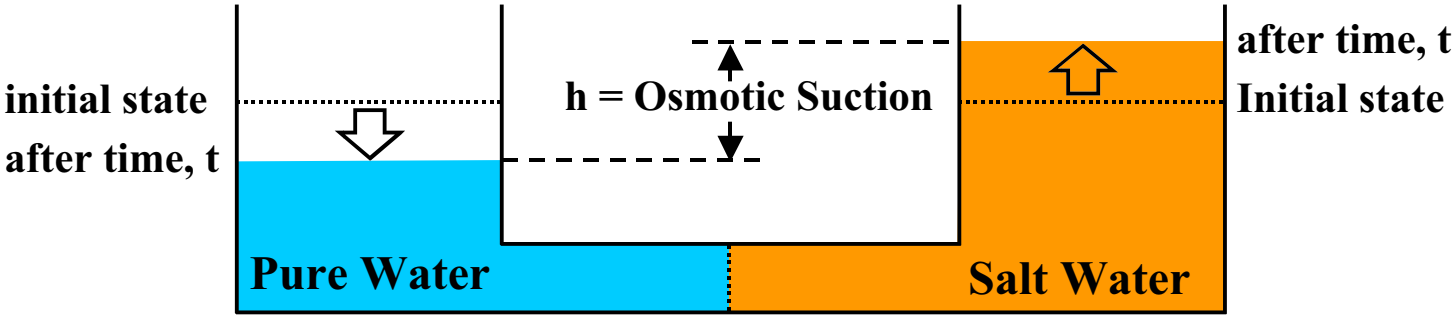
$u_a = 0$

$\sigma' = \sigma - \alpha u$

$$h_c = \frac{4\,T\cos á}{d\,ã_w}$$

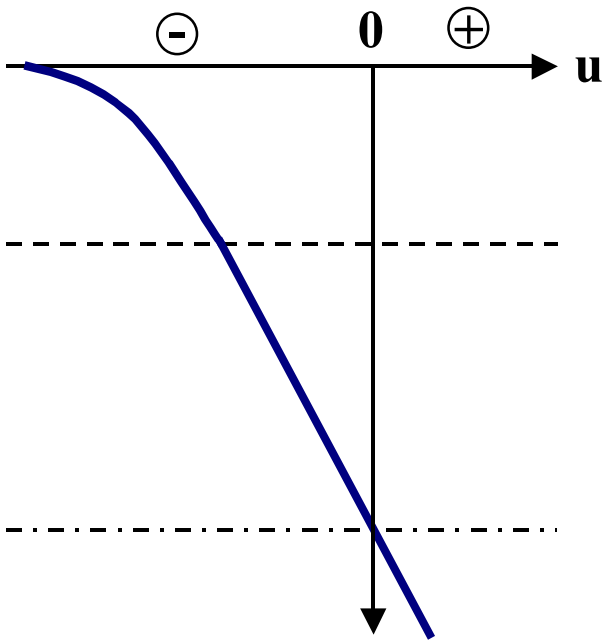
where $T = 72$ mN/m



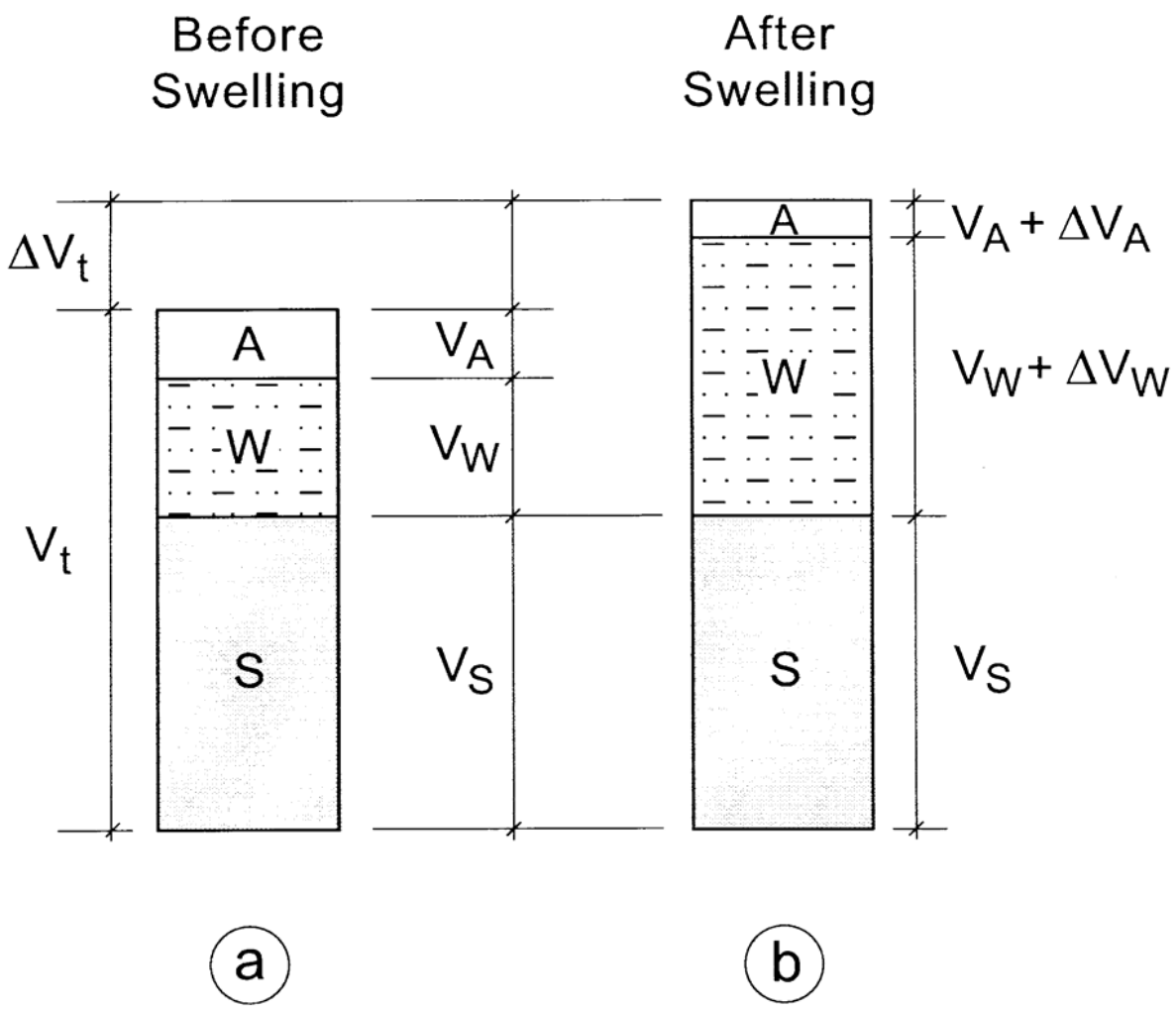

initial state
after time, t
h = Osmotic Suction
after time, t
Initial state
Pure Water
Salt Water

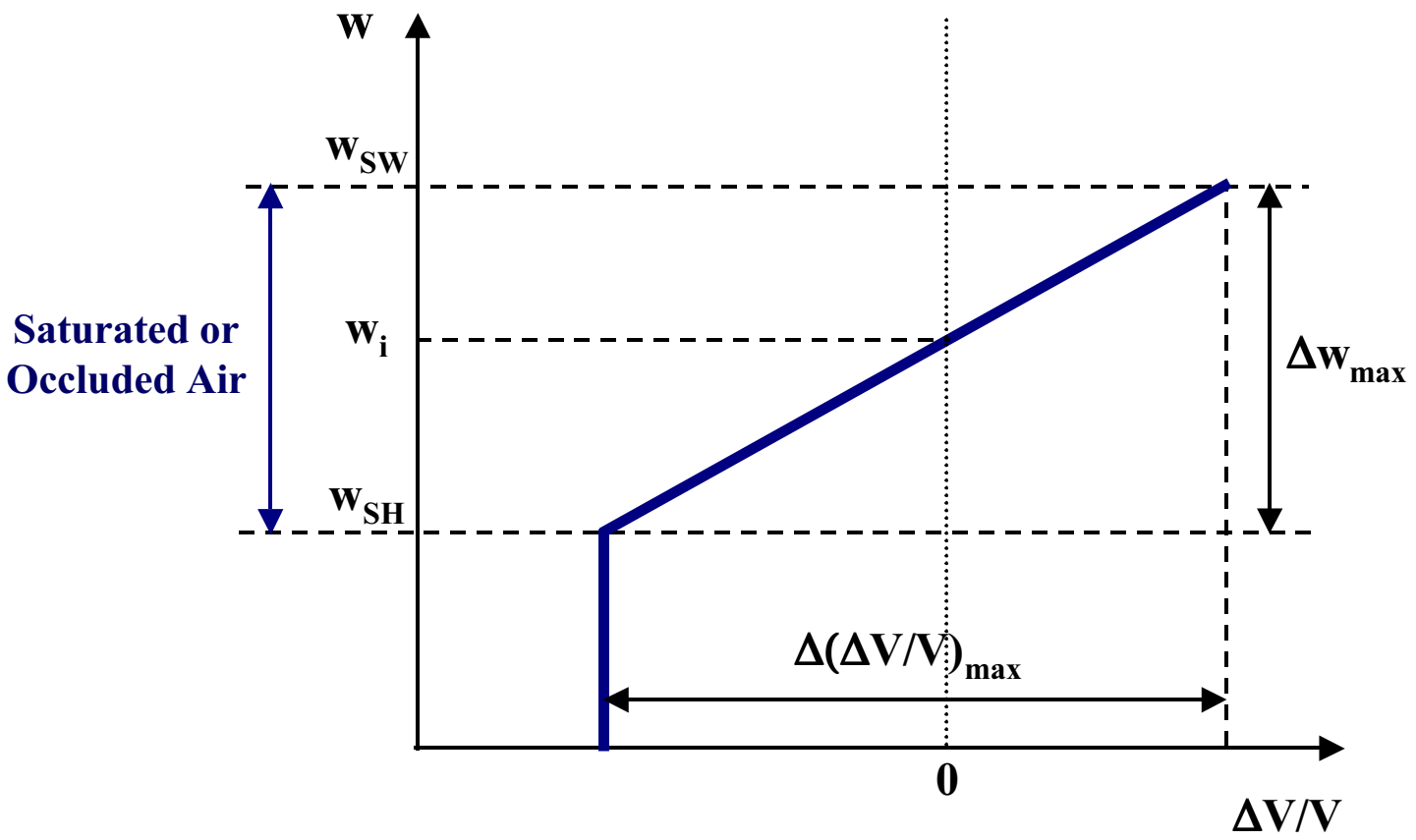
Water State	Examples	Suction pF	Suction cm	Suction kPa	Degree of Saturation	Water Content	Swell	Shrink
Suction	Oven Dry	7	-10^7	-10^6	0	0	YES	NO
	Air Dry	6	-10^6	-10^5				
Tension	Shrinkage Limit	4	-10^4	-10^3	Near 100 %	8 to 15 %		
	Field Capacity Swell Limit	2	-10^2	-10^1		25 to 50 %		
		0	0	0	100 %			
	Large River		10^3	10^2			NO	YES
Compression	Deepest Offshore Platforms		10^5	10^4				
	Bottom of Deepest Ocean		10^9	10^8				

Soil State	Swell	Shrink
Unsaturated	Yes	No
Saturated	Yes	Yes
GWL		
Saturated	No	Yes

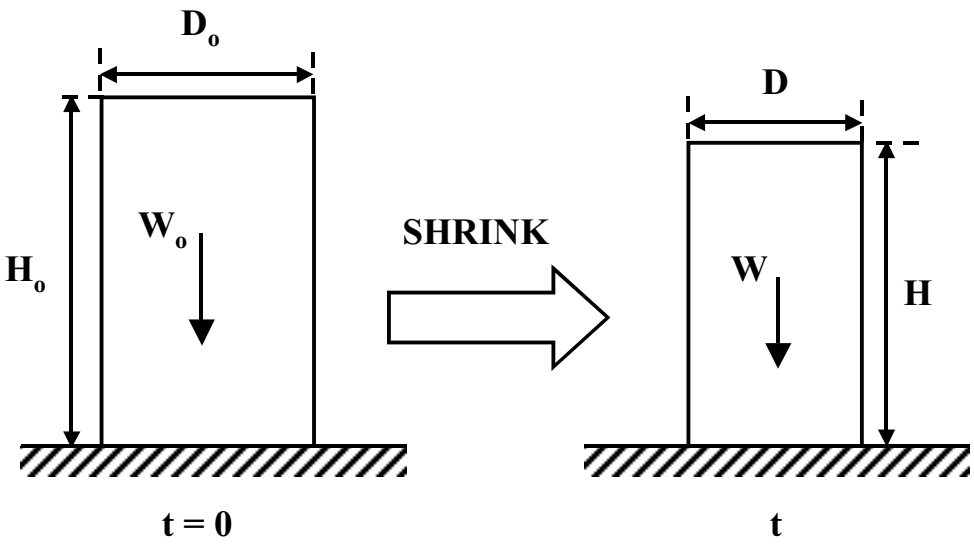


PHASE DIAGRAMS




w
w_{SW}
w_i
w_{SH}
Saturated or
Occluded Air
Δw_{max}
$\Delta(\Delta V/V)_{max}$
0
$\Delta V/V$

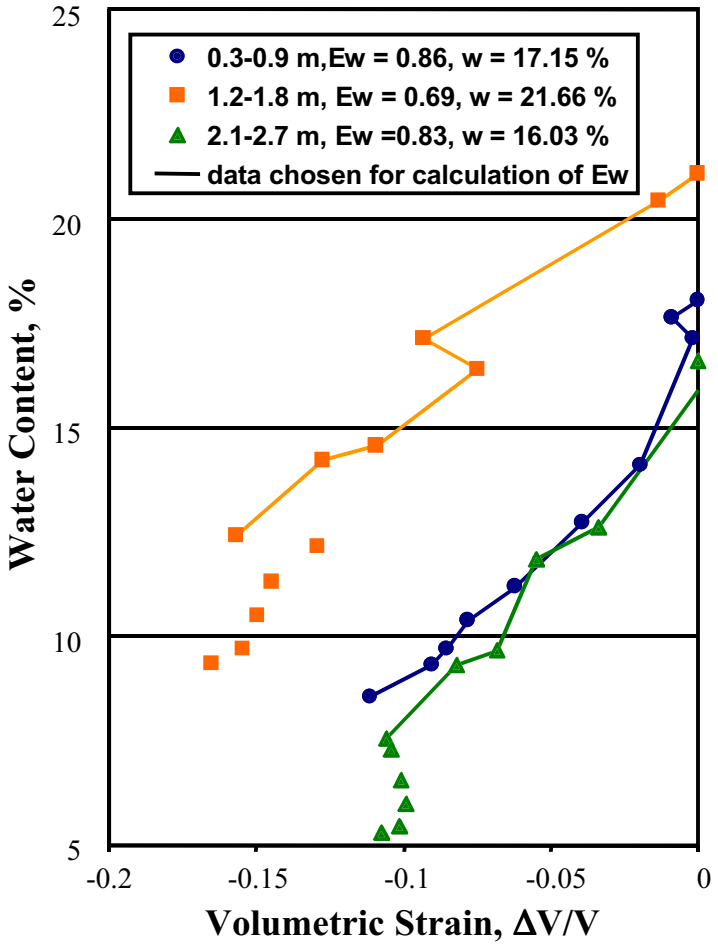
SHRINK TEST PARAMETERS



SHRINK TEST

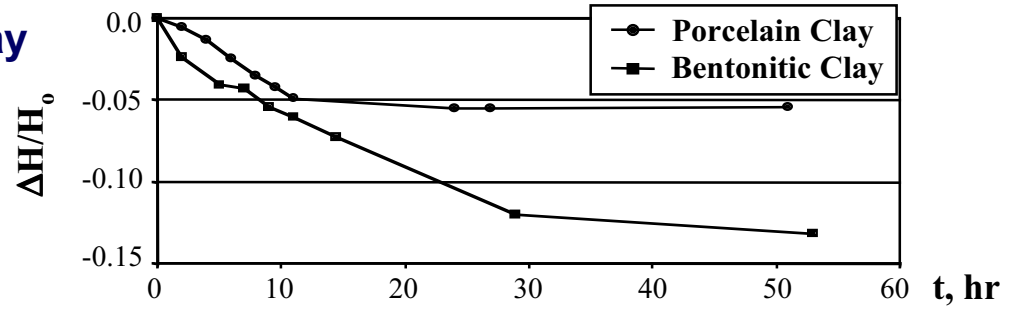
Shrink Test

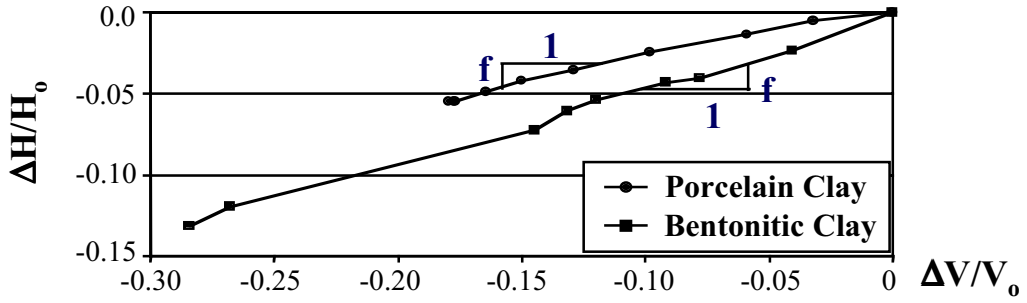
Shrink Test Example (B/RF1/6)

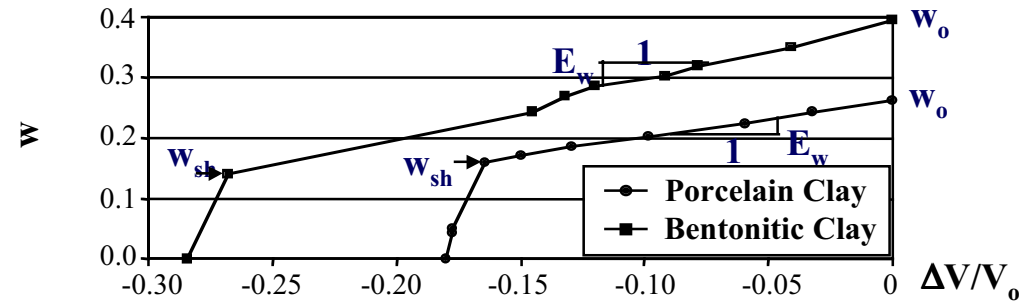


SHRINK TEST RESULTS (1)

Porecelain Clay and Bentonite Clay







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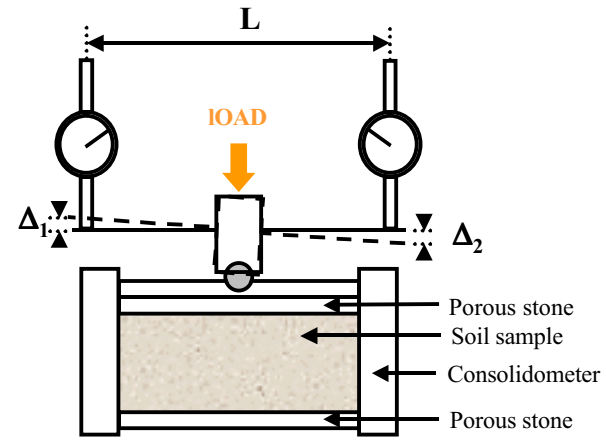
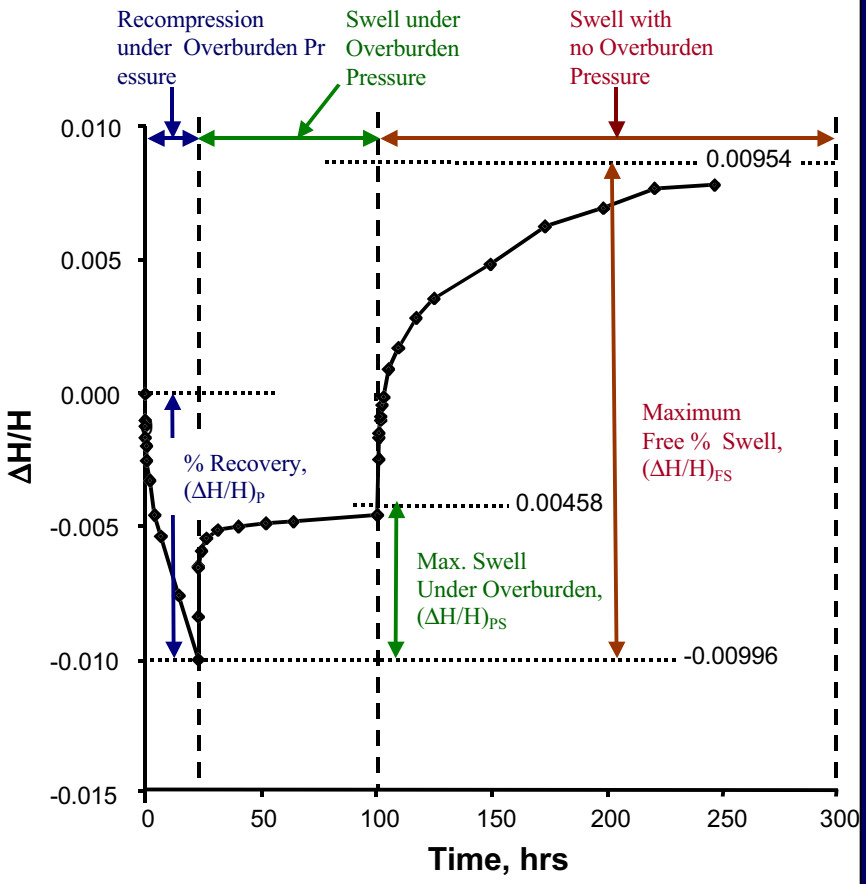
SWELL TEST

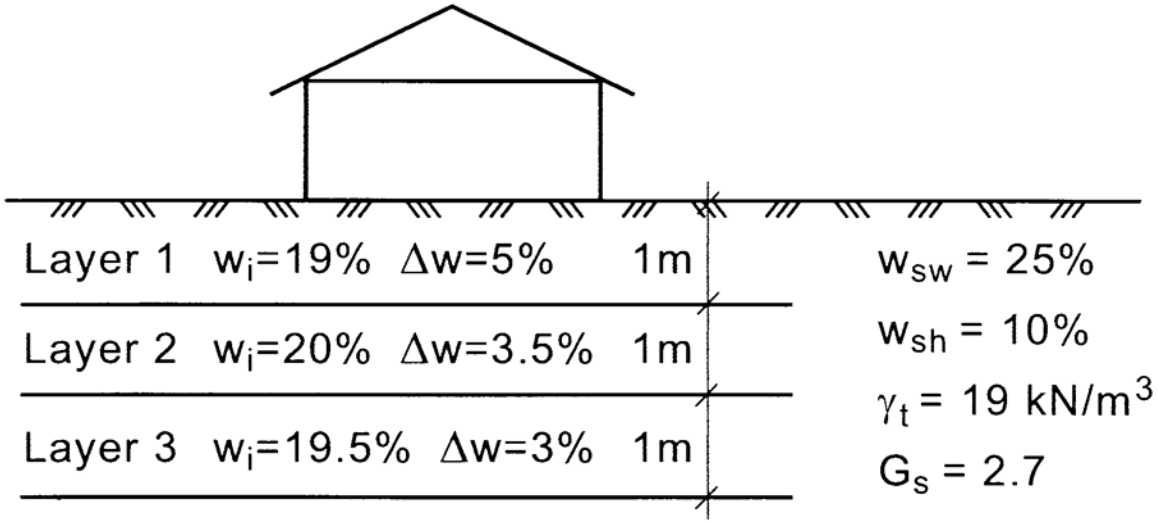
Swell Test



Swell Test Example (B/RF1/6 0.3–0.9 m)



EXAMPLE OF THE PREMISS METHOD



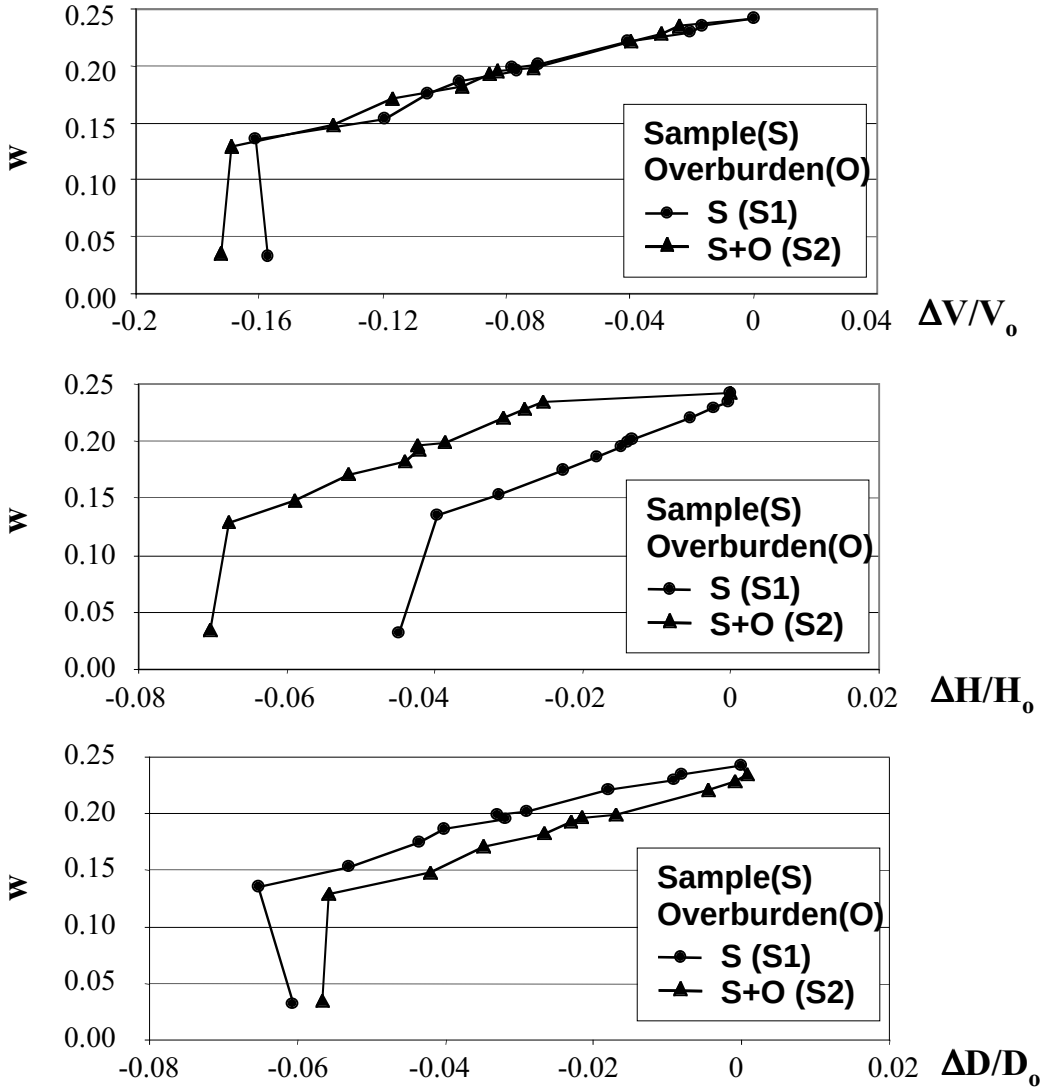
	w	s	n	Δw	$\frac{\Delta V_w}{V_t}$	$\frac{\Delta V_a}{V_t}$	$\frac{\Delta V_t}{V_t}$	ΔH* (mm)
Layer 1	0.19	0.78	0.40	0.05	0.0821	-0.0235	0.0586	58.6
Layer 2	0.20	0.80	0.40	0.035	0.0560	-0.0149	0.0411	41.1
Layer 3	0.195	0.79	0.40	0.03	0.0486	-0.0134	0.0352	35.2

*Using H_t = layer thickness and α = 1.

ΔH_t = 134.9 mm

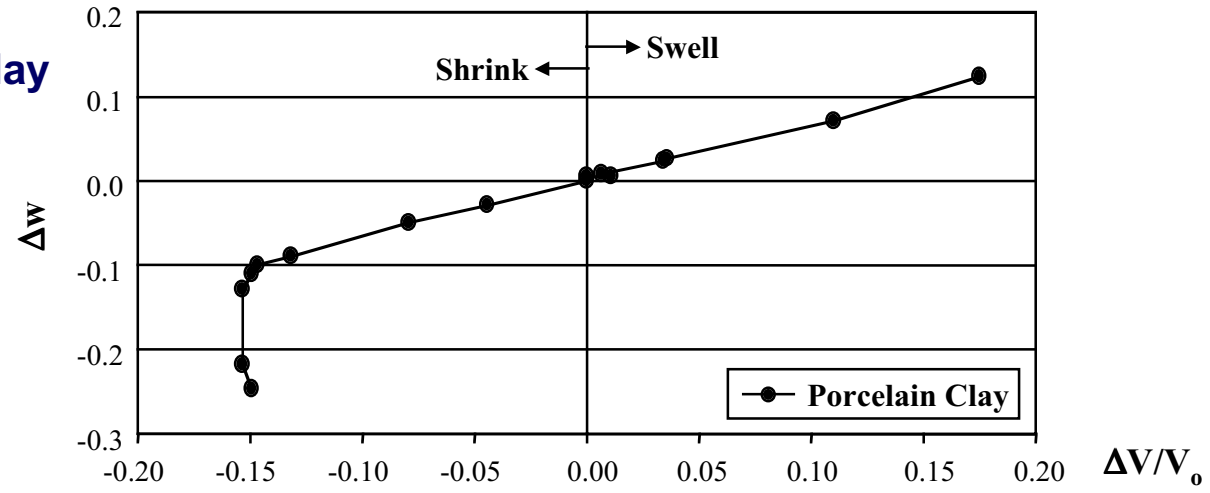
SHRINK TEST RESULTS (3)

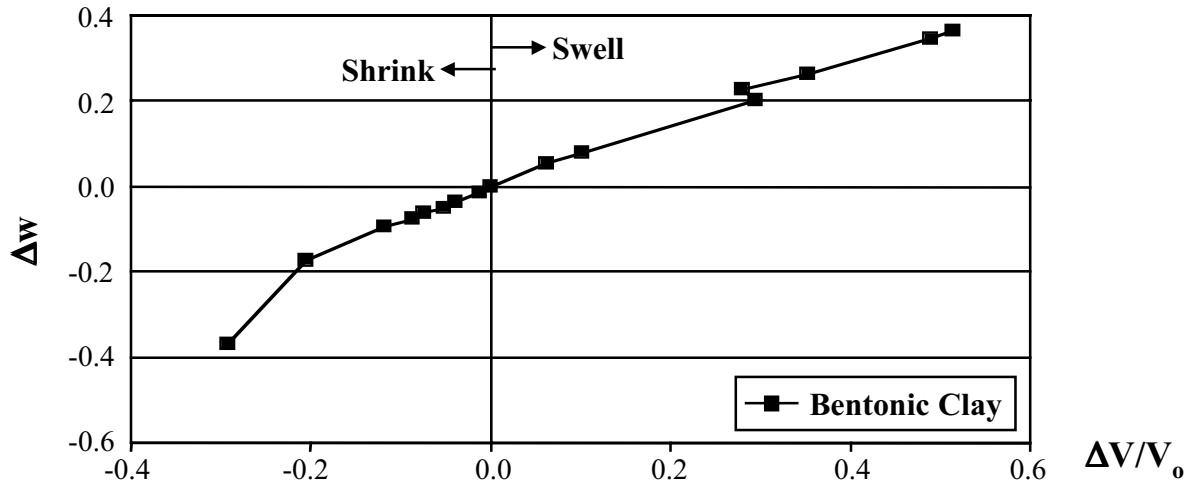
Influence of Vertical Pressure



SHRINK AND SWELL TEST RESULTS

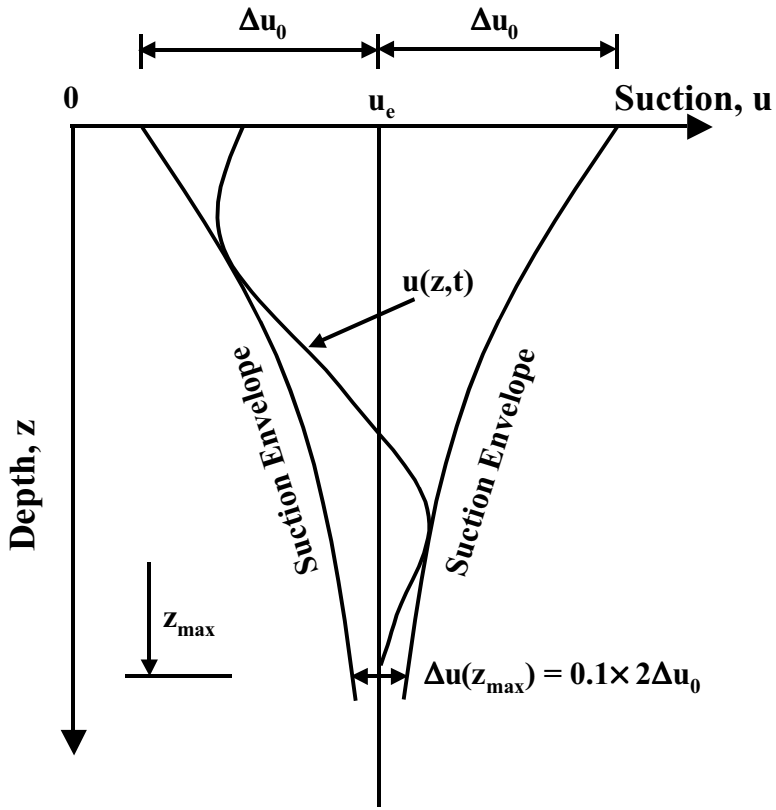
Porecelain Clay and Bentonite Clay





SUCTION VARIATION WITH DEPTH

After Mitchell (1979)



After Mitchell (1979)

$$\ddot{A}u(z) = 2\,\ddot{A}u_0 \exp\left(-(\partial / T_0\,\acute{a})^{0.5}\, z\right)$$

$$\ddot{A}w = f(\ddot{A}u) \quad \text{characteristic curve}$$

$$z_{max} = 1.3(T_0\,\acute{a})^{0.5}$$

where Δu = change in suction at depth z
Δu_0 = change in suction at ground surface
T_0 = period of weather cycle
α = diffusion coefficient
z = depth below ground surface
Δw = change in water content
z_{max} = maximum depth of water content change

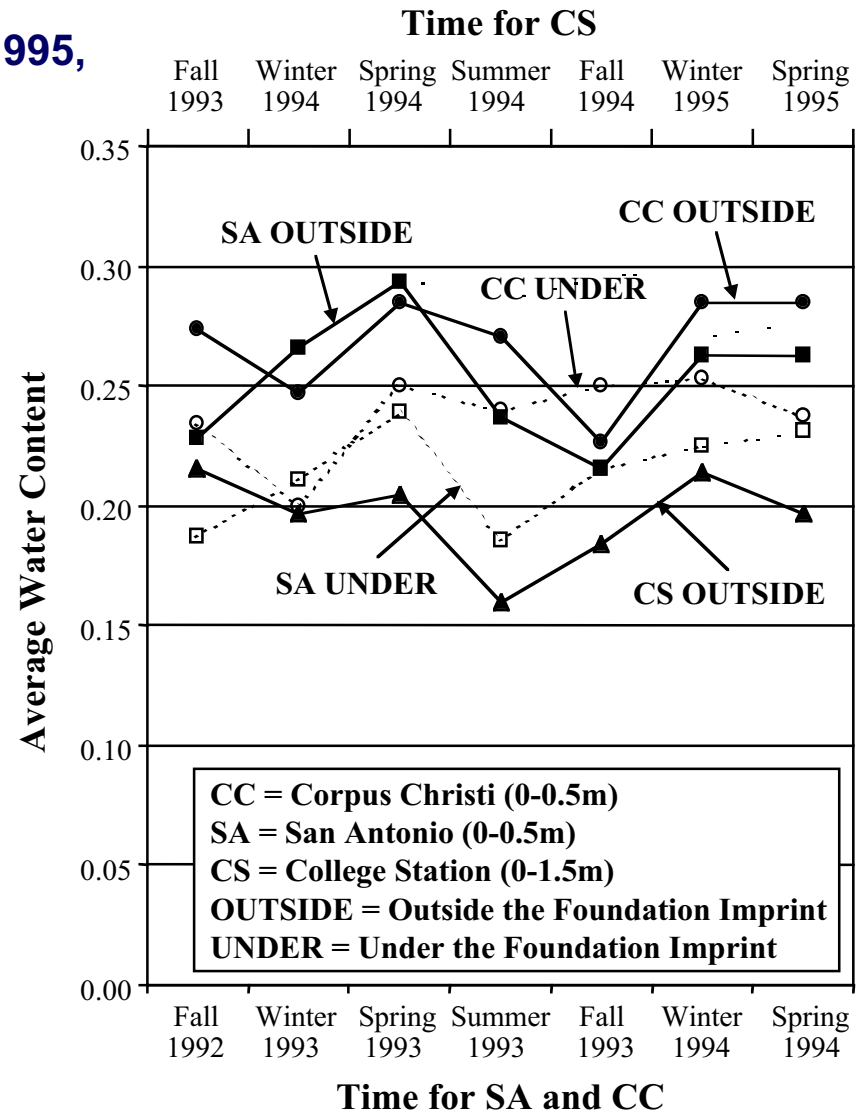
After Styron et al. (2001)

$$LI \times LL\,(\%) = \pm 30$$

$$\ddot{A}w = 0.6\,(PI/LL)$$

WATER CONTENT VARIATION AS A FUNCTION OF TIME

From Posey, Briaud, 1995,
Woodfin, Briaud, 1997



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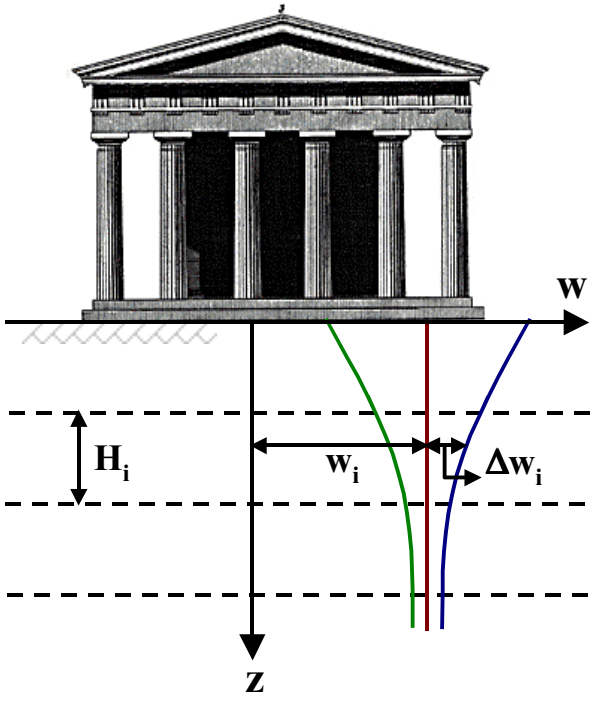
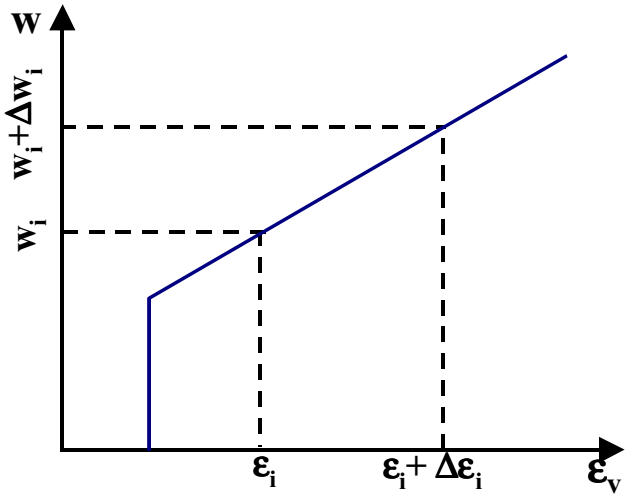
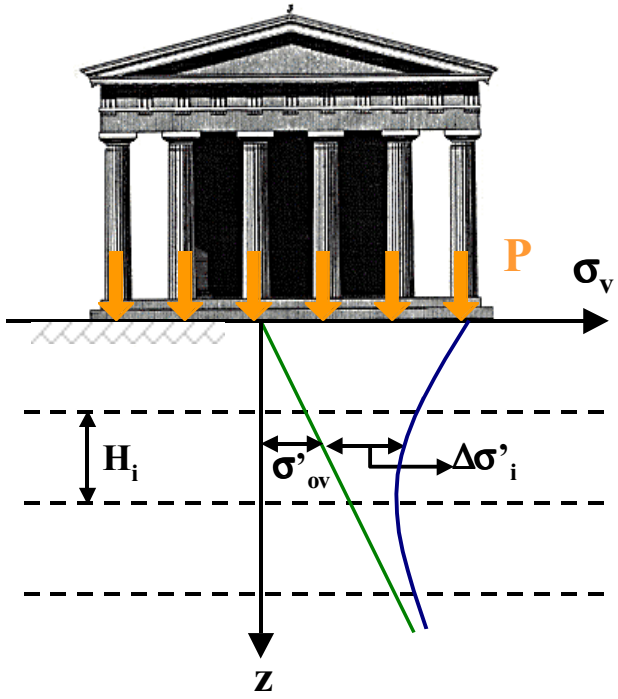
MOISTURE INDUCED MOVEMENT



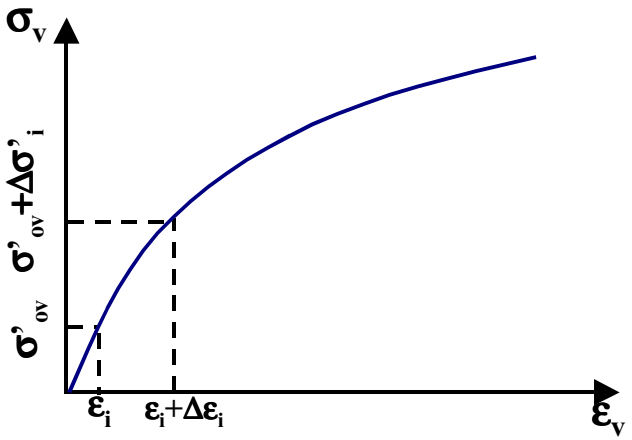
$$S = \sum H_i \, Äå_i = \sum H_i \, f \, \frac{Äw_i}{E_{w\,i}}$$



WEIGHT INDUCED SETTLEMENT

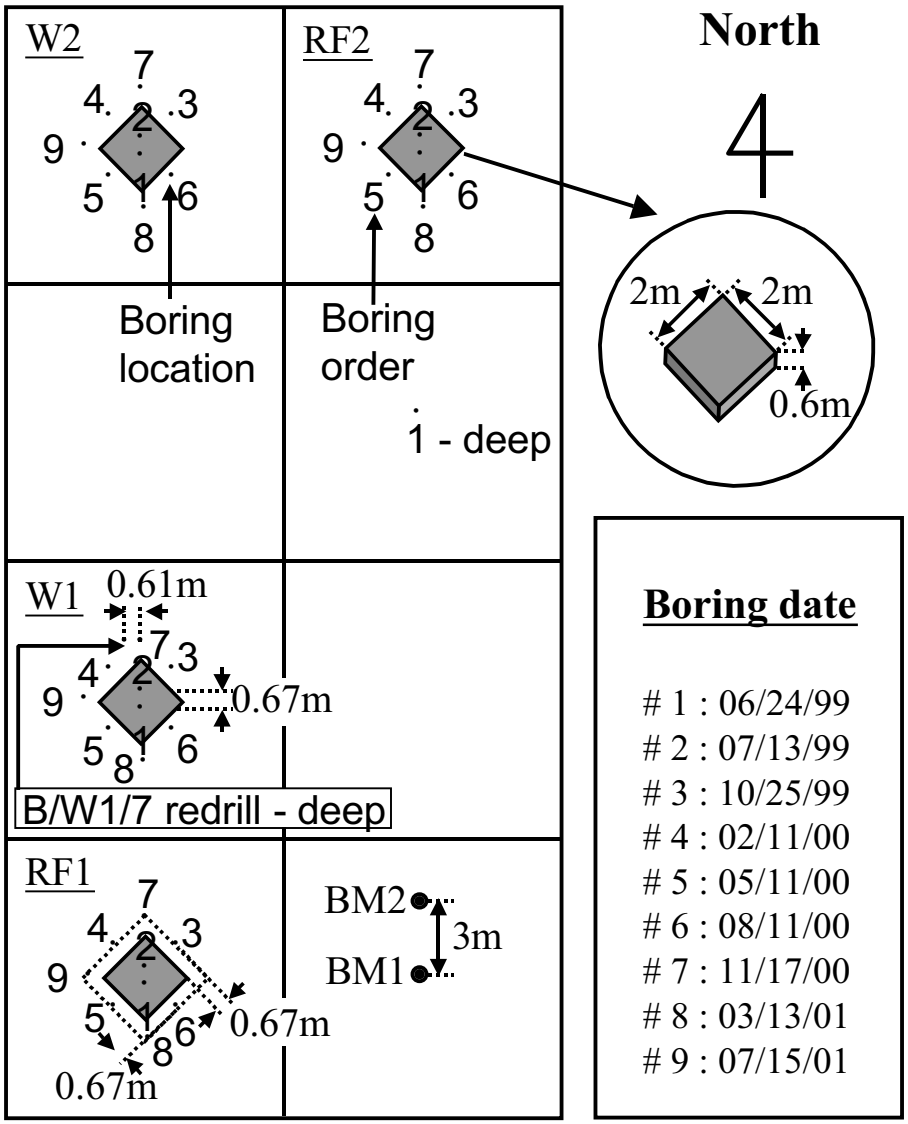


$$S = \sum H_i \, \ddot{A}\mathring{a}_i = \sum H_i \frac{\ddot{A}\sigma_i}{E_i}$$



PLAN VIEW OF THE SITE

Site in Arlington, Texas

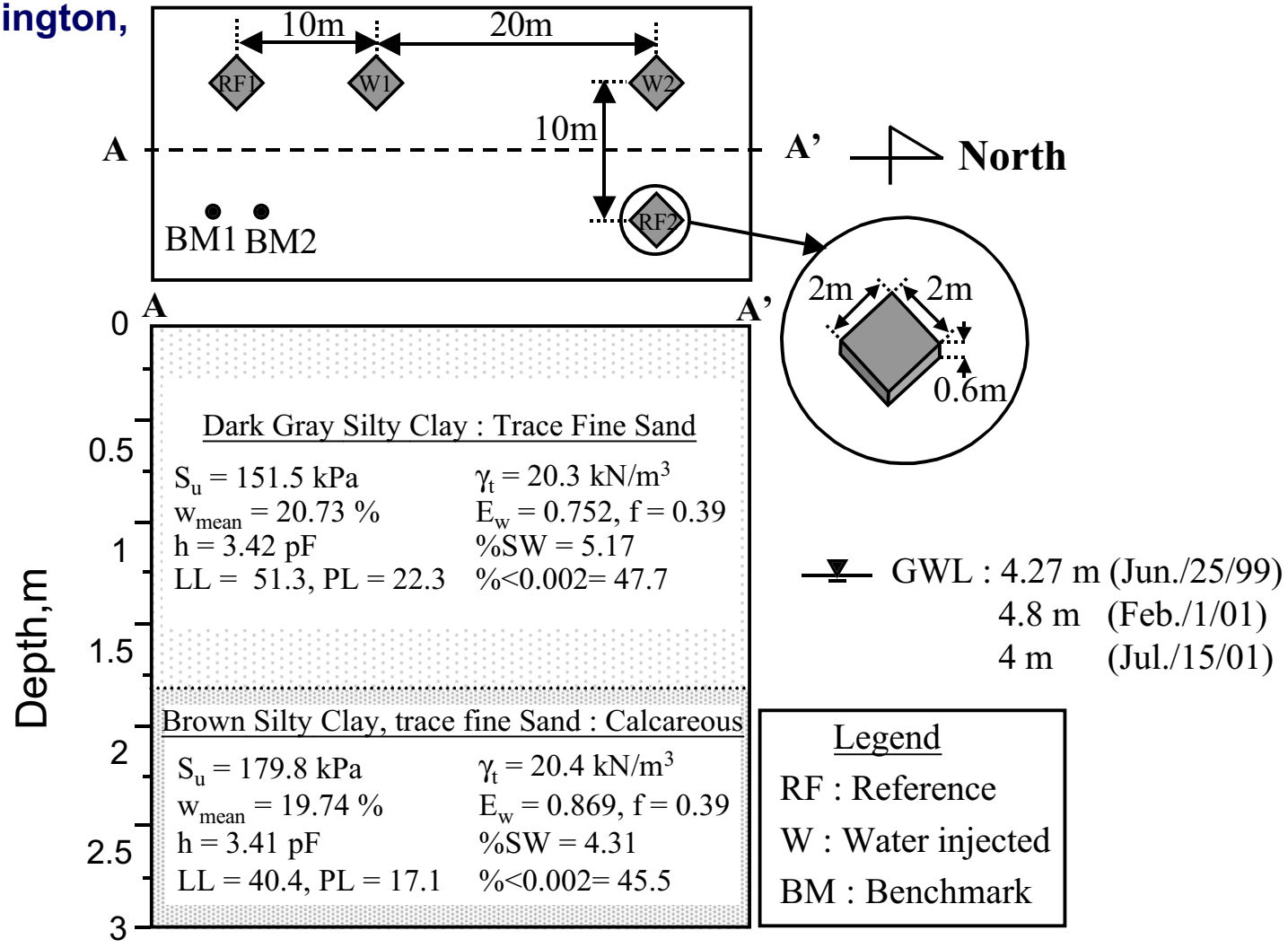


Boring date

1 : 06/24/99
2 : 07/13/99
3 : 10/25/99
4 : 02/11/00
5 : 05/11/00
6 : 08/11/00
7 : 11/17/00
8 : 03/13/01
9 : 07/15/01

SOIL STRATIGRAPHY

Site in Arlington, Texas



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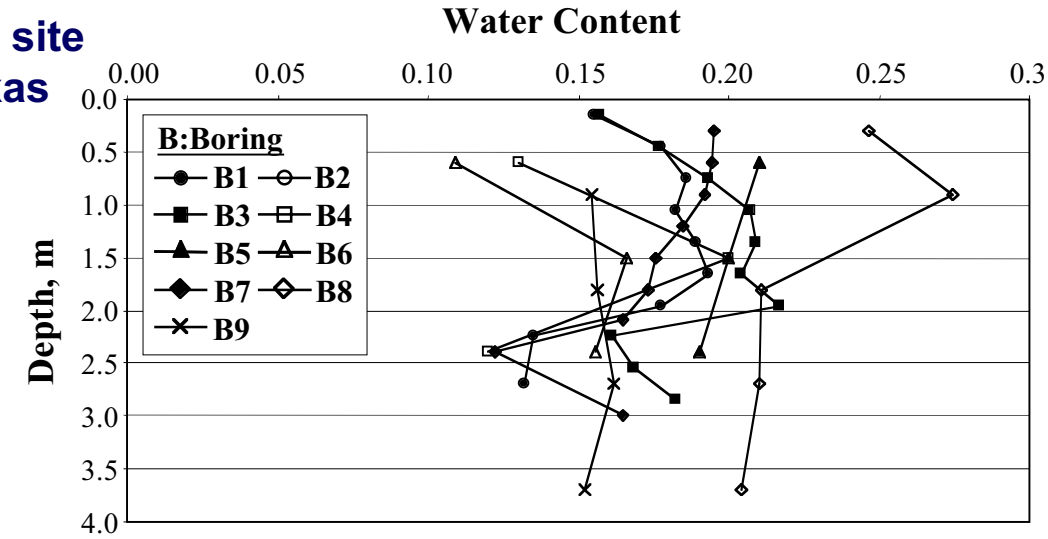
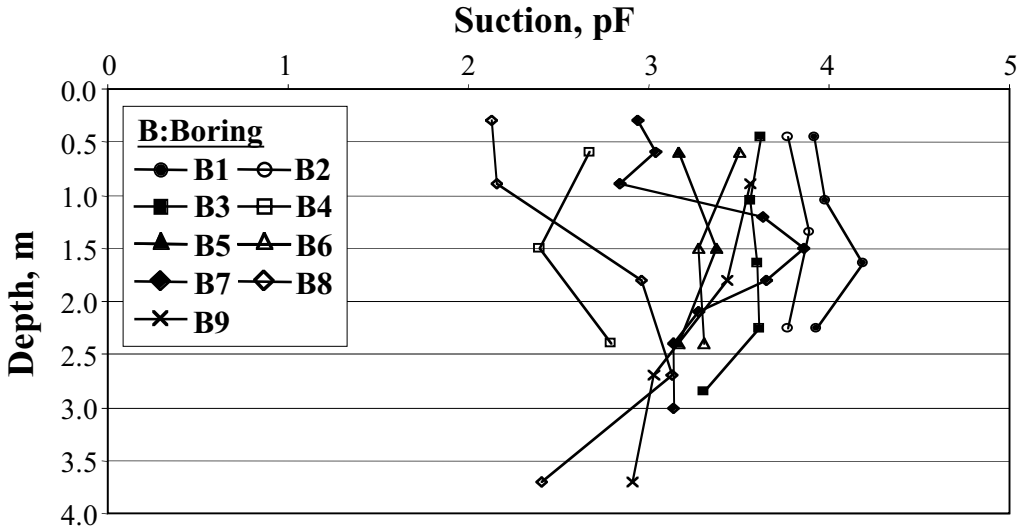
WATER CONTENT AND SUCTION vs. DEPTH

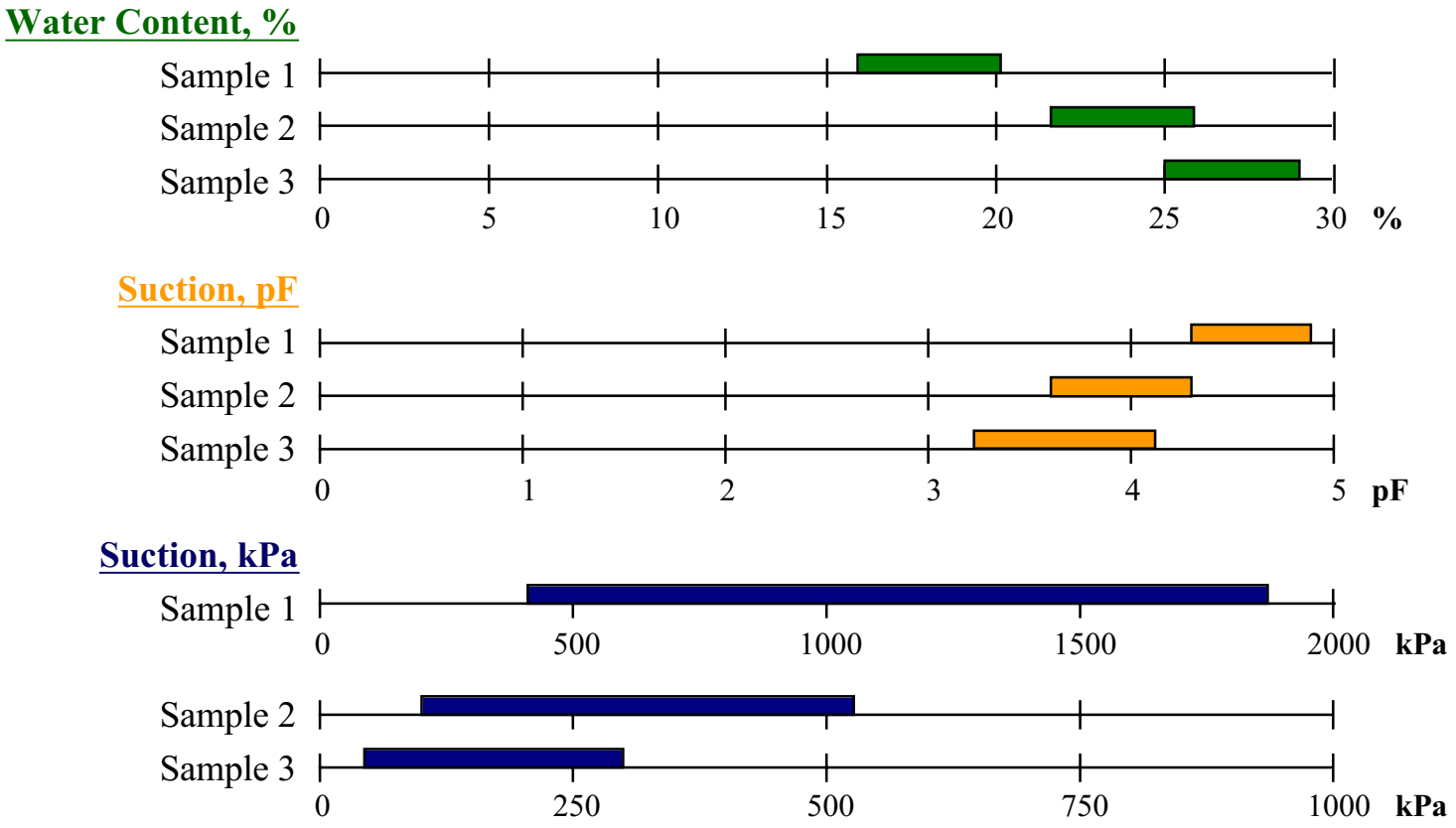
Footing RF1 at a site in Arlington, Texas





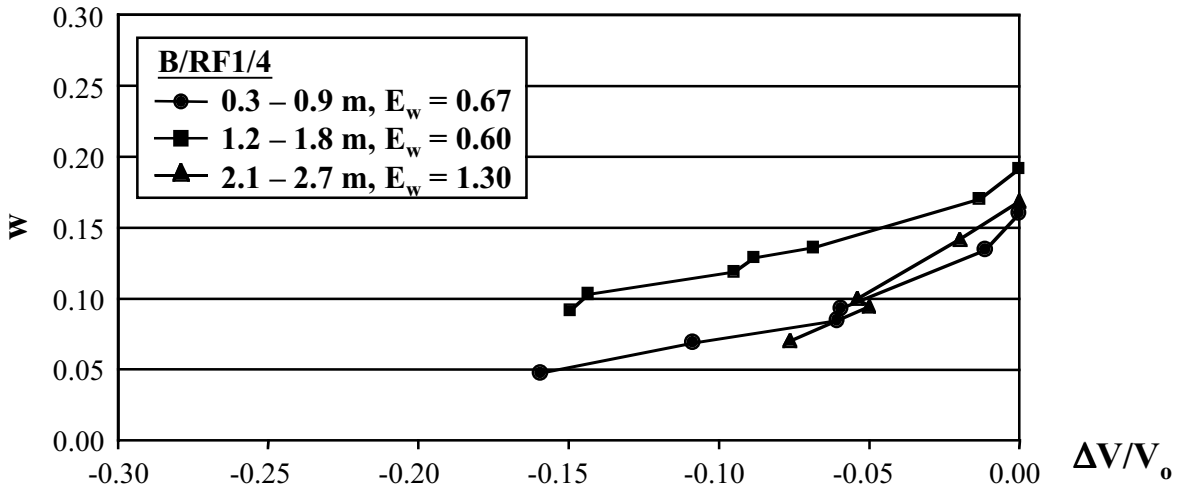
GARNER'S STUDY (1999)

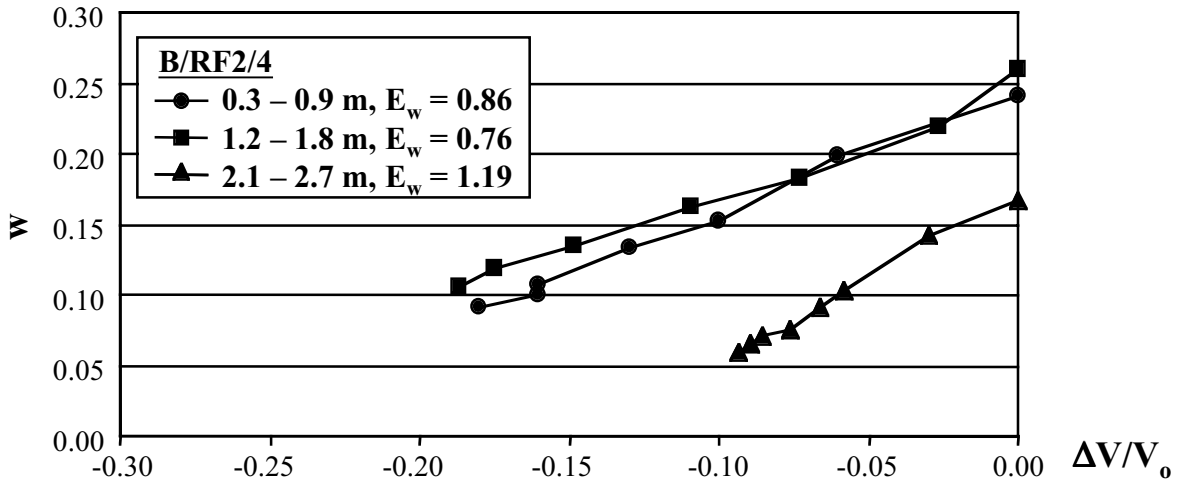
3 samples at 3 water contents sent to 5 laboratory.



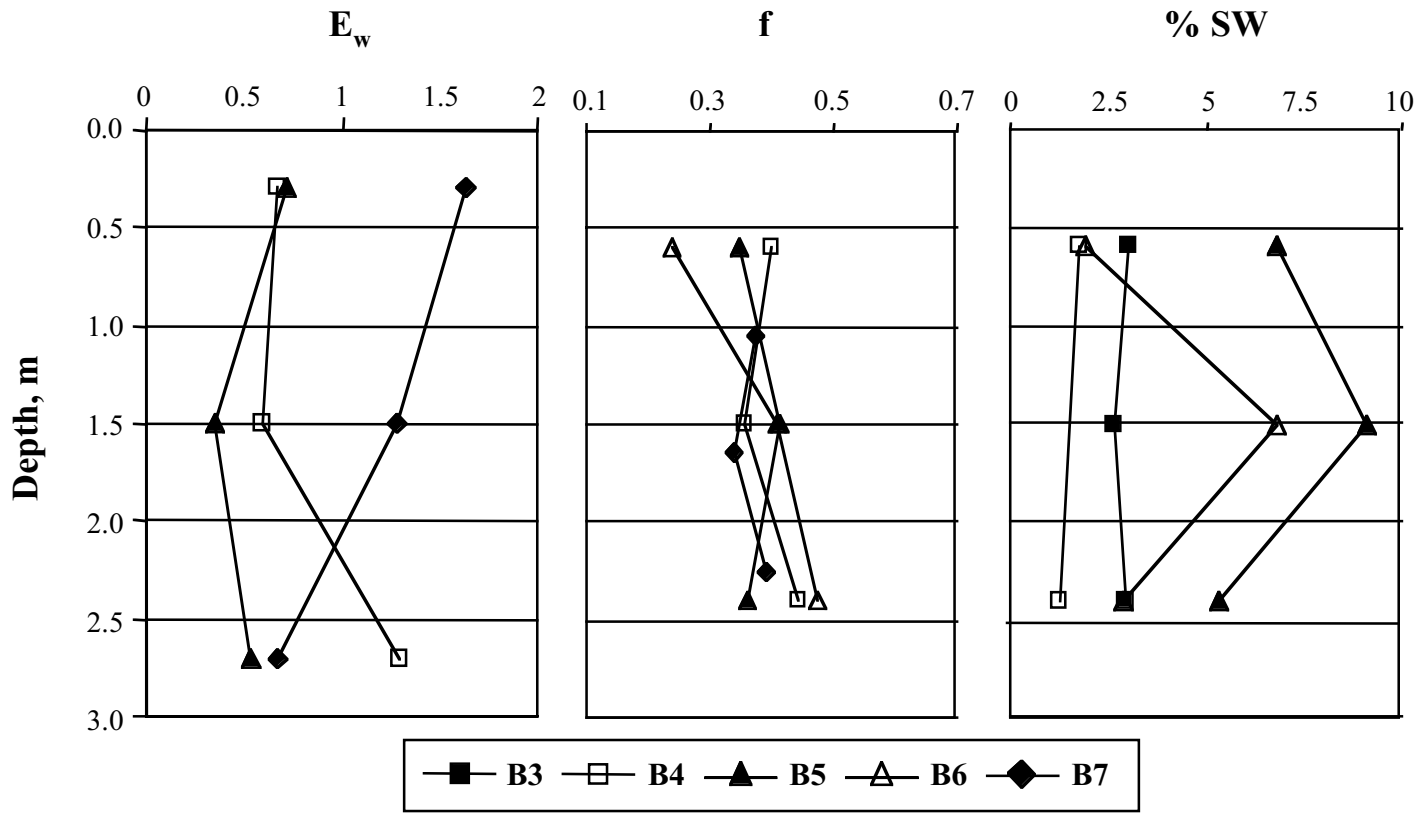
SHRINK TEST RESULTS (2)

Three Samples From Arlington, Texas





SELECTED SOIL TEST RESULT FOR RF1



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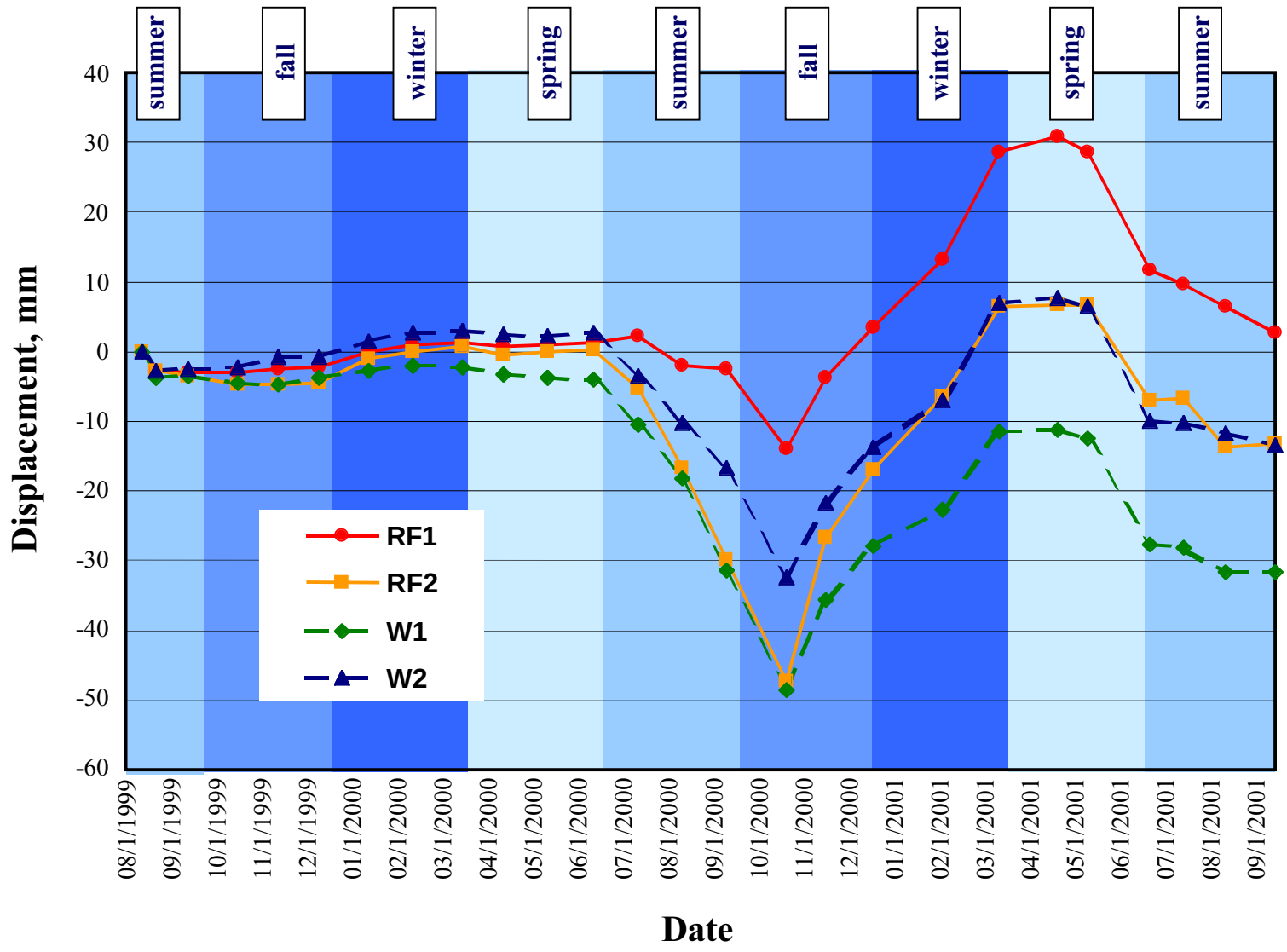
FOOTING MOVEMENT OVER TWO YEARS



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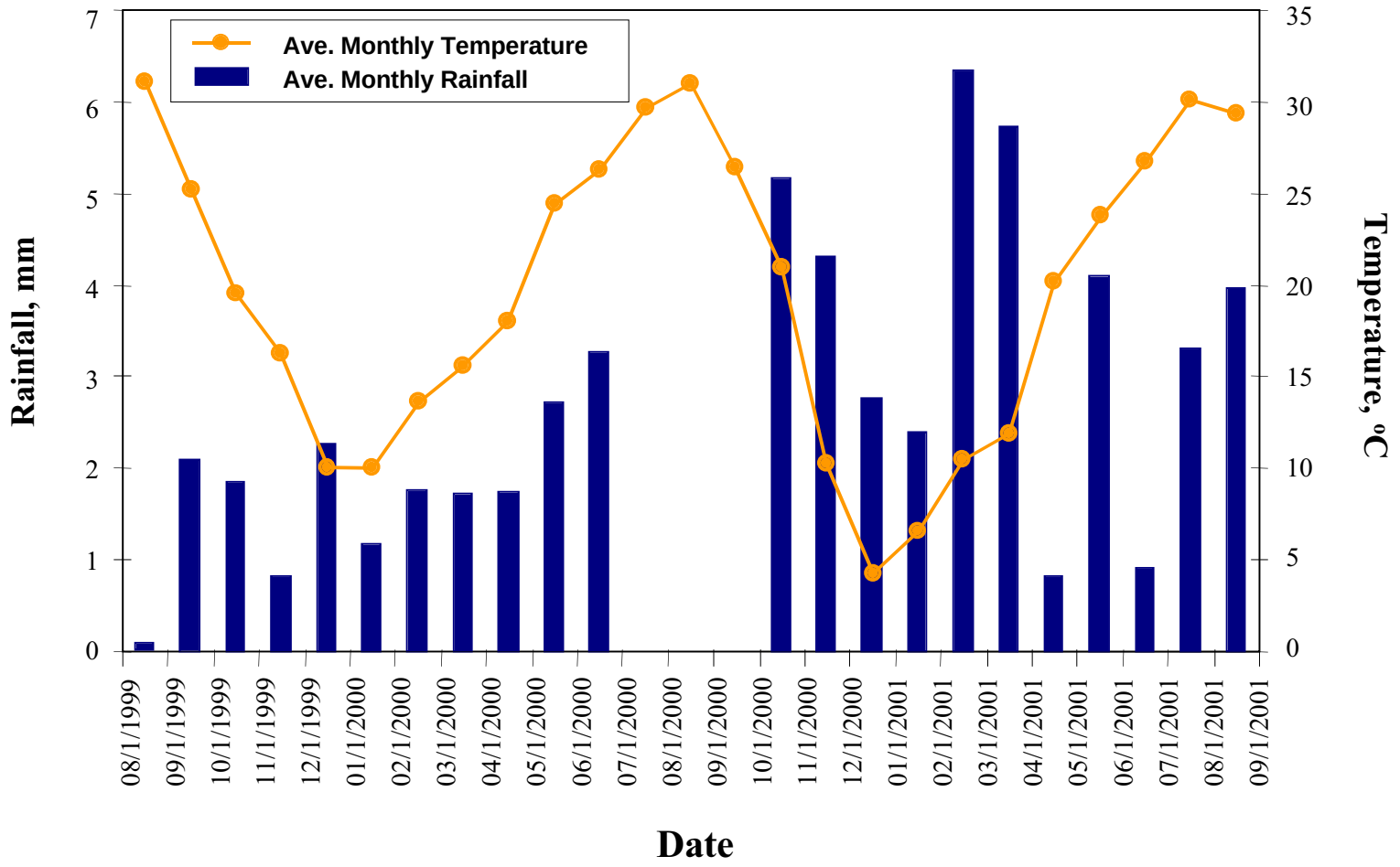
RAINFALL AND TEMPERATURE



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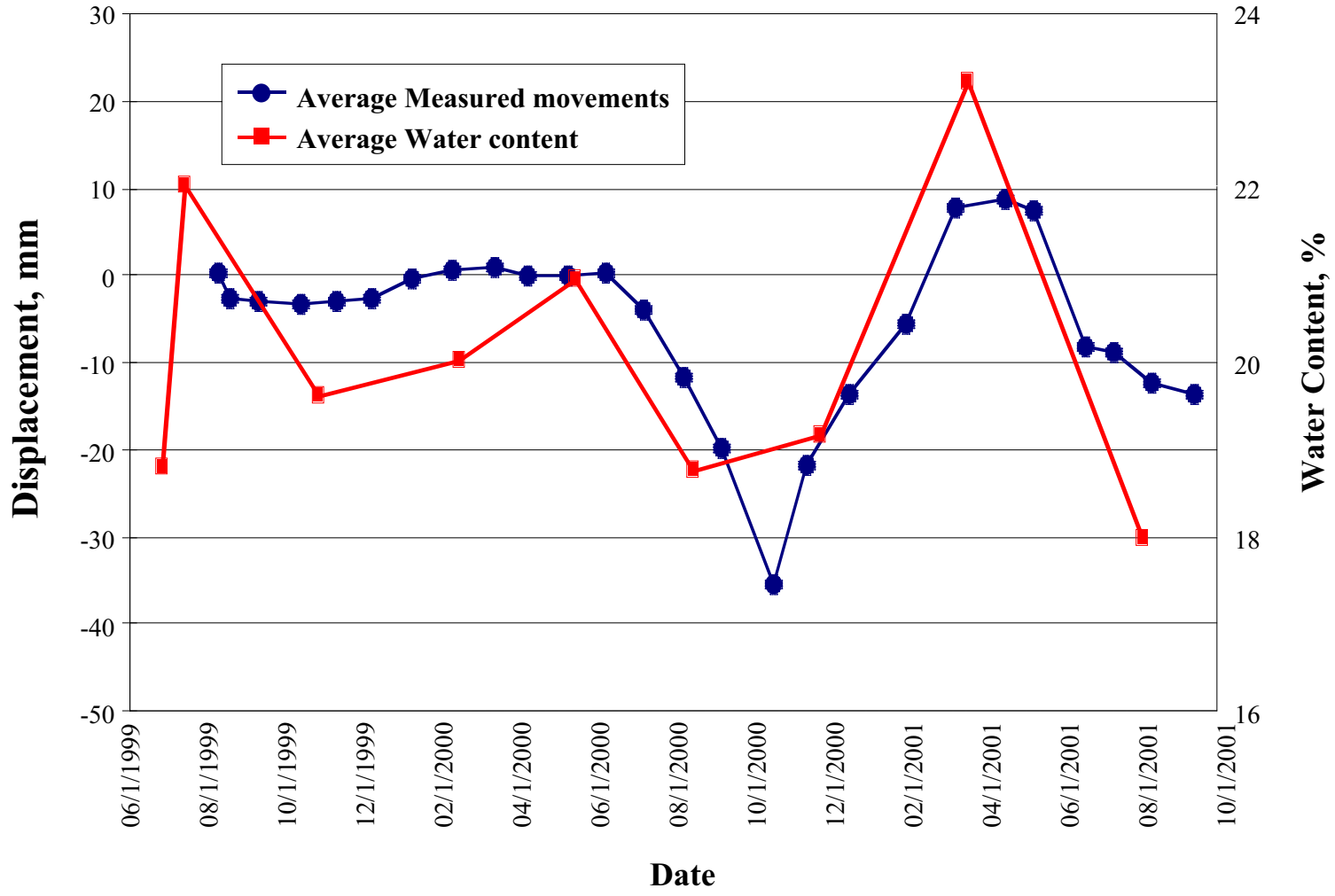
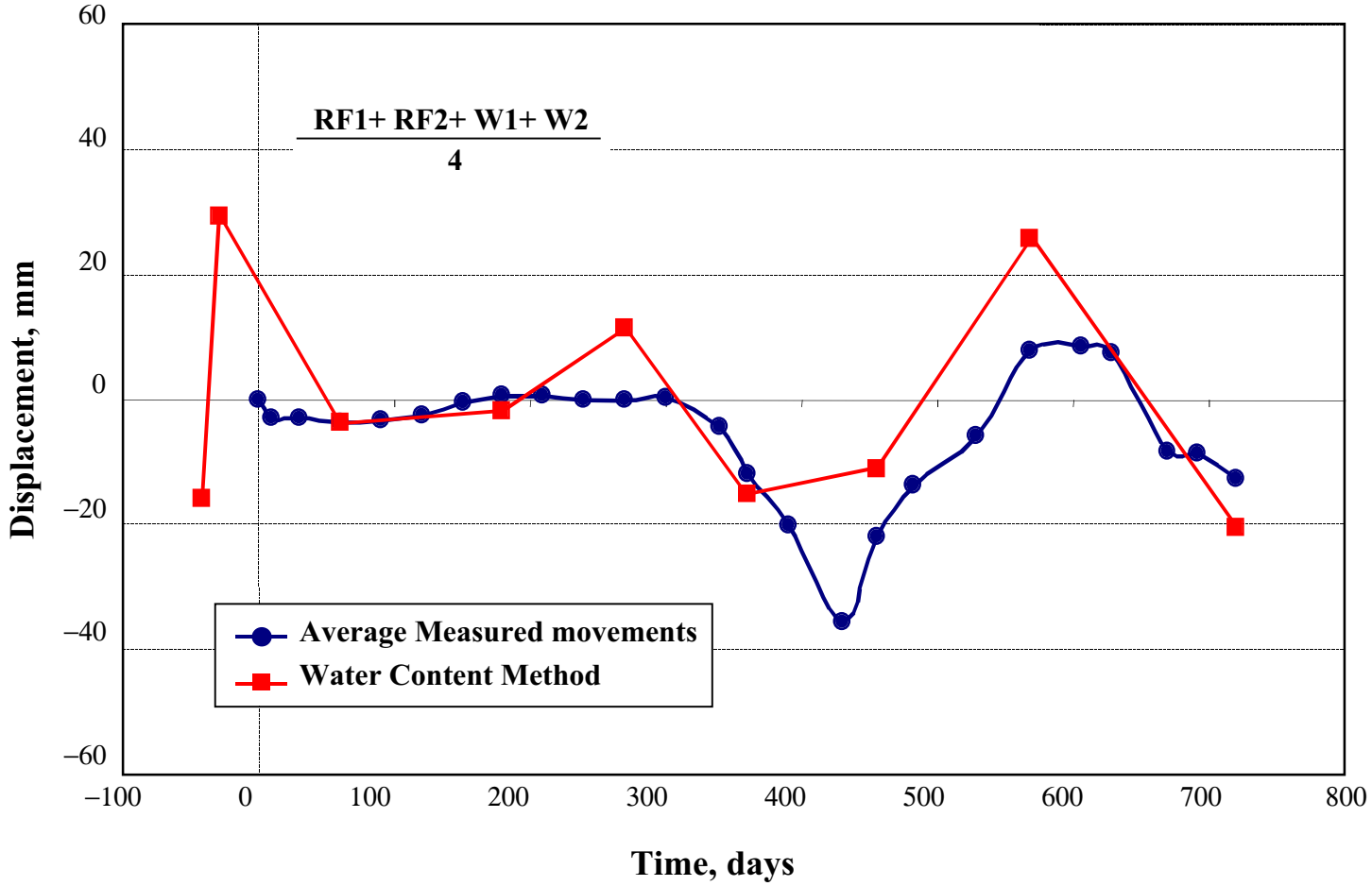
WATER CONTENT VARIATION AND MOVEMENT

Average of 4 Footings at a site in Arlington, Texas



PREDICTED AND MEASURED MOVEMENTS

Average of 4 Footings at a site in Arlington, Texas



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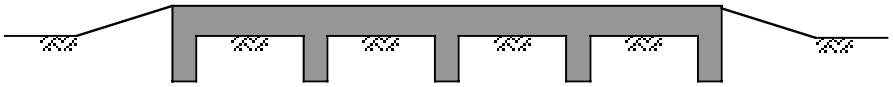
HOUSES ON EXPANSIVE CLAYS

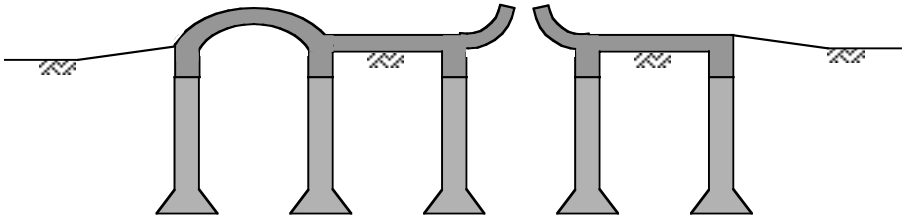
MOST EXPENSIVE NATURAL HAZARD IN THE COUNTRY

FOUNDATION SOLUTION

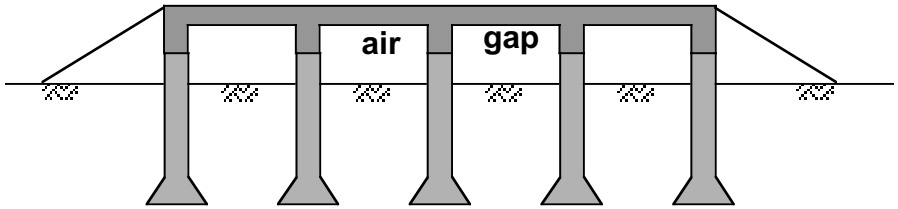
• Stiffened Slab on Grade



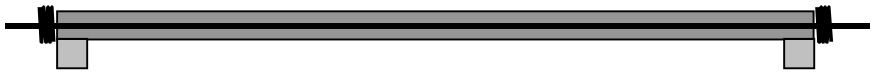
• Stiffened Slab on Grade & on Piers



• Elevated Structural Slab on Piers



• Thin Post Tensioned Slab



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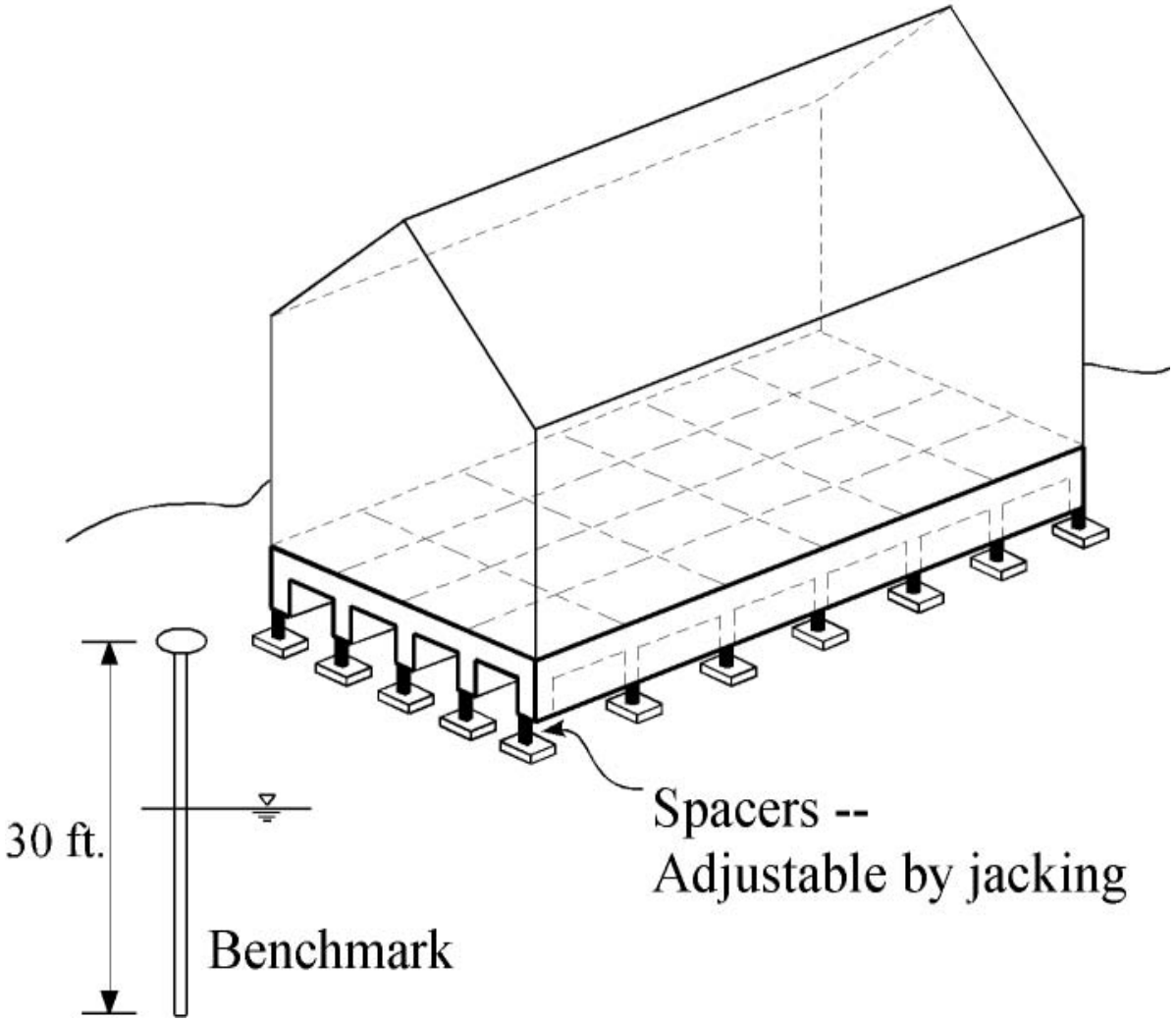
HOUSES ON EXPANSIVE CLAYS

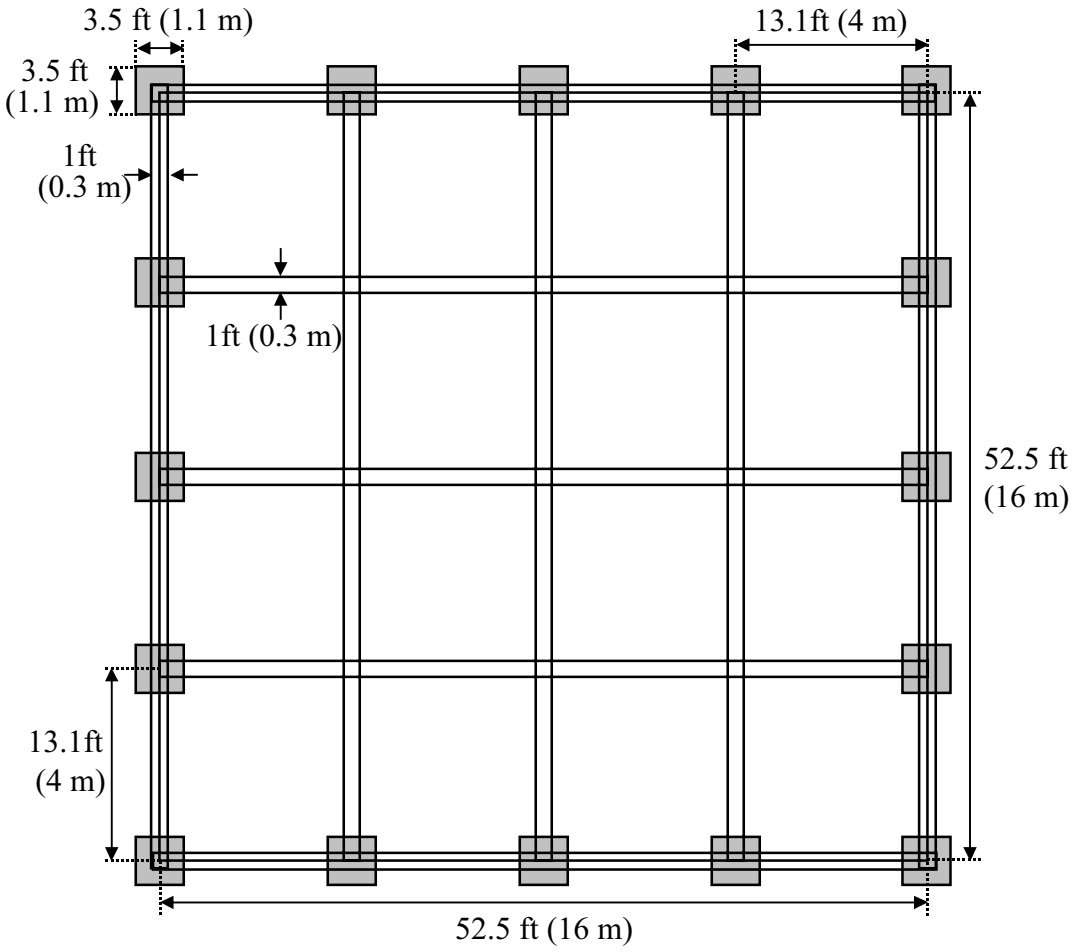
VERY DIFFICULT TO PREDICT THE SOIL MOVEMENT (WEATHER, VEGETATION, DRAINAGE)

MUCH EASIER TO DESIGN AN ADJUSTABLE FOUNDATION

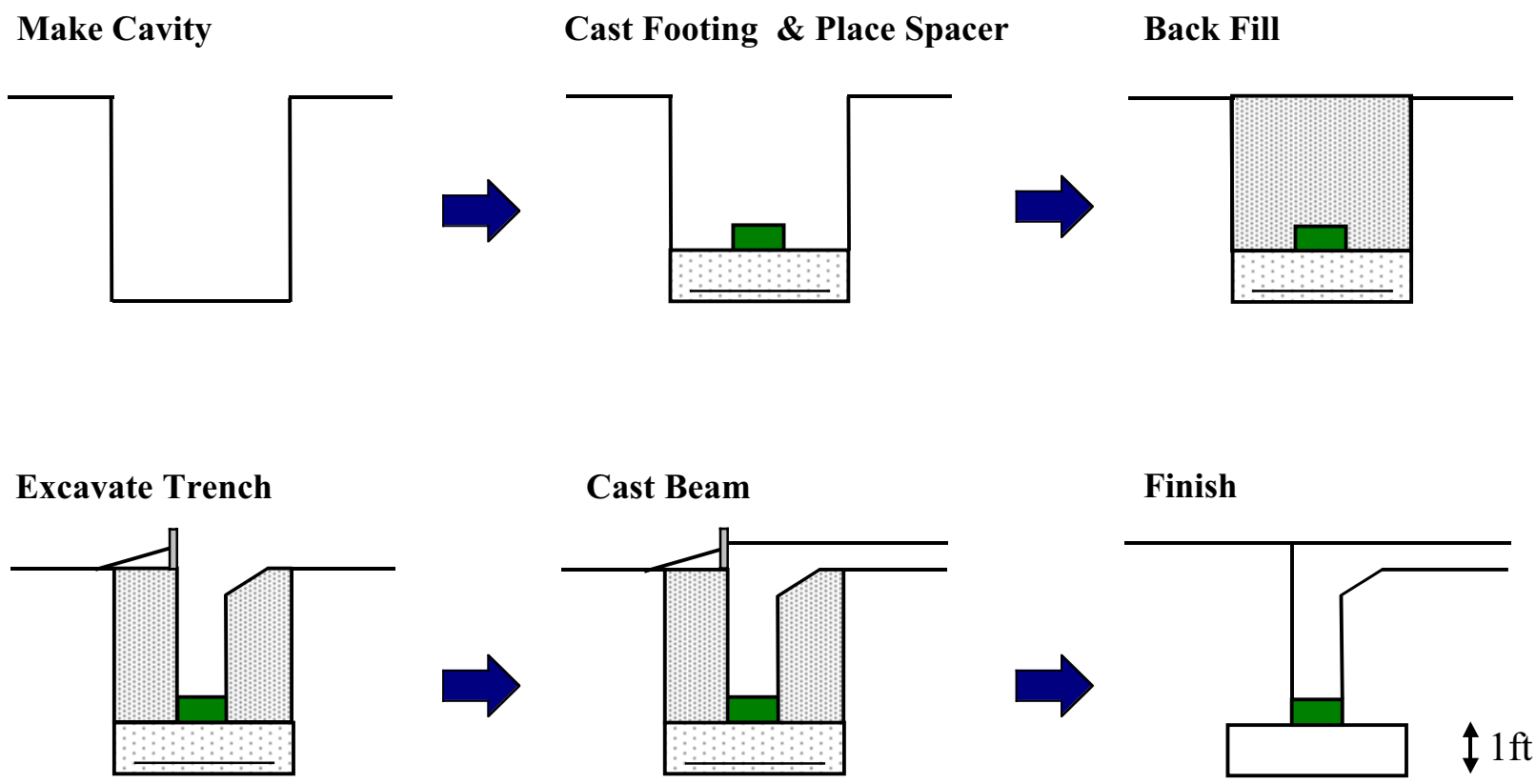
SMART FOUNDATION



SMART FOUNDATION



SMART FOUNDATION CONSTRUCTION



COST COMPARISON

Conventional Waffle Slab

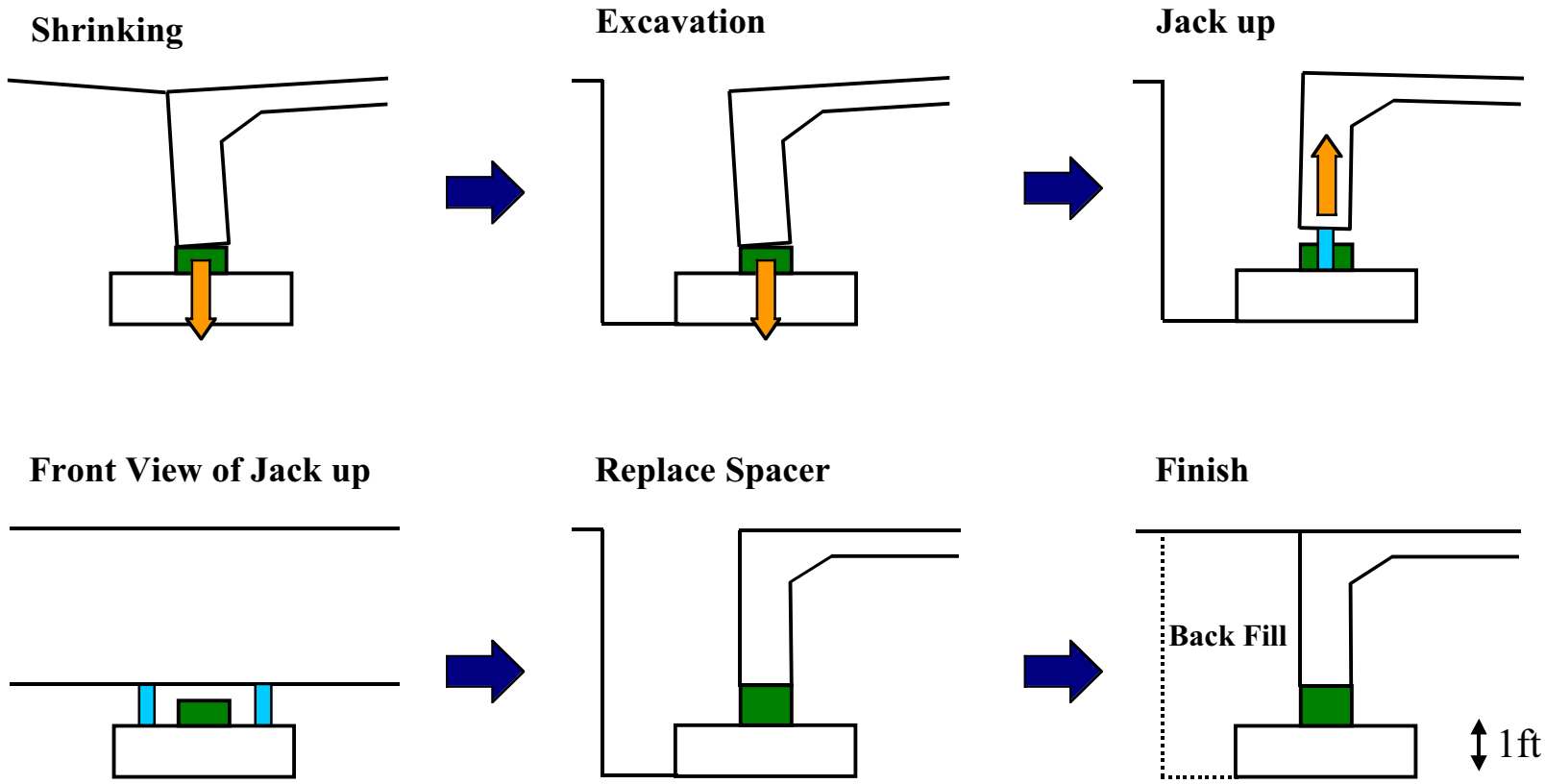
16 m × 16 m × 0.1 m Slab on Grade with
0.9 m deep × 0.3 m thick Beams every 4 m $24,000

Smart Foundation

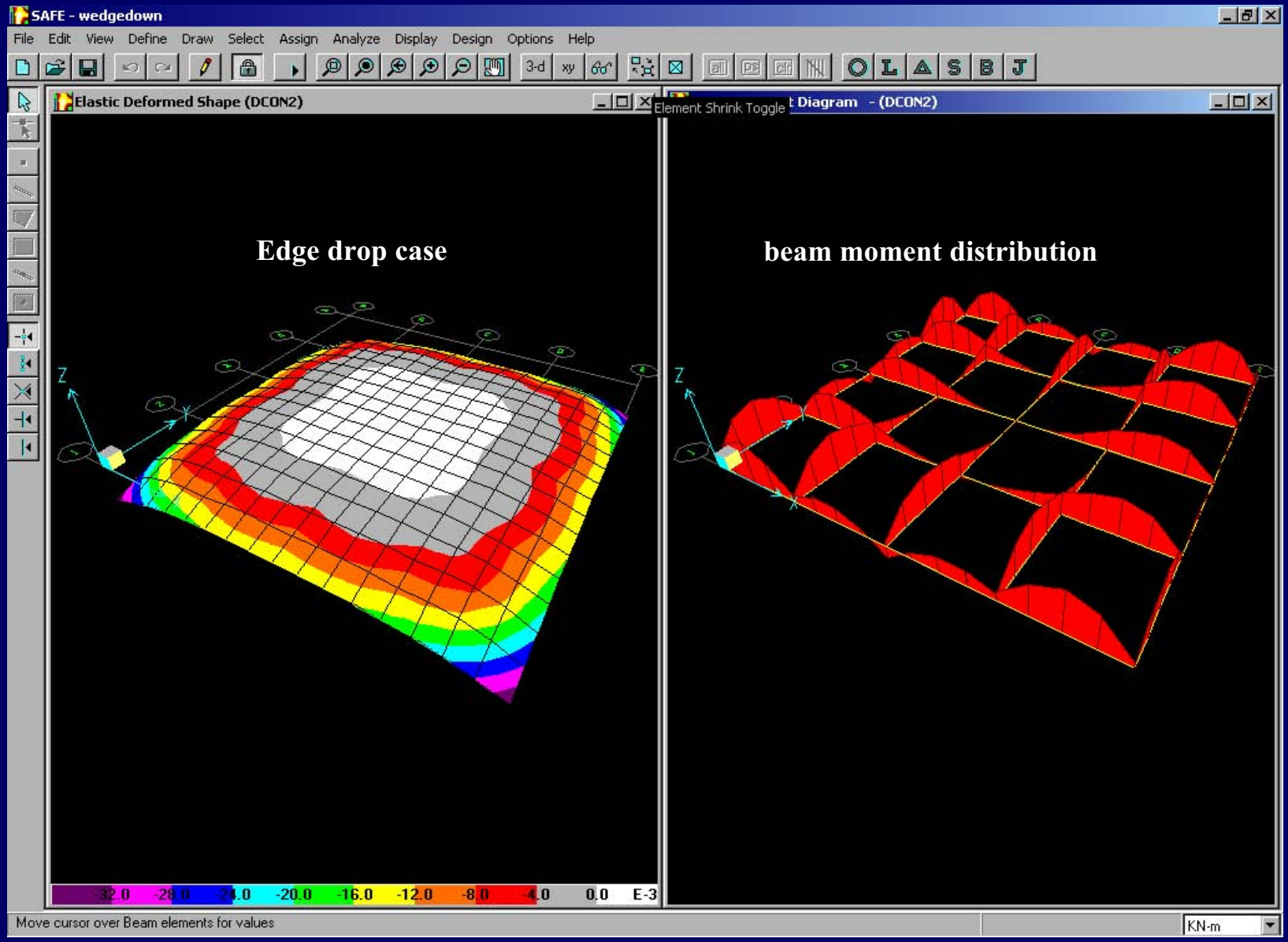
16 m × 16 m × 0.1 m Slab on Grade with
0.9 m deep × 0.3 m thick Beams every 4 m
and 1 m ×1 m ×0.3 m Footings $26,200

~ 10 % Increase in Cost

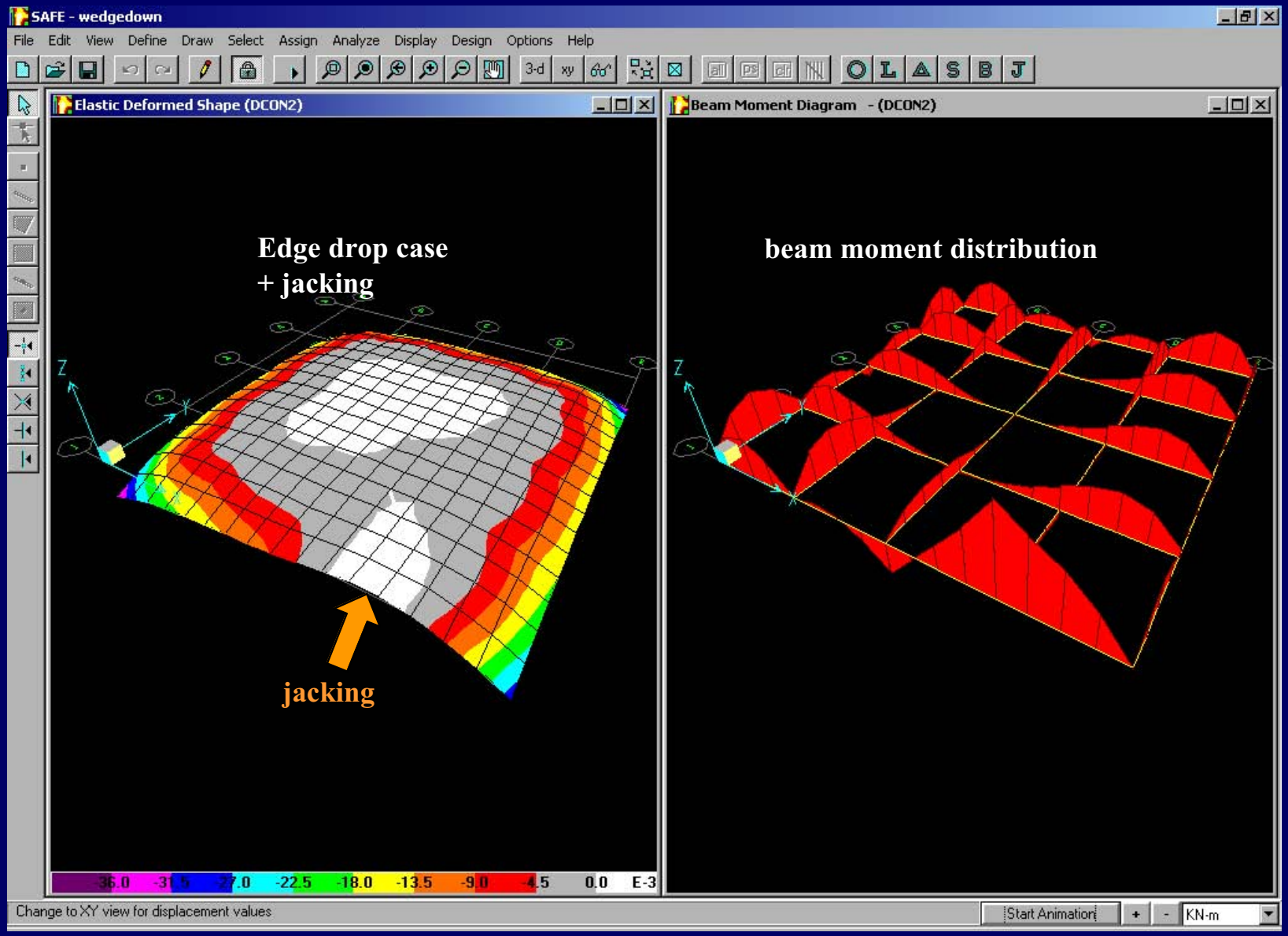
SMART FOUNDATION ADJUSTMENT



FOUNDATION ANALYSIS BY SAFE



FOUNDATION ANALYSIS BY SAFE



CONCLUSIONS

- FUNDAMENTAL BEHAVIOR
- SHRINK TEST – WATER CONTENT METHOD PROPOSED
- SHRINK TEST – WATER CONTENT METHOD VERIFIED
- SMART FOUNDATIONS = ADJUSTABLE SOLUTION