SLAB ON GRADE ON SHRINK SWELL SOIL: A NEW METHOD

The Cross-USA Lecture

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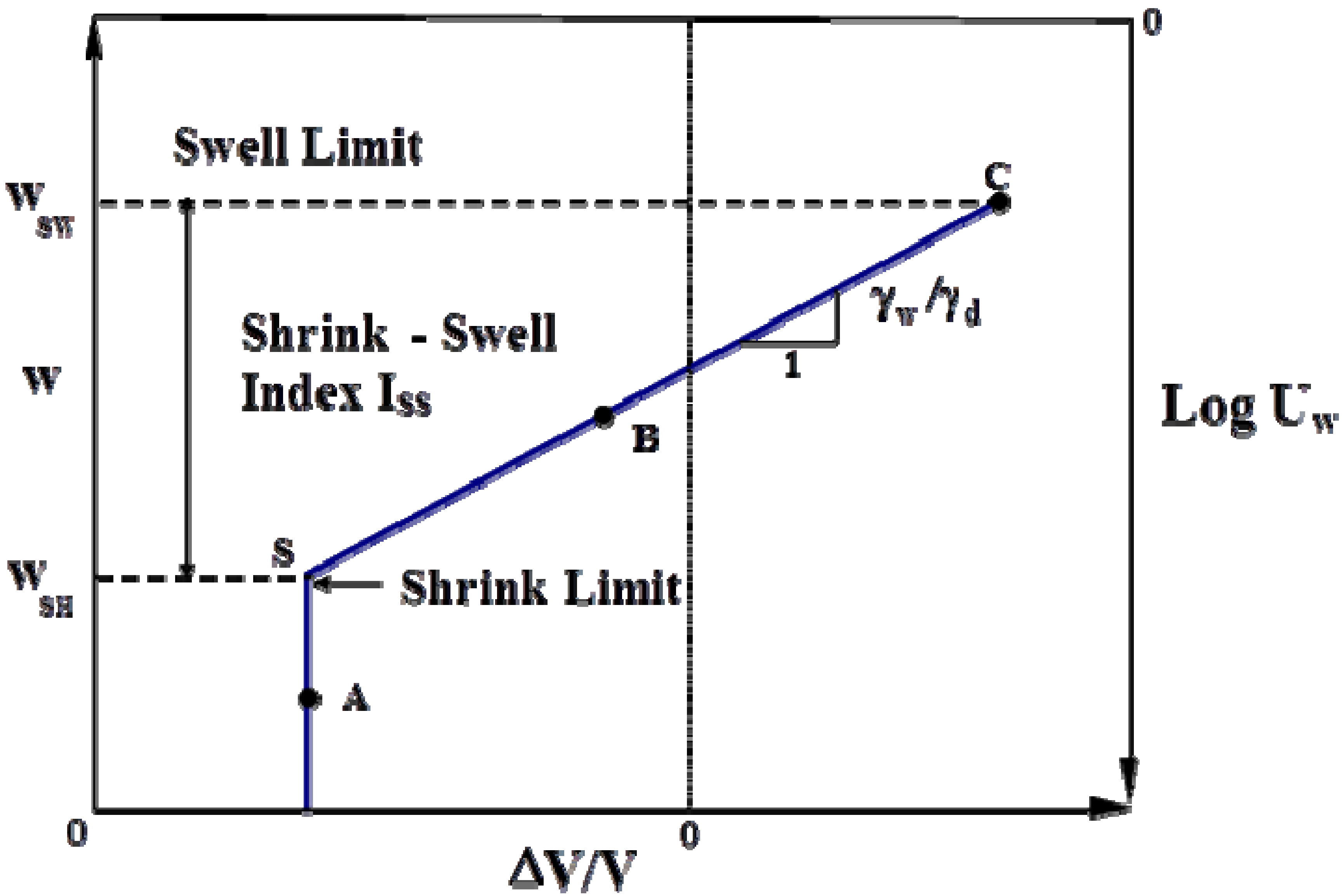
CONTENT

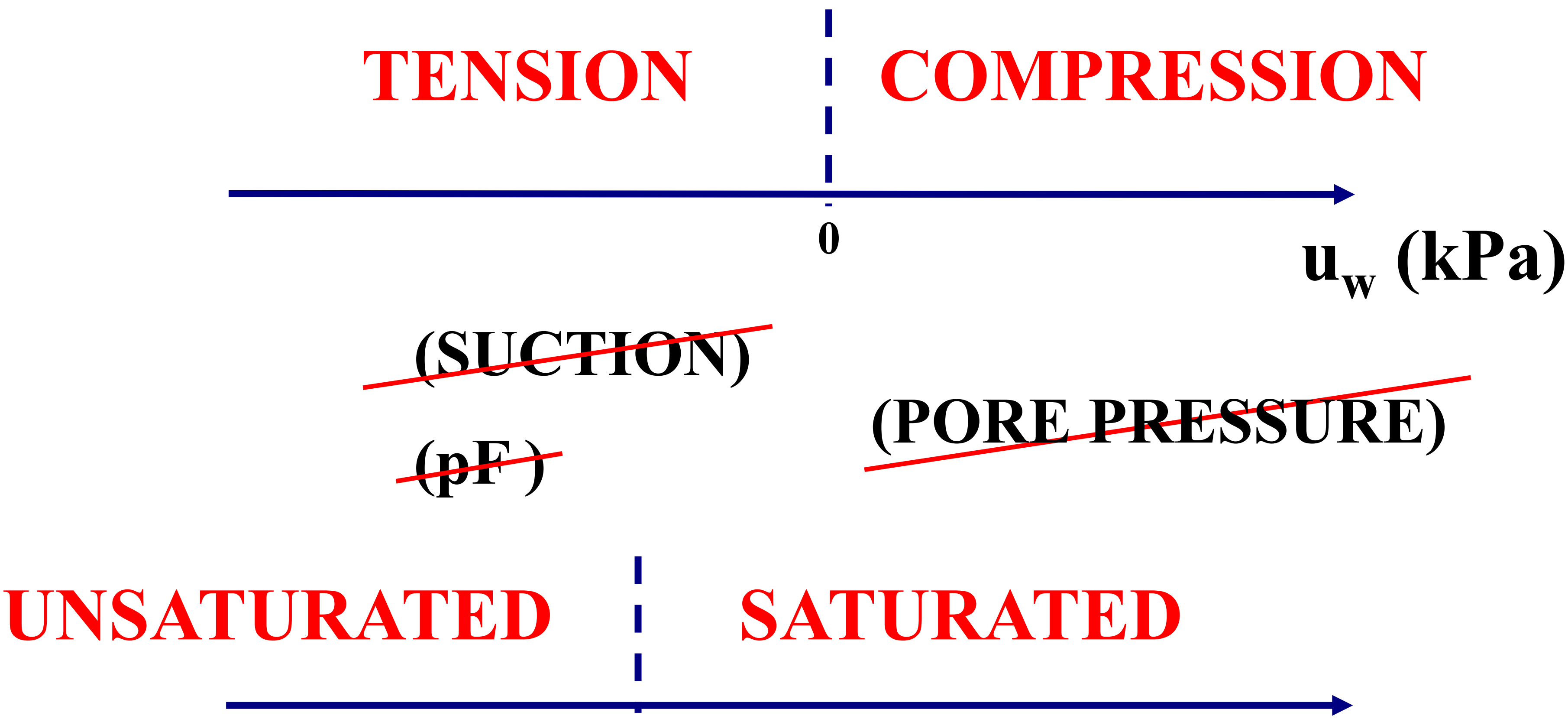
1. Shrink Swell Soils: a Background
2. Development of the method
3. The design charts
4. Superposition of loads
5. Verification
6. Case history
7. Example by hand
8. TAMU-SLAB: Excel spread sheet

Soil State	Swell	Shrink
Unsaturated A on Fig. 2	Yes	No
Saturated B on Fig. 2	Yes	Yes
GWL		
Saturated C on Fig. 2	No	Yes

Water content – volume change model



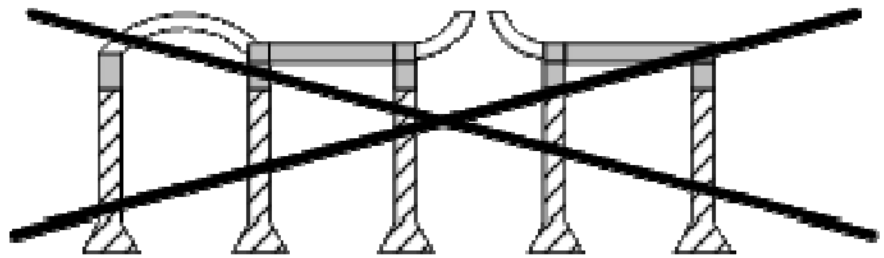
WATER NORMAL STRESS



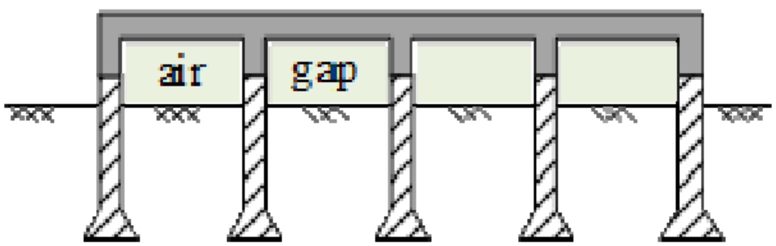
Foundation solutions for shrink swell soils

Stiffened Slab on Grade
Good if EI is sufficient

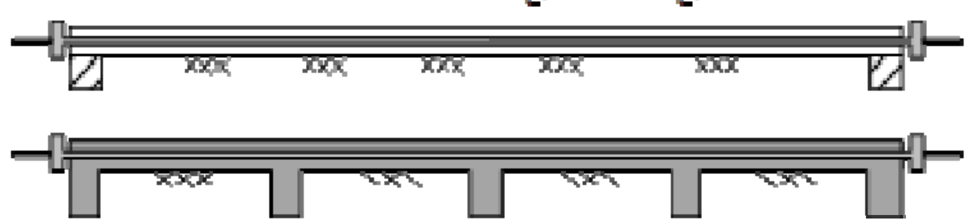
Stiffened Slab on Grade and on Piers
Bad in all Cases



Elevated Structural Slab on Piers
Good if Piles are Deep Enough and Gap is Sufficient



Post Tensioned Slab
Good if EI is High Enough

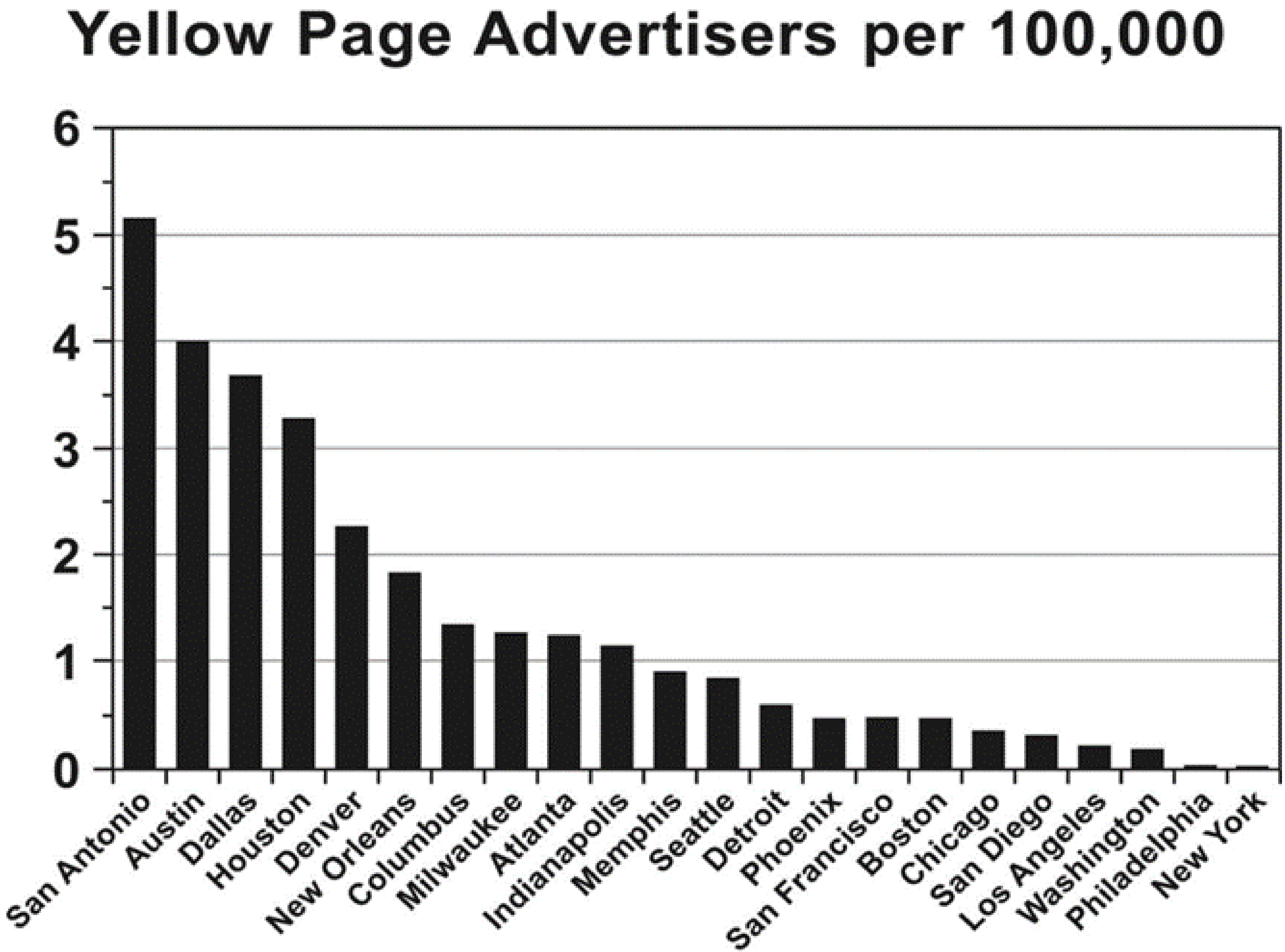


EXISITNG METHODS

1. BRAB (Building Research Advisory Board, 1968)
2. WRI (Wire Reinforcing Institute, 1981)
3. AS2870 (Australian Standard, 1996)
4. PTI (Post Tensioning Institute, 2012)

Development of the Method

1. Quantify the effect of the weather on the soil
2. Obtain a realistic shape of the soil mound
3. Place the foundation on top of that mound, find Mmax, Vmax, and Δmax
4. Parametric simulation study to identify main parameters.
5. Develop simple design charts
6. Develop spread sheet TAMU-SLAB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Philadelphia
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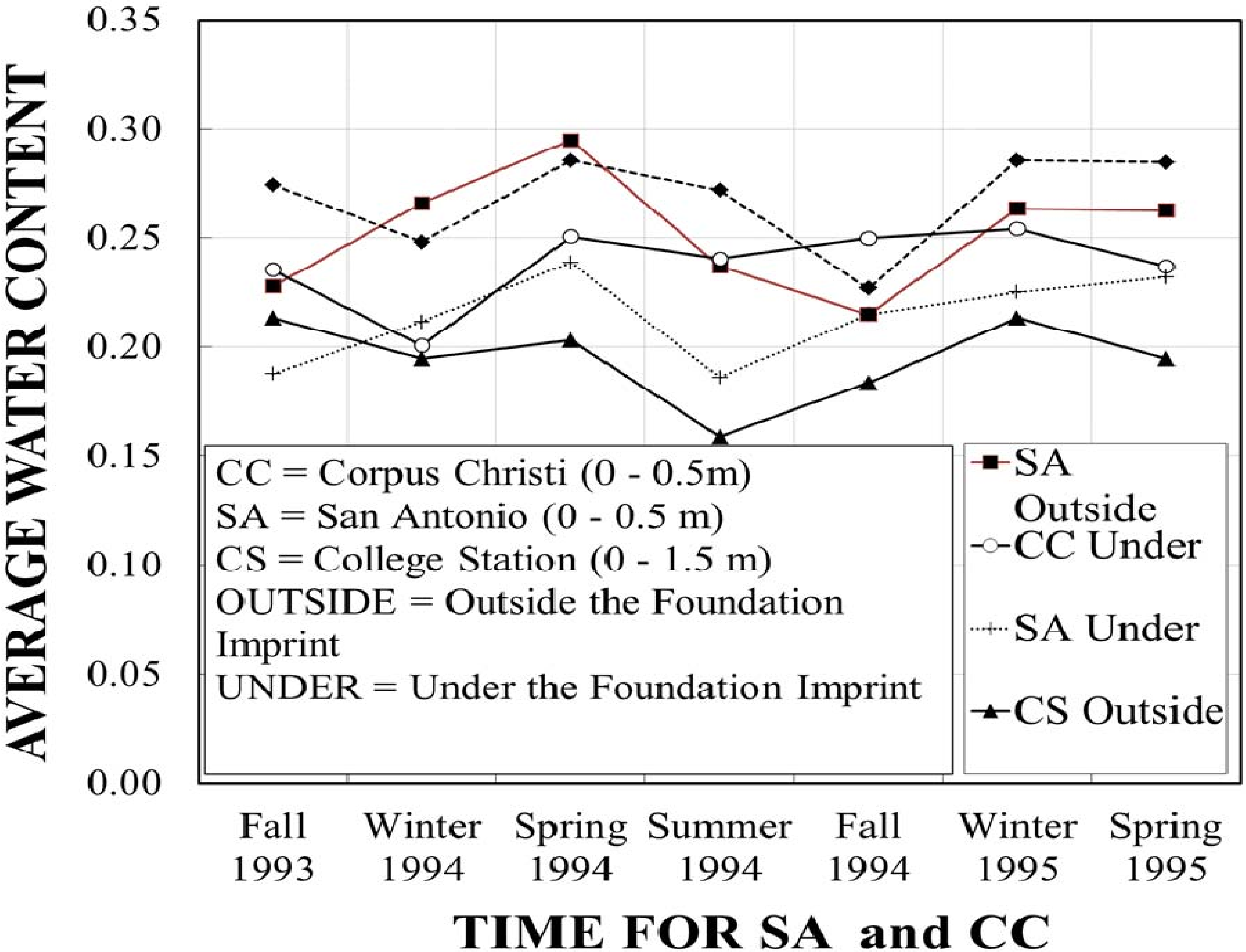
Weather Effect on the Soil

	College Station	San Antonio	Austin	Dallas	Houston	Denver
$\log (u_{f\,max} / u_{f\,min})$	0.788	1.392	0.866	1.295	1.283	1.374
$\log (u_{e\,max} / u_{e\,min})$	0.394	0.696	0.433	0.648	0.642	0.687

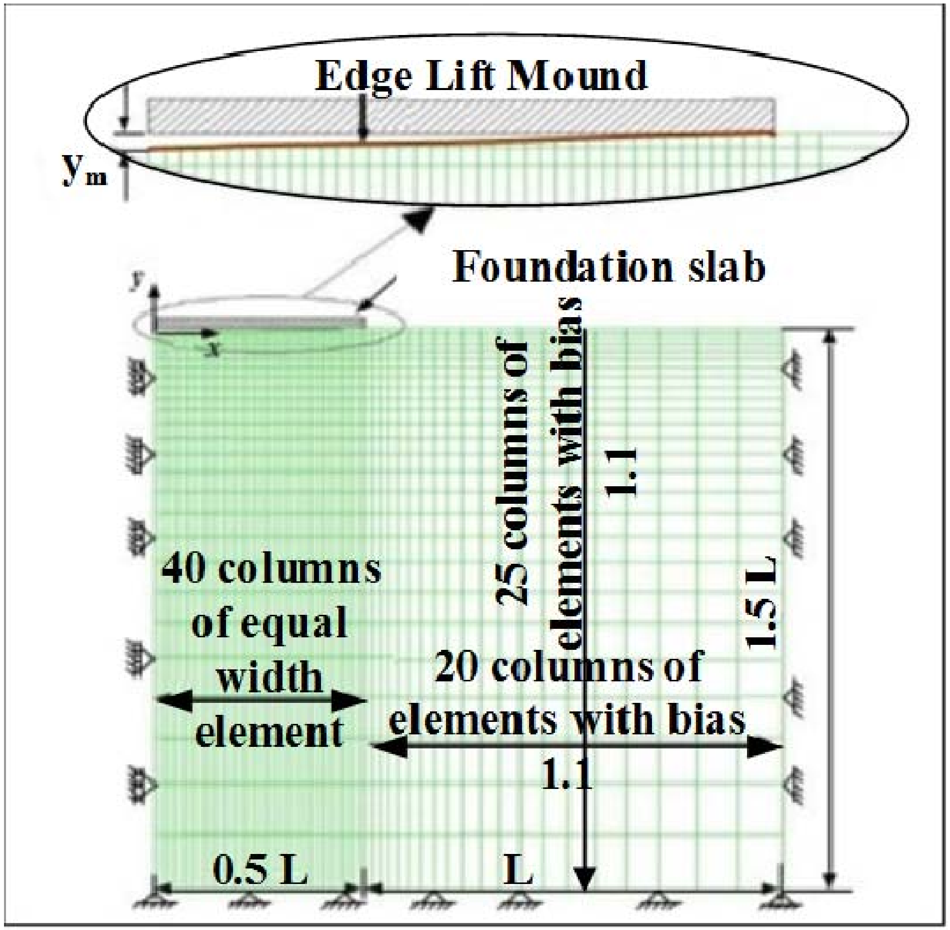
Water content vs Time (2 years)

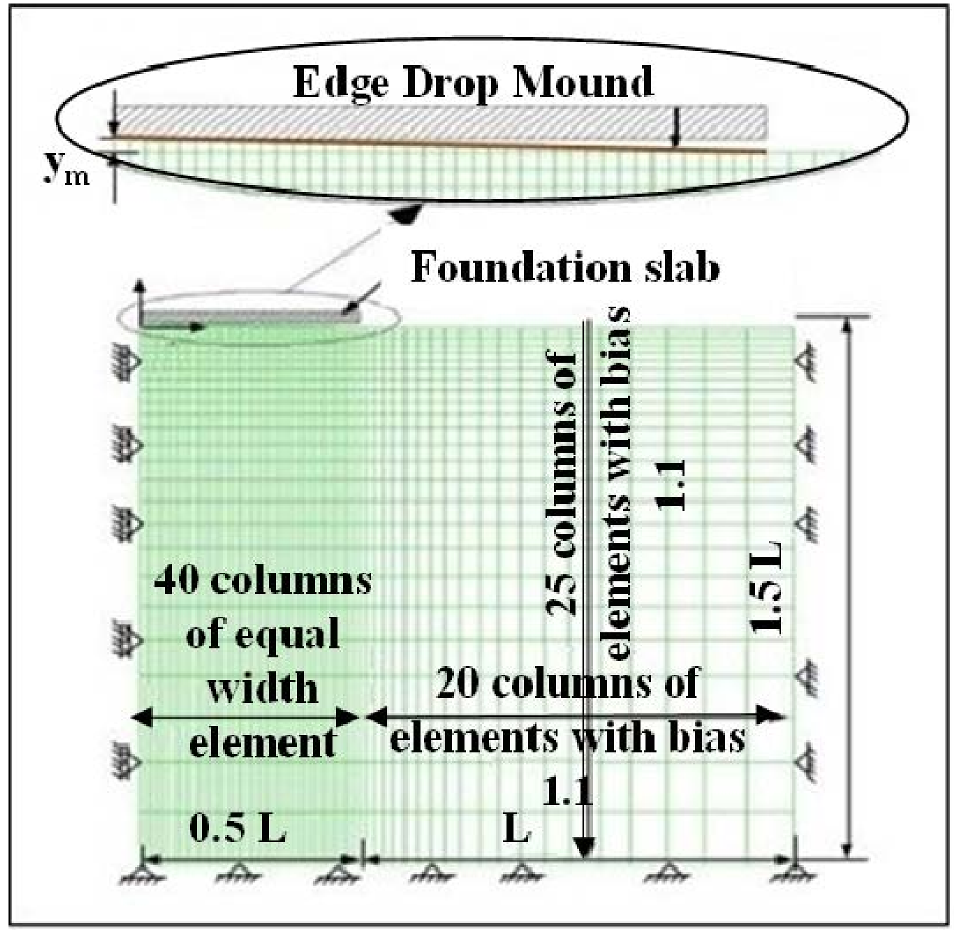


Realistic Shape of Mound

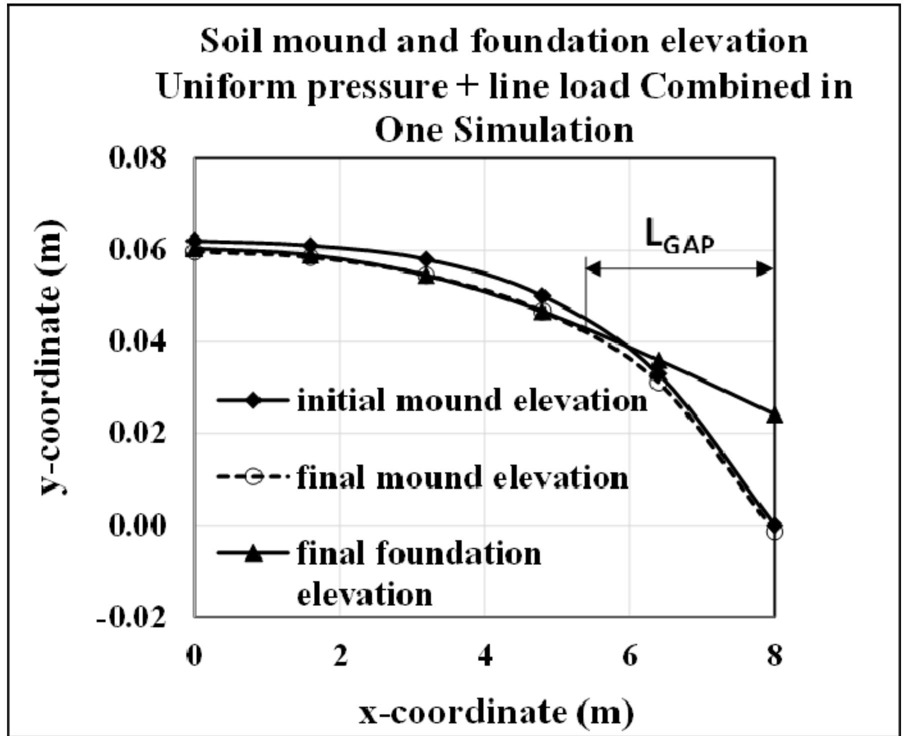
$$\rho(x) = f\gamma_h H \Delta U_{edge} \sum_{n=1}^{\infty} \left\{ \left[\frac{2\pi\left(n-\frac{1}{2}\right)(-1)^{n-1} \exp\left(-\sqrt{\frac{\omega H^2}{2\alpha_{field}}}\right) + 2\sqrt{\frac{\omega H^2}{2\alpha_{field}}}}{\frac{\omega H^2}{2\alpha_{field}} + \pi^2\left(n-\frac{1}{2}\right)^2} \right] \left[\frac{\cosh\left(\left(n-\frac{1}{2}\right)\pi \frac{x}{H}\right)}{\cosh\left(\left(n-\frac{1}{2}\right)\pi \frac{L}{2H}\right)} \frac{(-1)^{n-1}}{\pi\left(n-\frac{1}{2}\right)} \right] \right\}$$

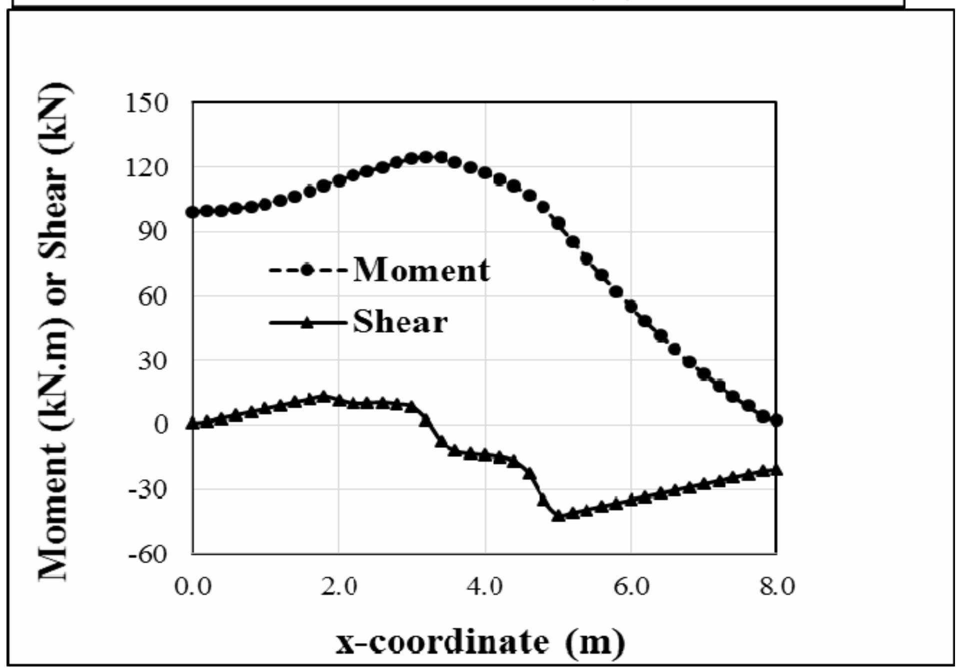
Mesh for numerical simulations





Example results of Abaqus simulation





Most Important Input Parameters

1. Shrink-swell index I_{SS}
2. Depth of the active zone H
3. Change of soil surface water tension (suction) $u_{e\ max}/u_{e\ min}$
4. Slab stiffness represented by the equivalent flat slab thickness d

Soil Weather Index

$$I_{sw} = \frac{1}{2} I_{ss} H \log\left(\frac{u_{e\max}}{u_{e\min}}\right)$$

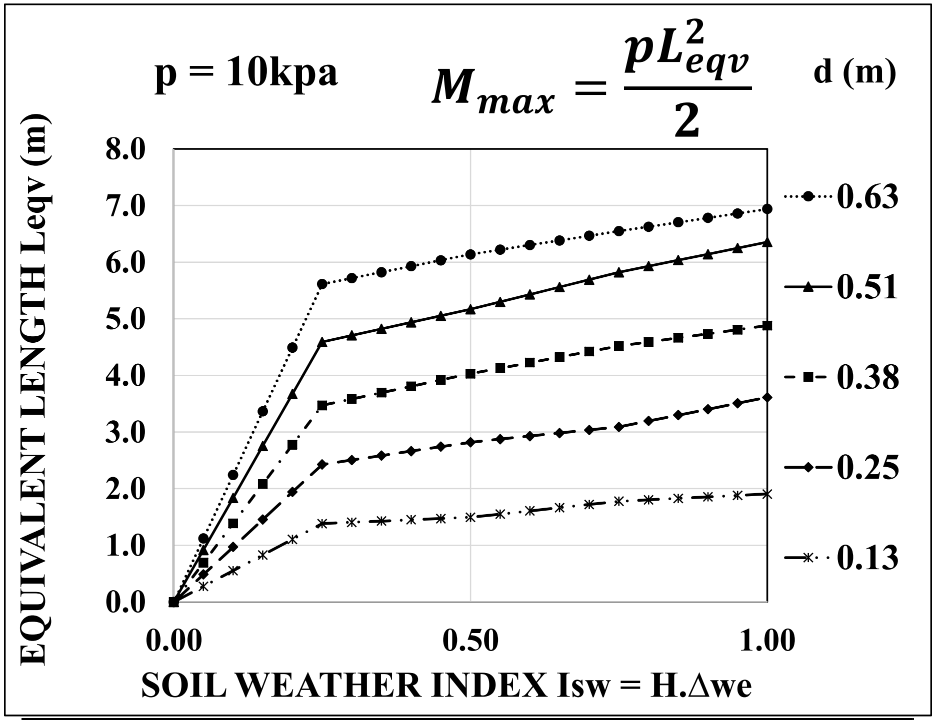
$$I_{sw} = H \Delta w_e$$

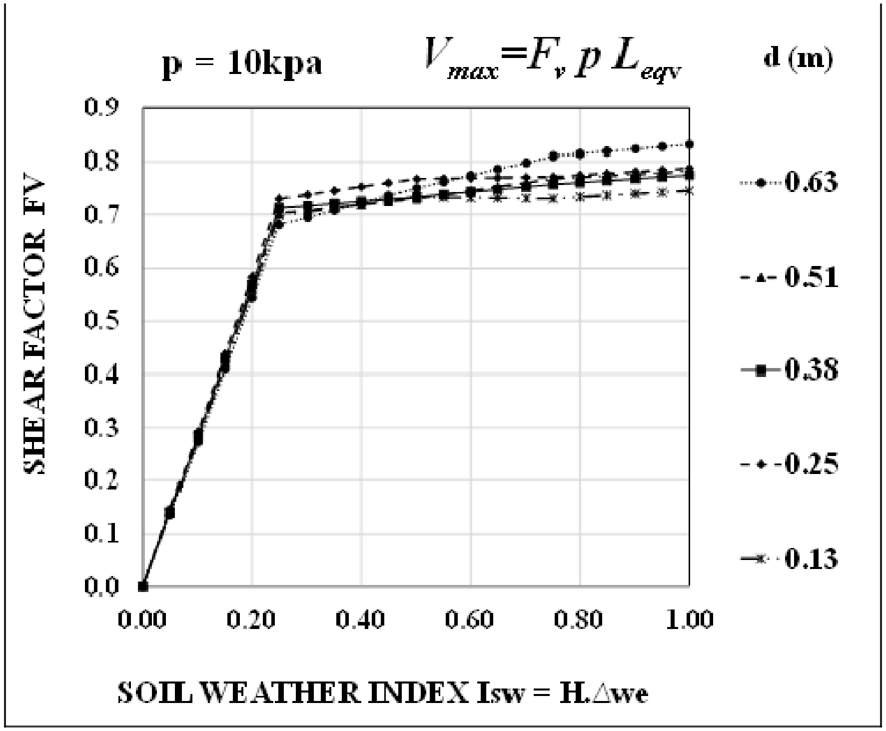
Equivalent Thickness

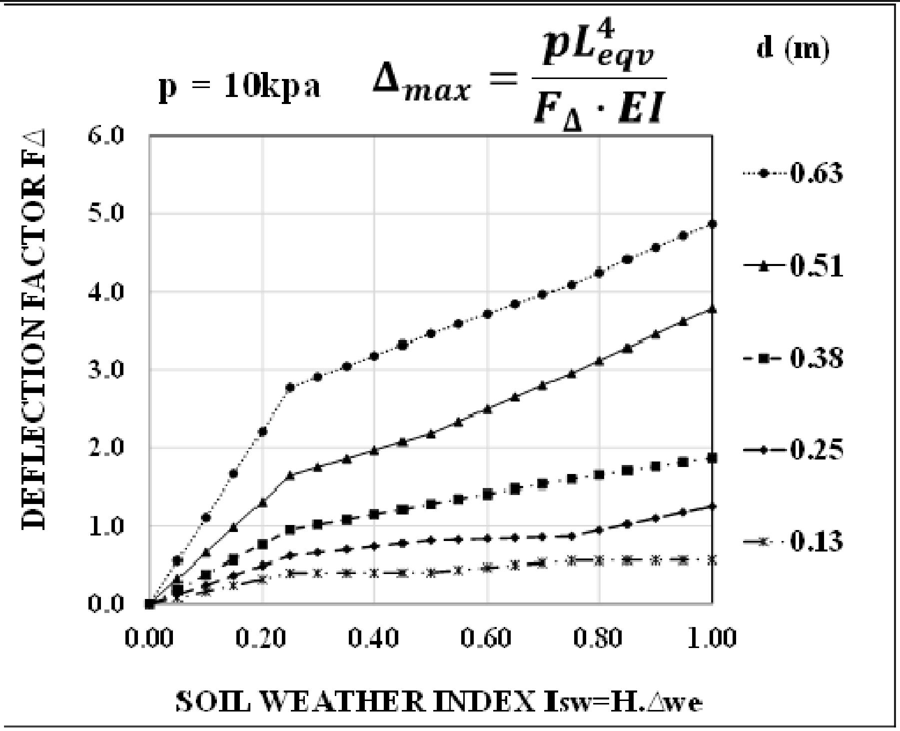
$$b\frac{D^3}{12} = S\frac{d^3}{12}$$

$$d = D\left(\frac{b}{S}\right)^{1/3}$$

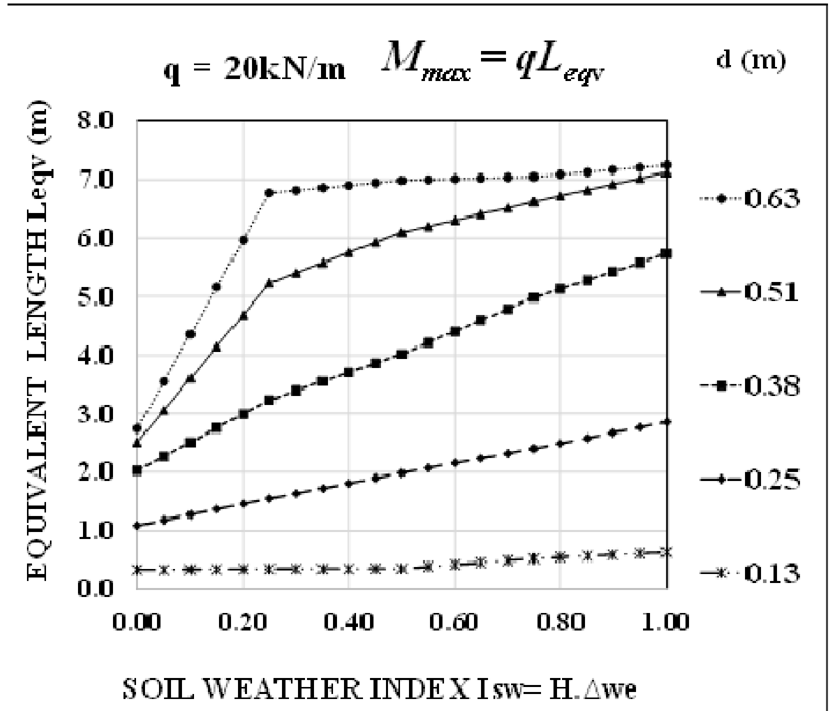
EDGE DROP UNIFORM LOAD

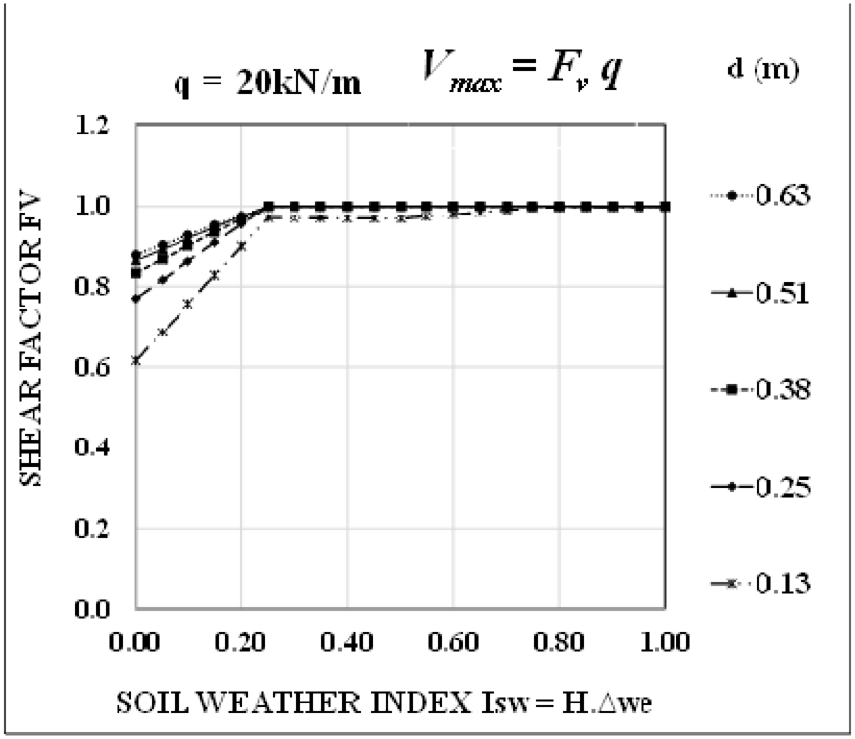


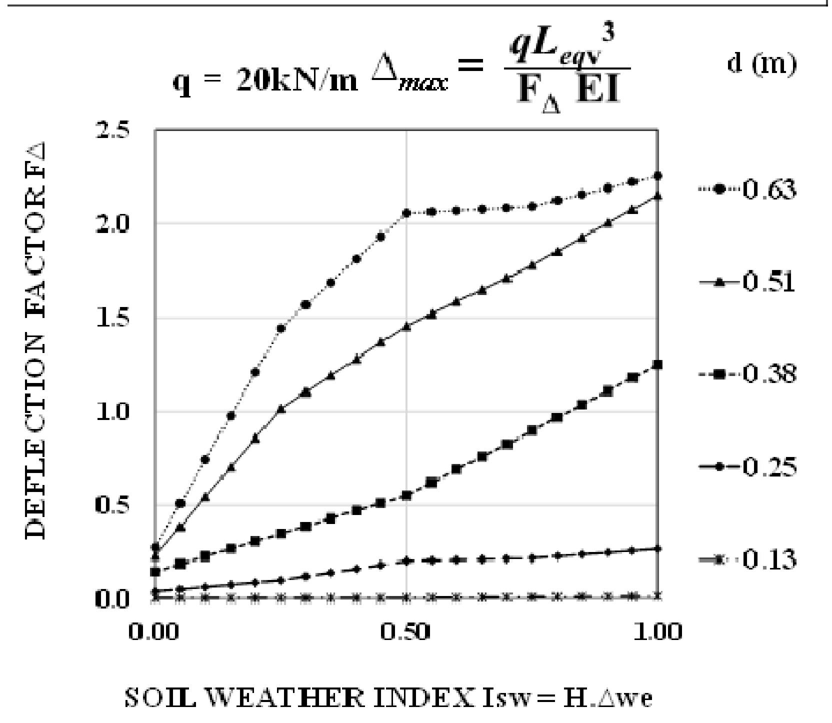




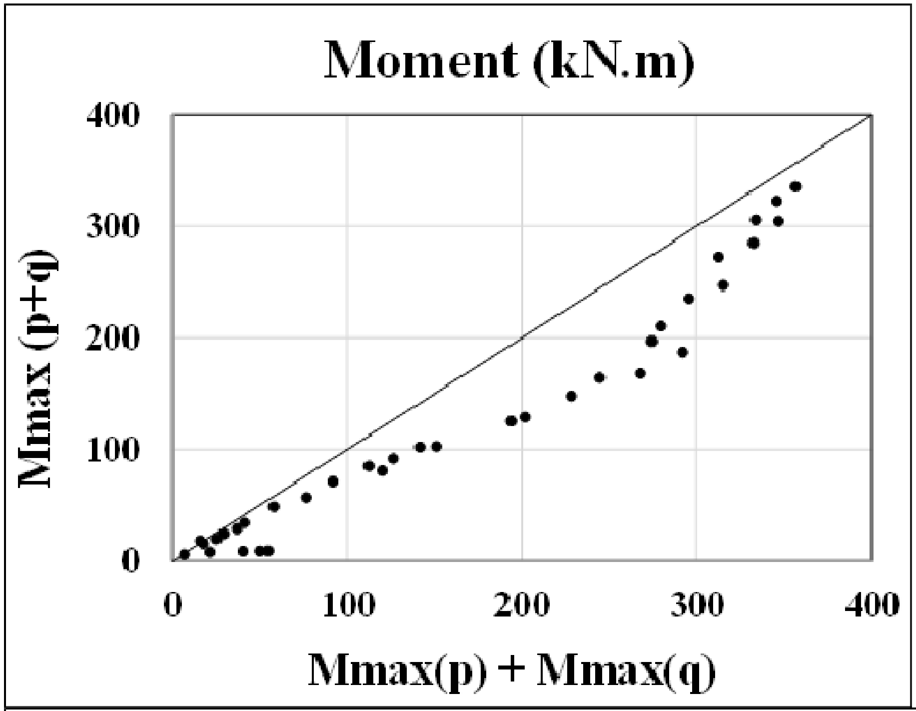
EDGE DROP
LINE LOAD (EDGE)

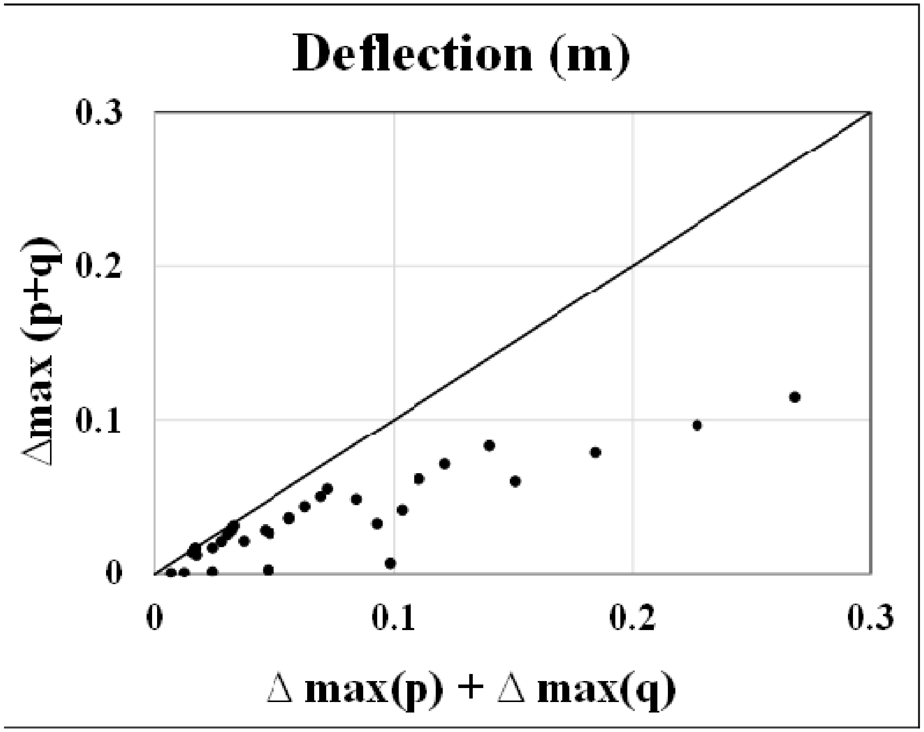


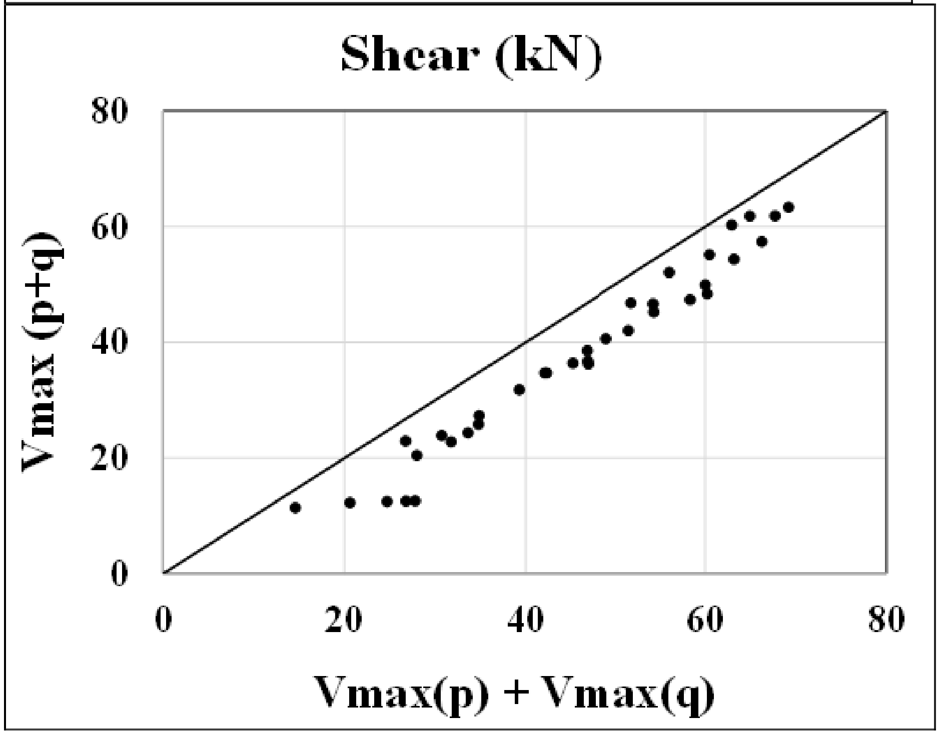




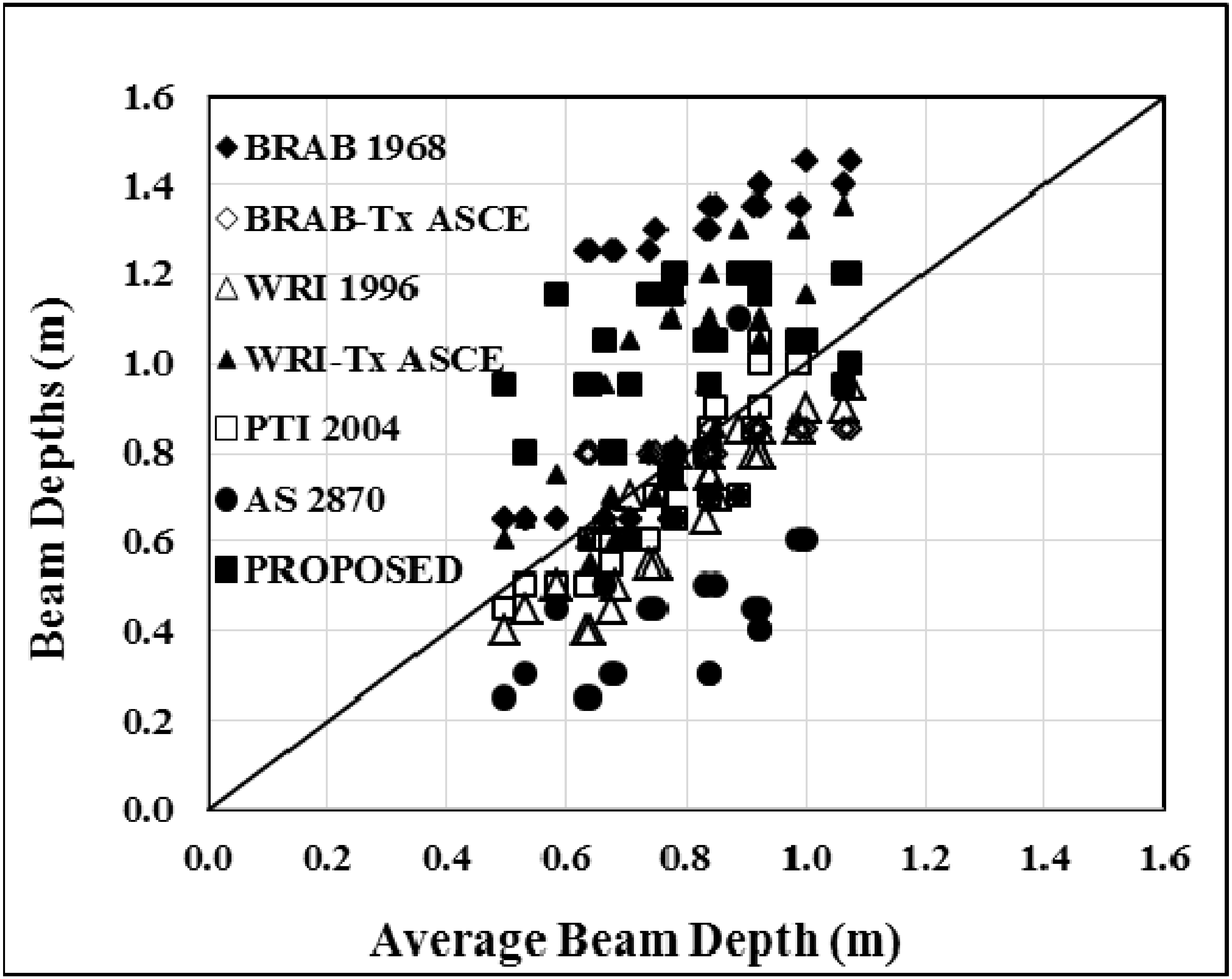
Superposition of uniform load and line load



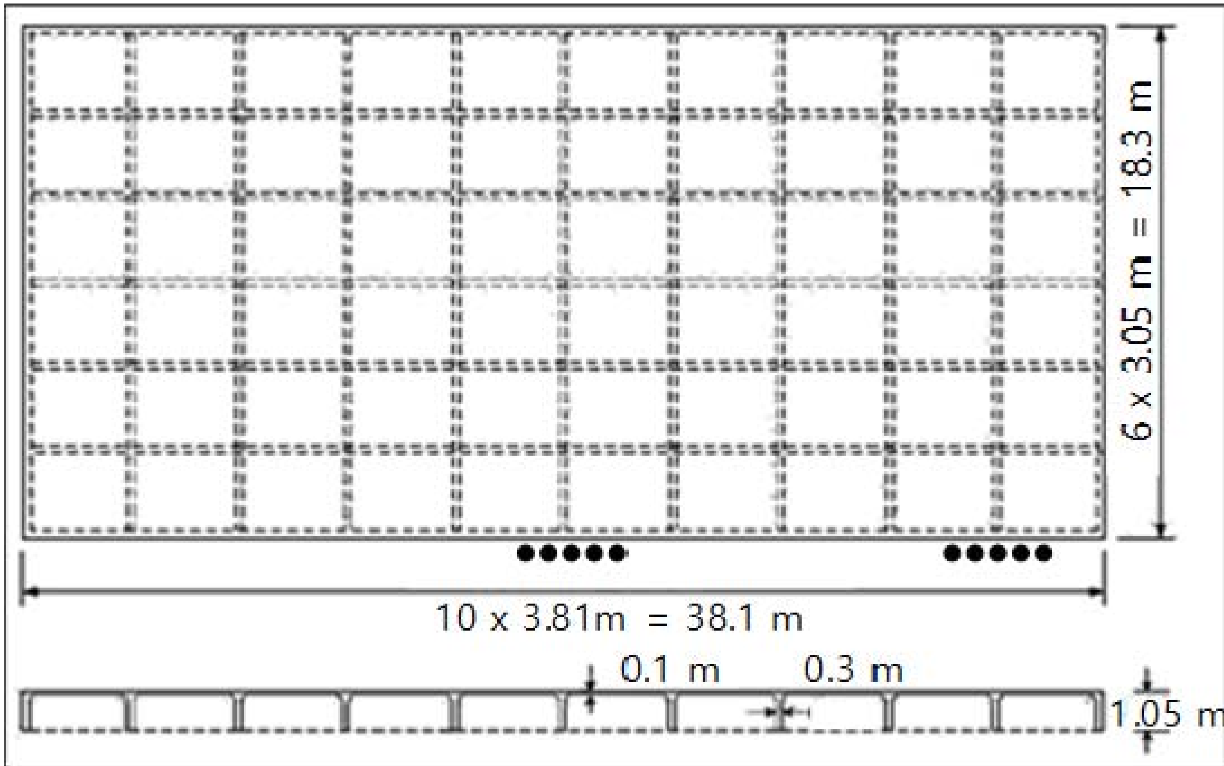


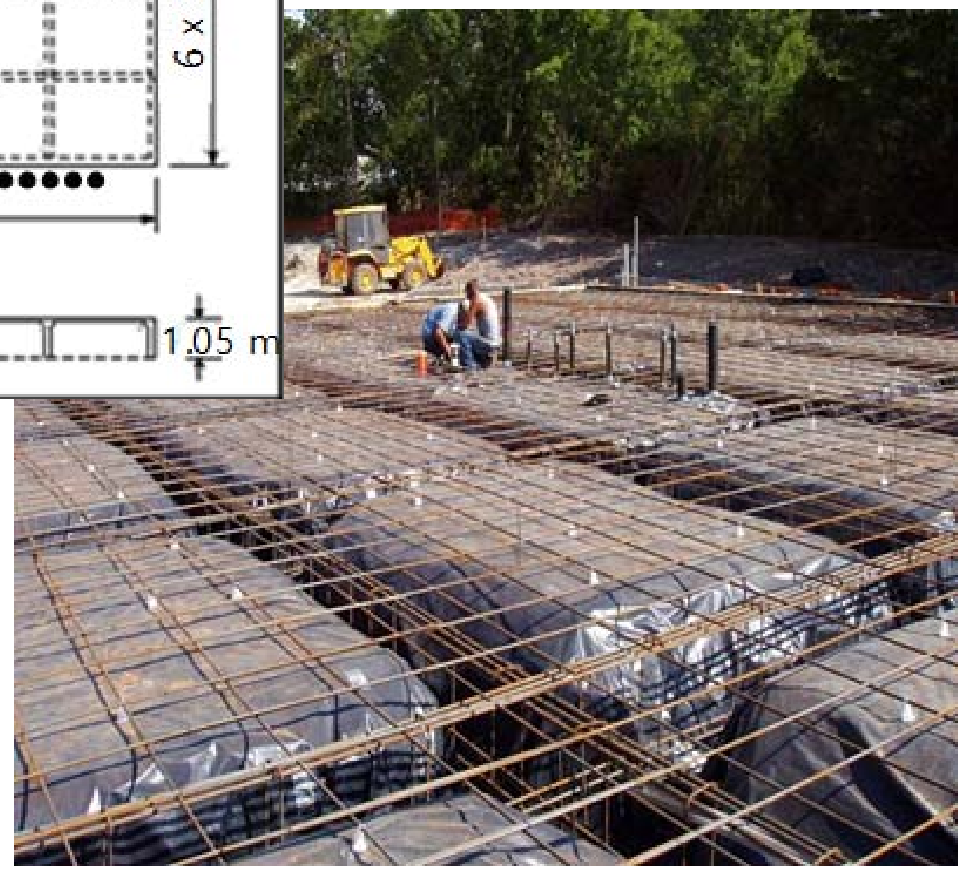


Predictions vs mean prediction

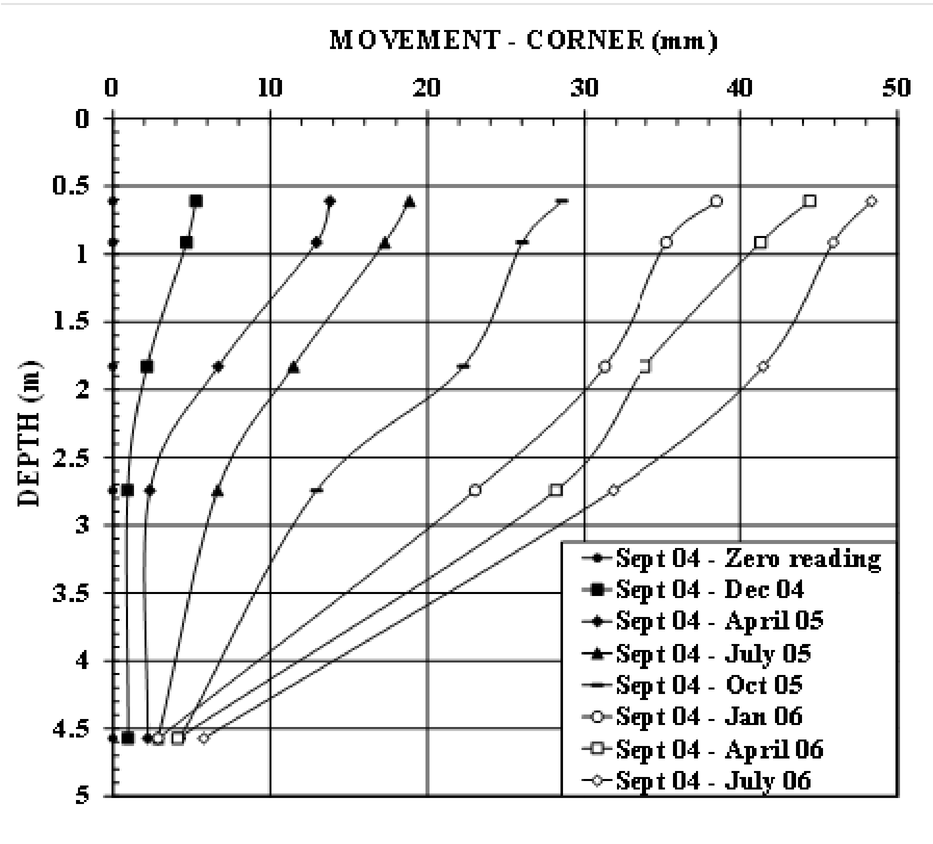


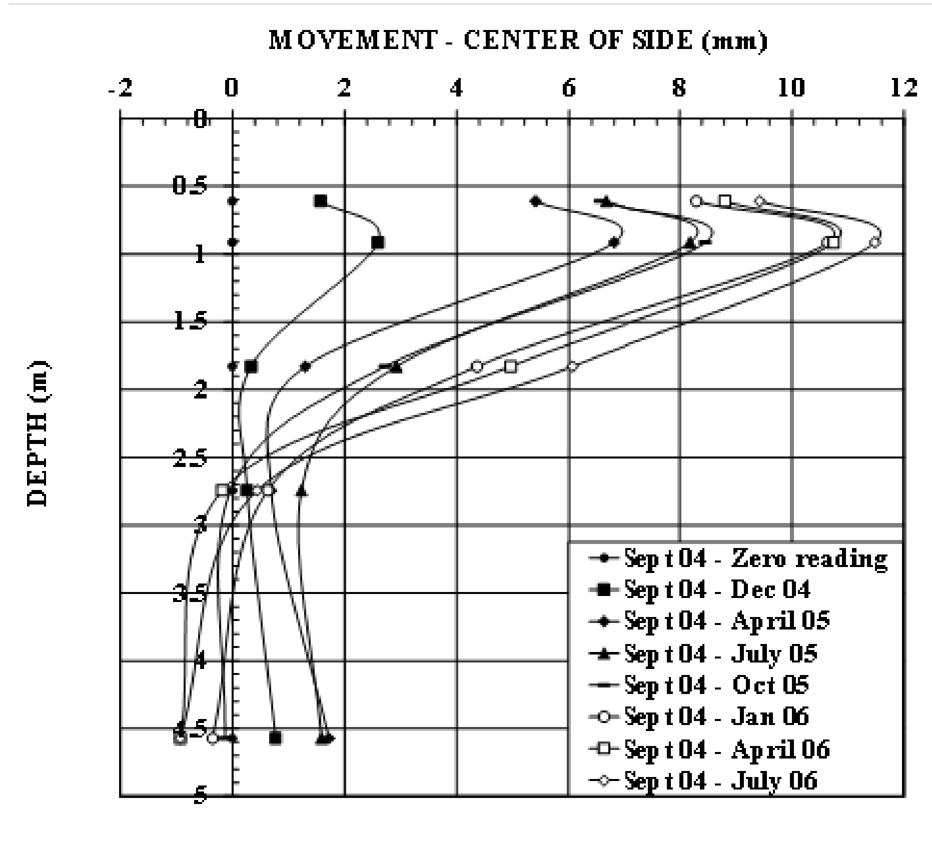
Case history



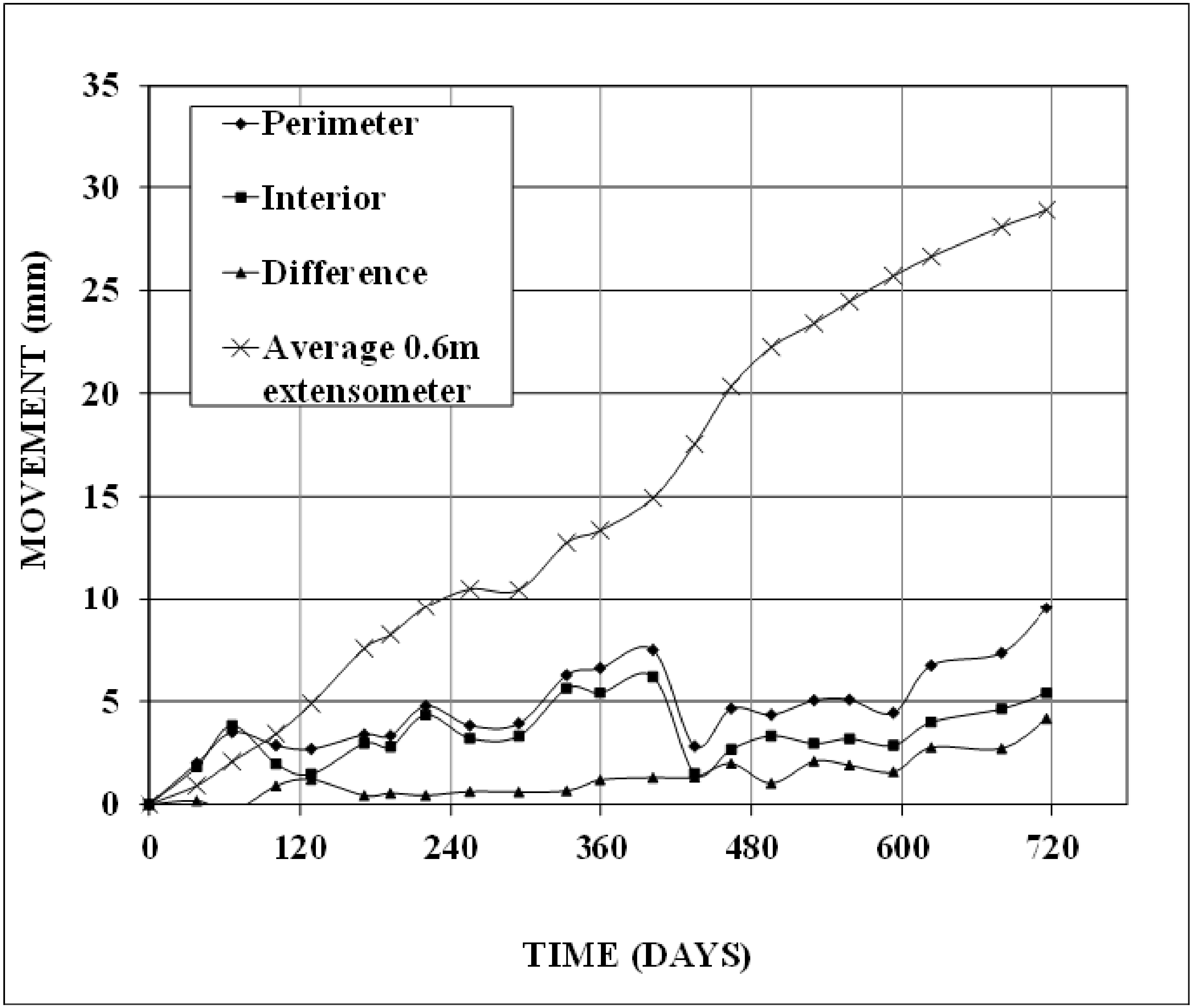


Soil movement vs depth (5 meters)





Soil movement vs time (2 years)



DESIGN EXAMPLE

INPUT:

Depth of active zone H = 3.0 m,
Water content $\Delta w_f = 20\%$,
Slab 20 m x 20 m,
Beams S = 3.0 m, D = 1.2m, b = 0.3 m,
Load p = 10 kPa, q = 10 kN/m.

CRITERION: $L/\Delta > 360$

CALCULATION:

Water content at edge of the slab $\Delta w_e = 0.5\Delta w_f = 0.5 \times 0.2 = 0.1$,
Soil weather index $I_{sw} = H \times \Delta w_e = 3 \times 0.1 = 0.3$m,
Slab stiffness $EI = EbD^3/12 = 2 \times 10^7 \times 0.3 \times 1.2^3/12 = 8.64 \times 10^5$ kNm^2,
Equivalent depth $d = D\,(b/S)^{1/3} = 1.2(0.3/3)^{1/3} = 0.56$m

CHARTS:

Uniform pressure: $L_{eqv} = 5.11$m, $F_v = 0.70$, and $F_\Delta = 2.21$
Line load: $L_{eqv} = 7.07$m, $F_v = 1$, $F_\Delta = 2.12$

DESIGN EXAMPLE

MOMENT, SHEAR, DEFLECTION CALCULATIONS

Uniform pressure

Spacing of 3 m: P = 10 x 3 = 30kN/m

$M_{max} = PL_{eq}^2/2 = 30 \times 5.11^2/2 = 392$kNm

$V_{max} = F_v \; P \, L_{eq} = 0.70 \times 30 \times 5.11 = 107.31$kN

$\Delta_{max} = PL_{eq}^4/F_\Delta EI = 30 \times 5.11^4/2.21 \times 8.64 \times 10^5 = 1.07 \times 10^{-2}$m.

Line load

Spacing of 3 m: Q = 3 x10 = 30kN

$M_{max} = Q \, L_{eqv} = 30 \times 7.07 = 212$kN.m

$V_{max} = F_v Q = 1 \times 30$ kN = 30kN

$\Delta_{max} = Q \, L_{eqv}^3/F_\Delta EI = 30 \text{ X } 7.07^3/2.12 \text{ X } 8.64 \text{ X } 10^5 = 5.80 \text{ X } 10^{-3}$m.

Combined load

$M_{max}(p) + M_{max}(q) = 392 + 212 = 604$kNm

$V_{max}(p) + V_{max}(q) = 107.3 + 30$ kN = 137.3kN

$\Delta_{max}(p) + \Delta_{max}(q) = 1.07 \times 10^{-2} + 5.80 \text{ X } 10^{-3} = 1.65 \times 10^{-2}$m.

CHECK DISTORTION $L_{eqv(ave)}/\Delta_{max} = (5.11+7.07)/2 \, / \, 1.65 \times 10^{-2} = 369 > 360$.

TAMU-SLAB

- Excel SPREAD SHEET
- AUTOMATES THE DESIGN PROCESS
- INPUT SOIL, WEATHER, SLAB, LOAD
- CONTAINS ALL DESIGN CHARTS
- CALCULATES MOMENT, SHEAR, DEFLECTION
- CHECKS DISTORTION CRITERION
- TRIAL AND ERROR APPROACH