INFLUENCE OF SAND STATE ON PERFORMANCES OF MICROPILES

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STATE OF GEOTECHNICAL PRACTICE OF SAND

SPT	Sand State	Friction Angle (1)	Friction Angle (2)	Friction Angle (3)
<4	Very Loose	<30	<29	25-27
4-10	Loose	30-35	29-30	28-30
4-30	Medium Dense	35-40	30-36	31-34
30-50	Dense	40-45	36-41	35-37
>50	Very Dense	>45	>41	38-40

(1) From Meyerhof (1956) (2): From Peck (1974) (3): From Shu (2010)

Friction Angle Decays ?

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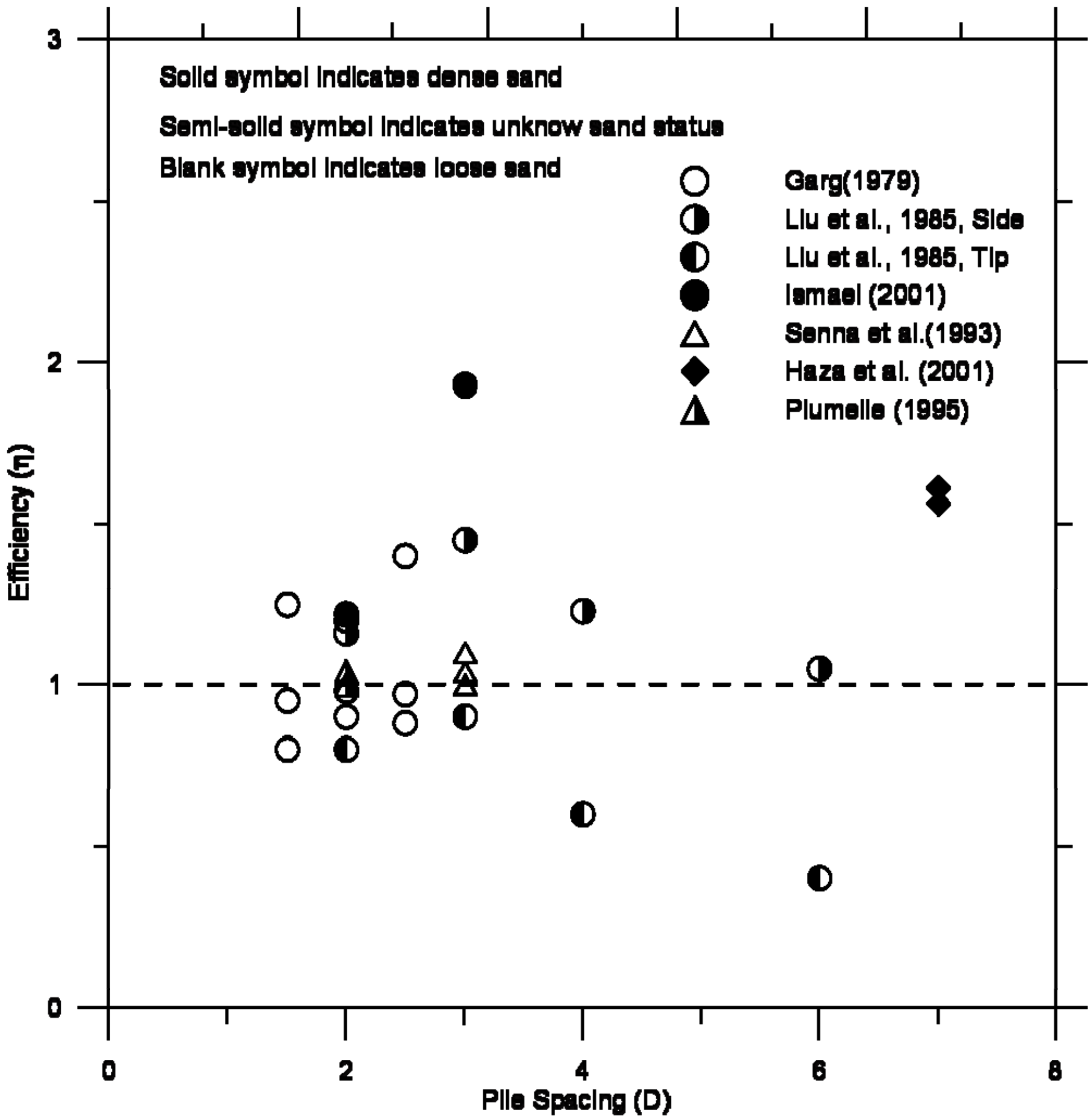
STATE OF GEOTECHNICAL PRACTICE OF SAND

- Advantages:
  - Simplicity
  - Database

- Disadvantages:
  - Ignorance of dilatancy
  - Incorrectness of sand state (Based on Critical State Soil Mechanics)

GROUP EFFECT OF PILES

Bored Piles



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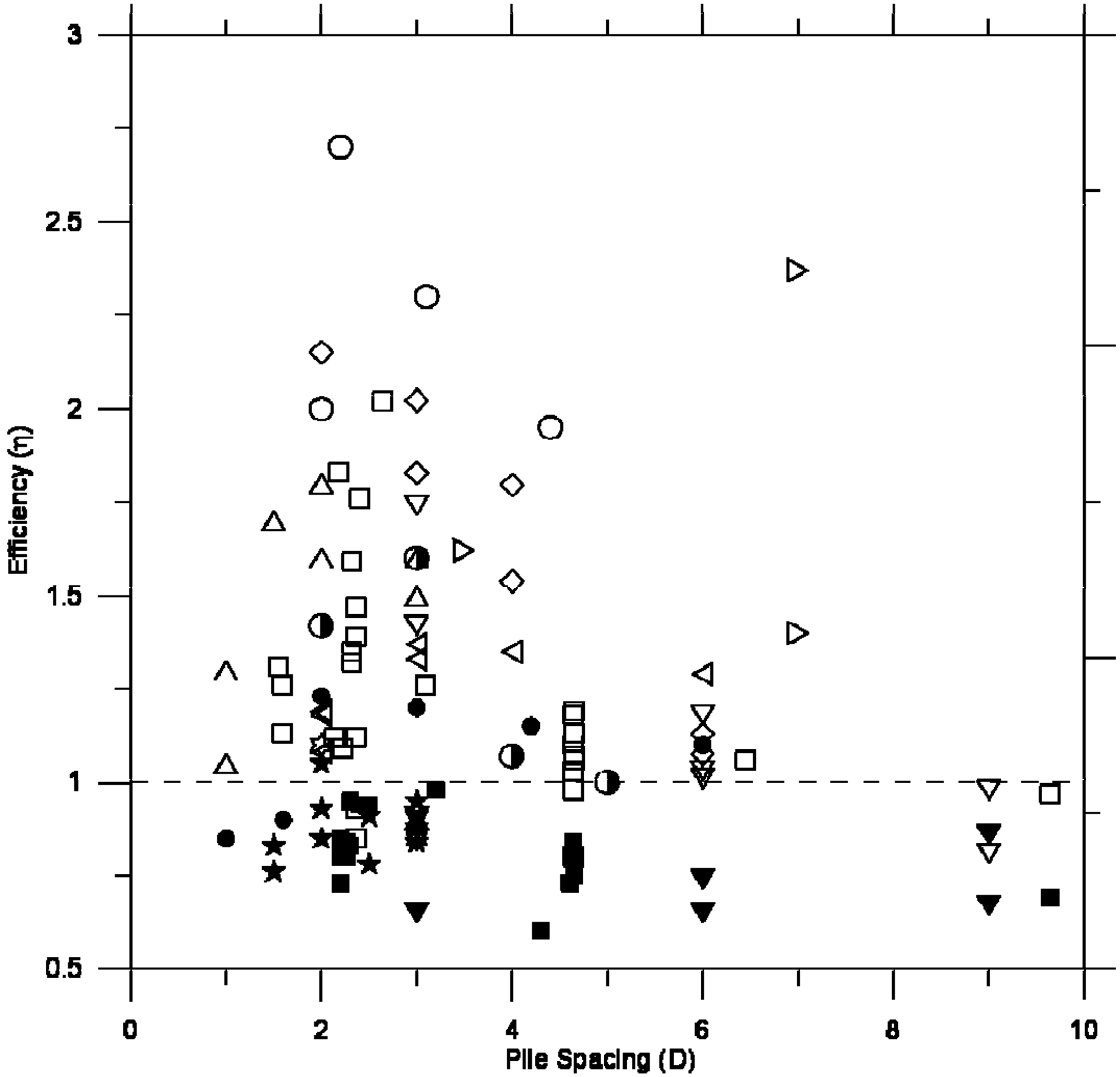
GROUP EFFECT OF PILES

Driven Piles



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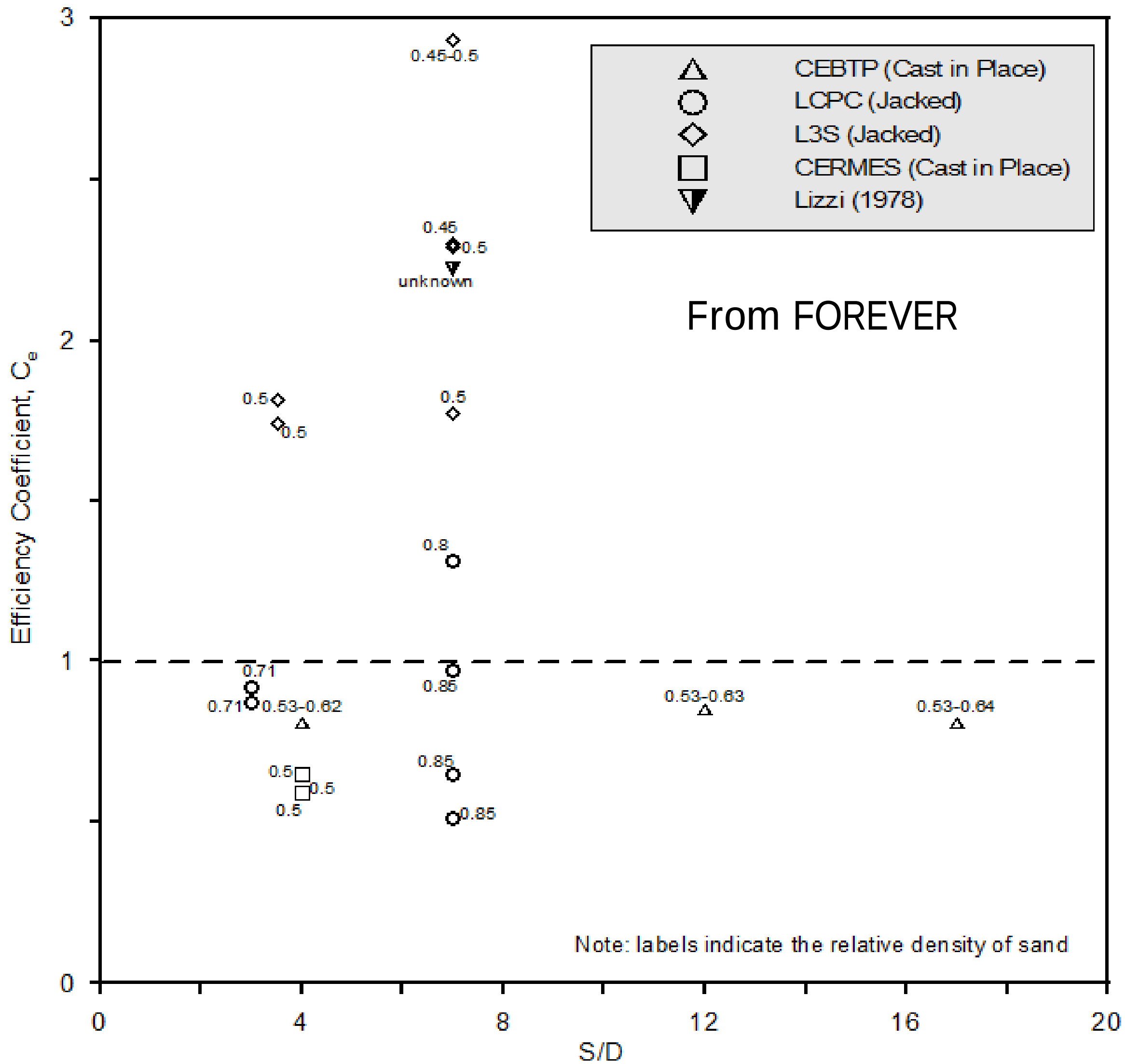
NETWORK EFFECT OF MICROPILES



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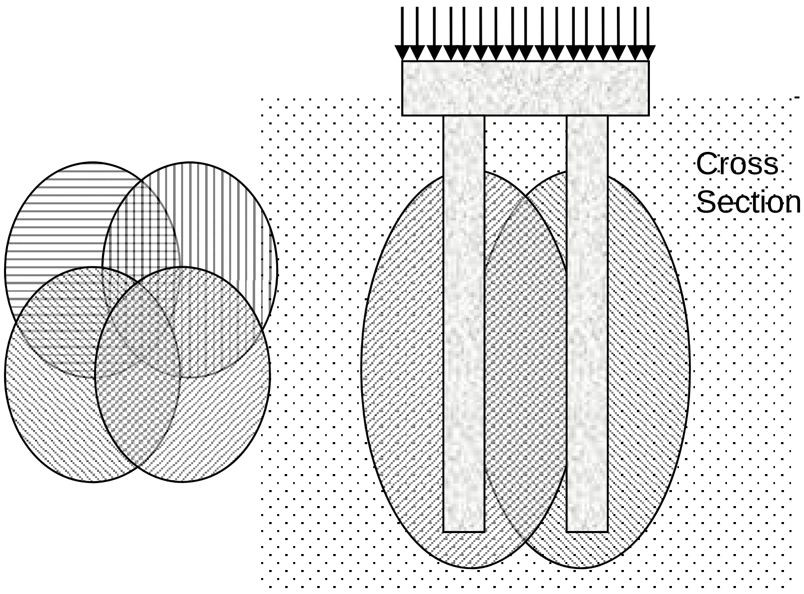
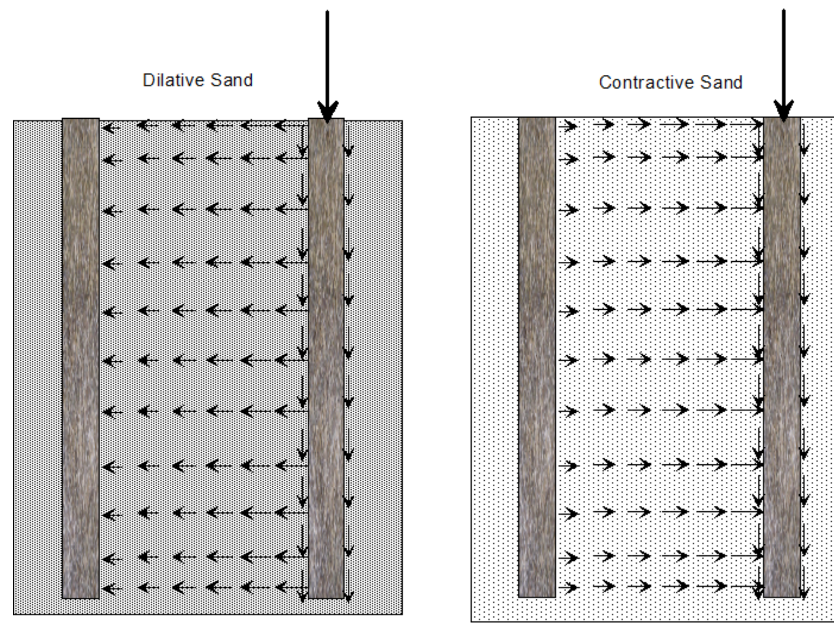
SUMMARY OF PREVIOUS RESEARCHES ANALYSES

- There are some negative group and network effects but also some positive effects.
- Group and network effects are related to sand state and pile installation methods.
- Current practices, enforced by practice codes and based on consideration of conservative design, either use negative group effect or avoid group effect by designing large pile spacing.
- Experimental study by ignorance of sand state would lead to conflicting results.

MECHANISMS OF GROUP EFFECT AND NETWORK EFFECT OF MICROPILES



Mechanism of Stress Overlapping



Mechanism of Dilatancy

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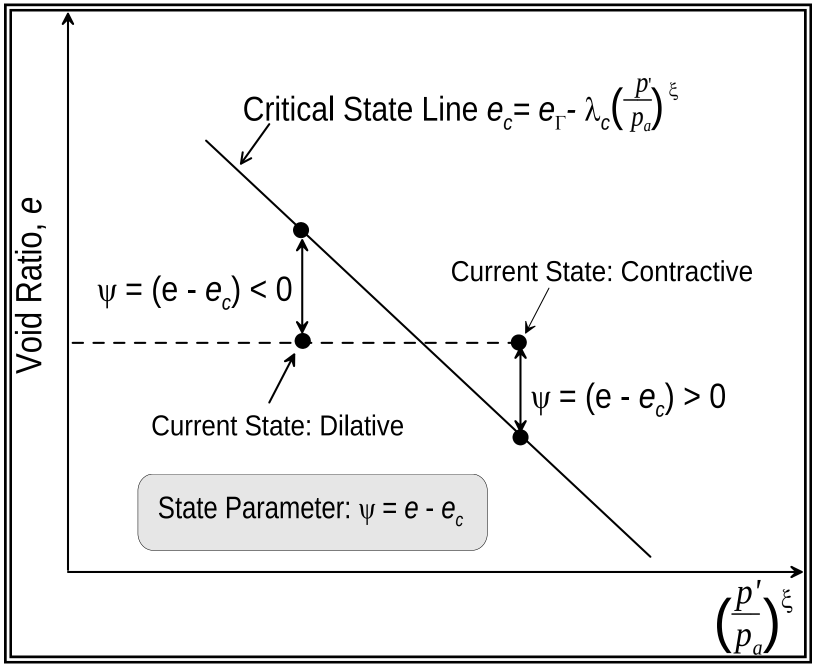
CONSTITUTIVE MODEL FOR SAND

- Bounding Surface Sand Constitutive Model by X S Li (2002), Li & Dafalias (2000)
- Dilatancy:

  1) Stress ratio   2) State-dependent

- State Parameter (ψ)



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CONSTITUTIVE MODEL FOR SAND

- Coded with C++
- Implemented into FLAC3D
- Verified through Li's Data, Laboratory Data and Field Data

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SIMULATION OF NETWORK AND GROUP MICROPILES

- Code: FLAC3D w/ the Sand Constitutive Model
- Micropile:
  - Length (L) 6m; Diameter (D) 200mm; L/D=30; Freestanding
- Sand: Uniform Toyoura Sand
- State Parameter (ψ): 0.1(Contractive) to -0.1 (Dilative)
- Assumption: No state change before and after micropile installation

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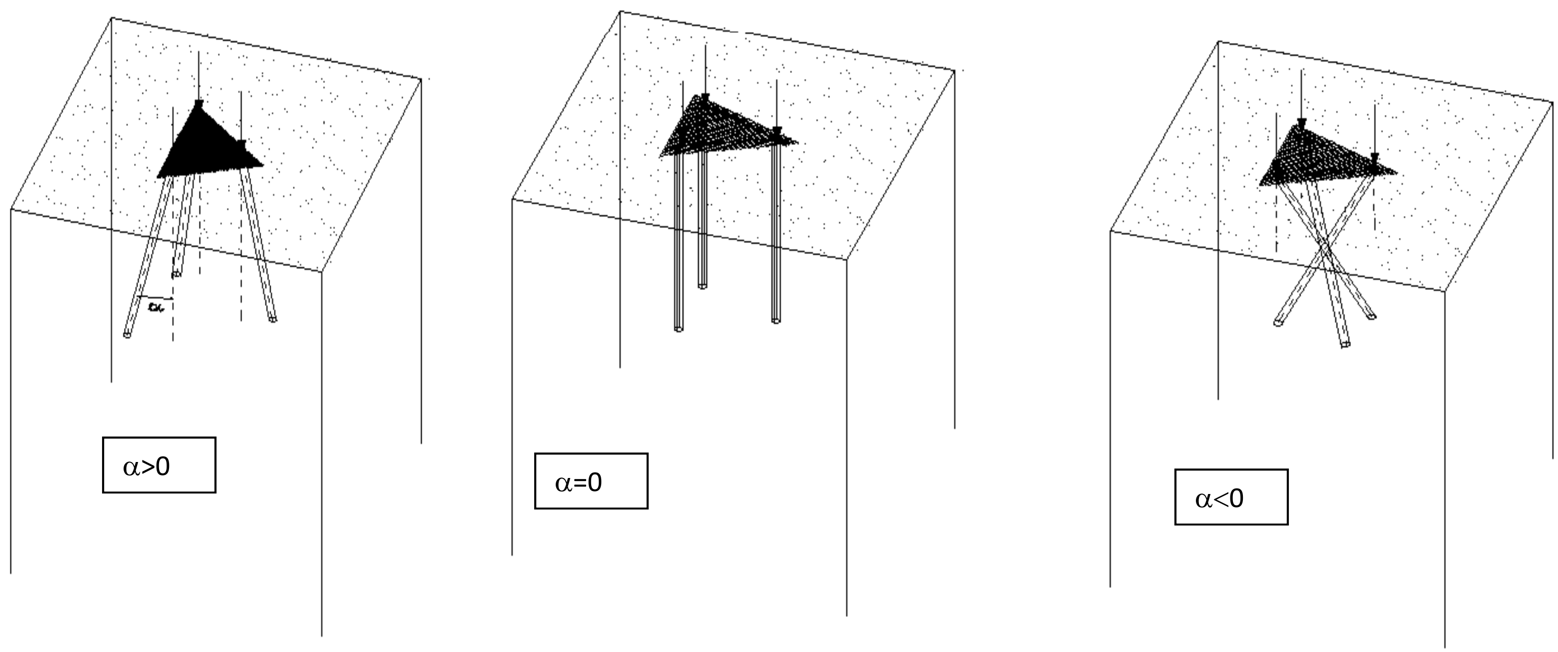
SIMULATION OF NETWORK OF MICROPILES



S=400mm, S/D=2, α=0º, 5º, 10º, 15º , -5º, -10º, -15º

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SIMULATION OF INDIVIDUAL AXIALLY LOADED MICROPILE

Model Parameters for Toyoura Sand (Li, 2002)

Elastic parameters	Critical state parameters	Parameters associated with dr-mechanisms[1]	Parameters associated with dp-mechanisms[2]	Default parameters
G_0=125 ν=0.25	M=1.25 c=0.75 e_Γ=0.934 λ_c=0.019 ξ=0.7	$\boldsymbol{d_1}$**=0.41** m=3.5 h_1=3.15 h_2=3.05 h_3=2.2 n=1.1	d_2=1 h_4=3.5	a=1 b_1=0.005 b_2=2 b_3=0.001

Model Parameters for Micropiles and the Springs

Elastic Modulus of Micropiles, E	50 GPa
Poisson's Ratio, ν	0.25
Stiffness of the Shear Coupling Spring, ks	2×10^{11} N/m/m
Friction of the Shear Coupling Spring, ϕ_s	30°
Cohesive Strength of the Shear Coupling Spring, c_s	0

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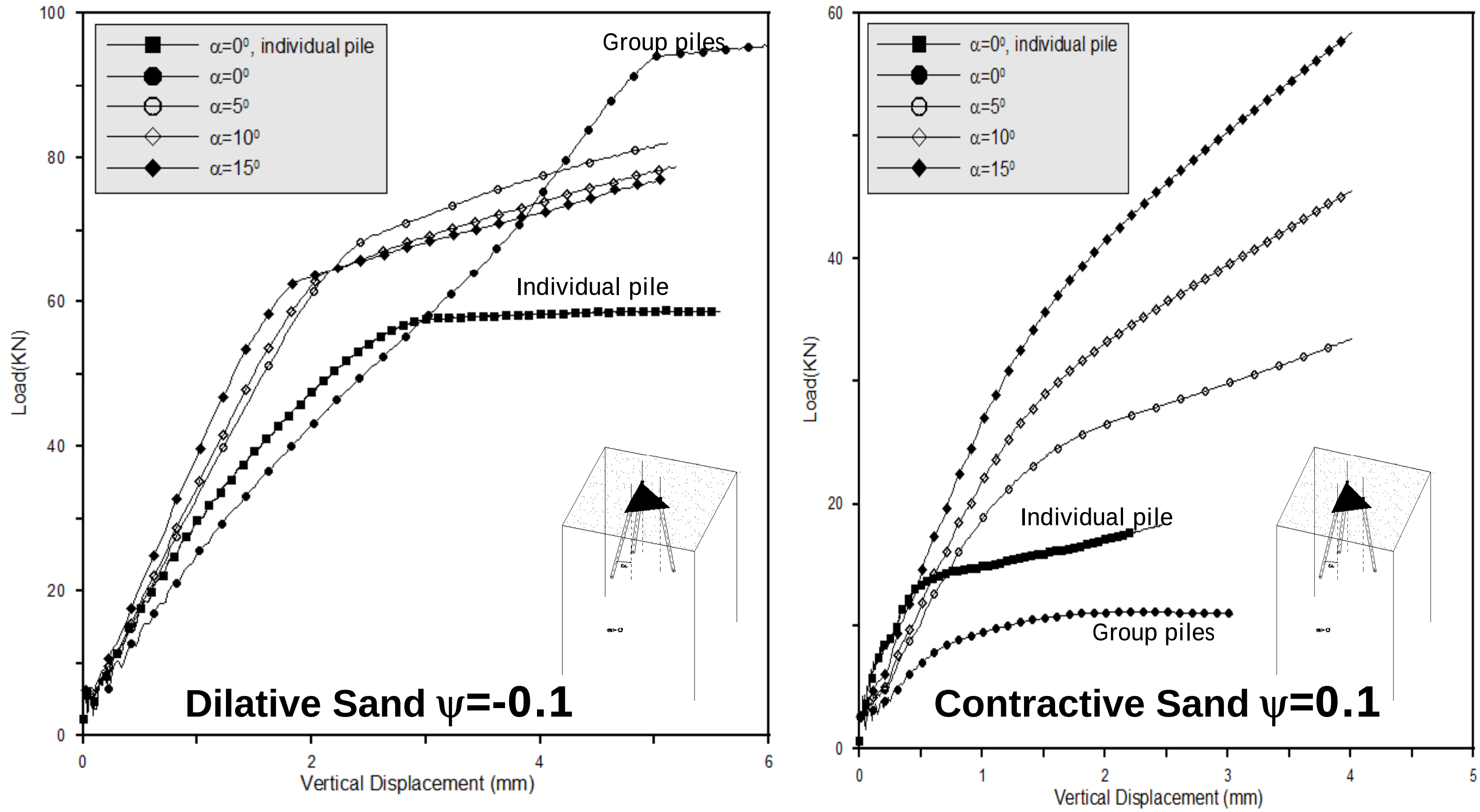
SIMULATION OF NETWORK OF MICROPILES



Side Resistance

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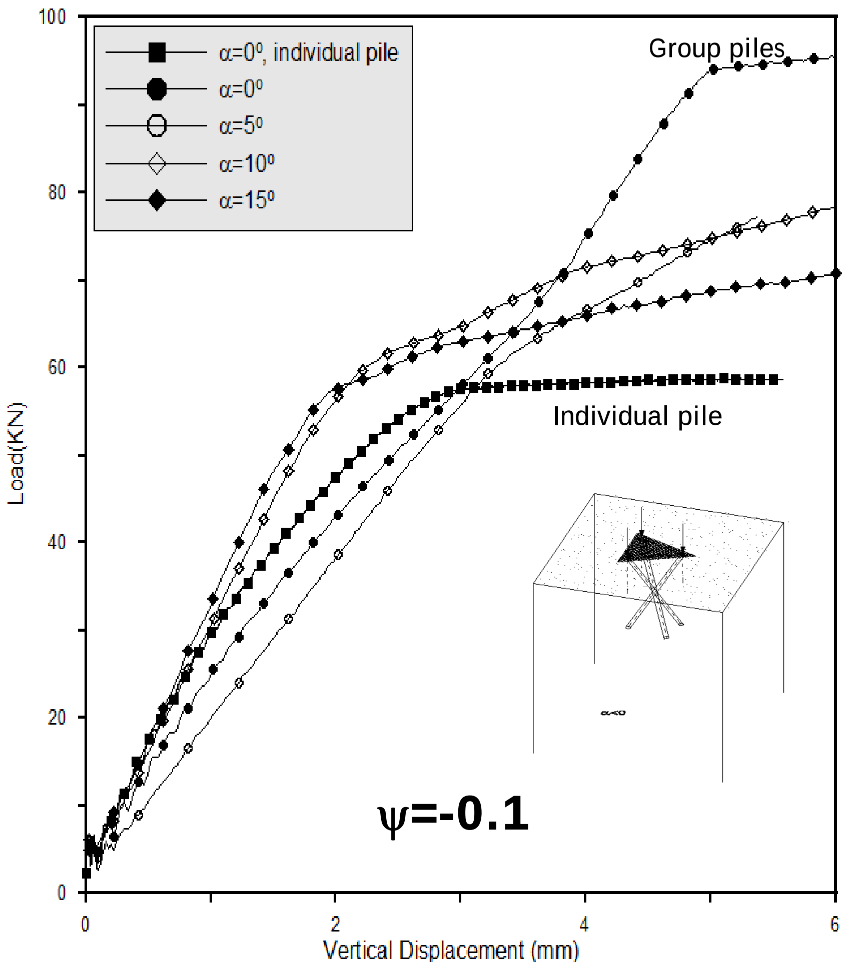
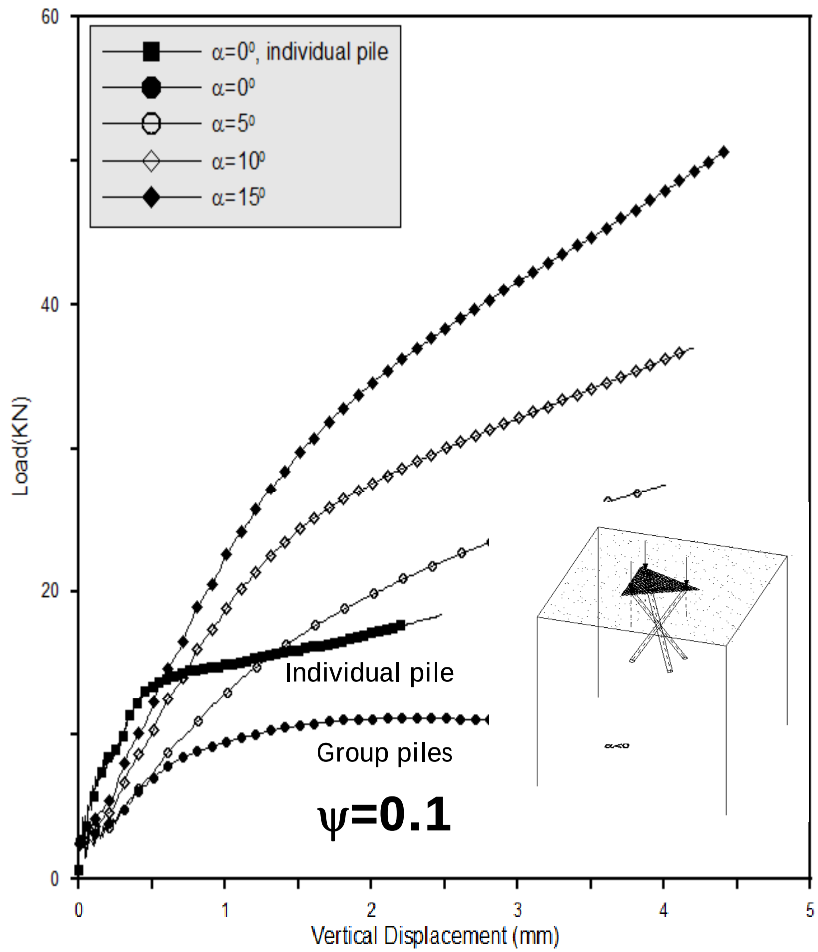
SIMULATION OF NETWORK OF MICROPILES





Side Resistance

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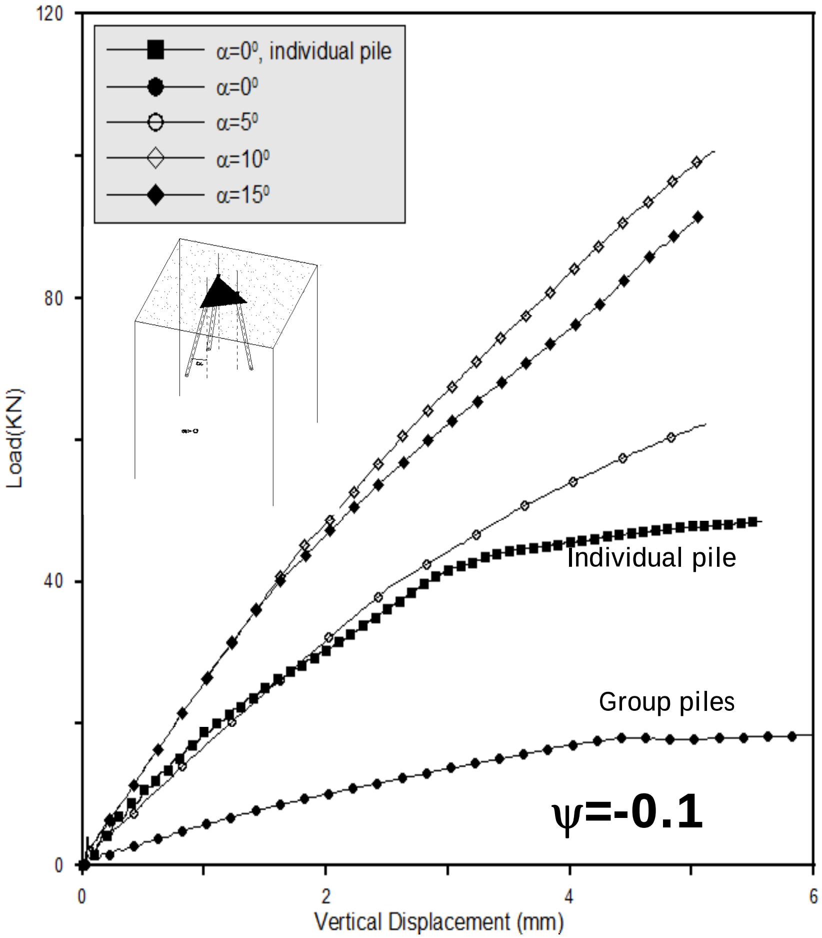
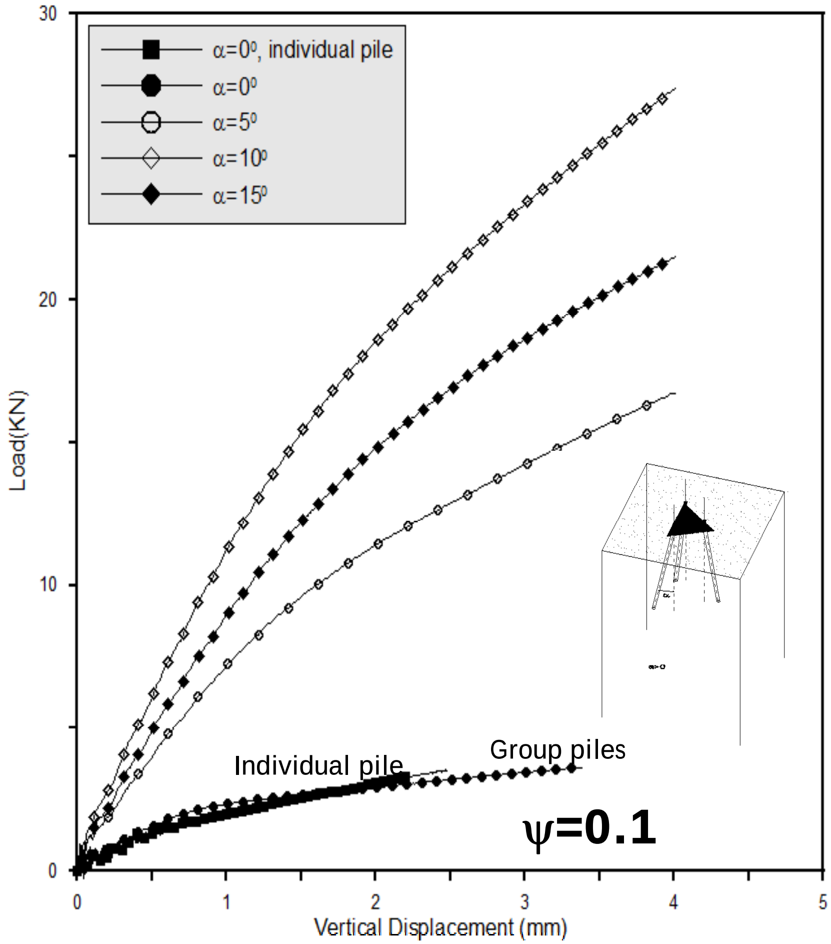
SIMULATION OF NETWORK OF MICROPILES





Tip Resistance

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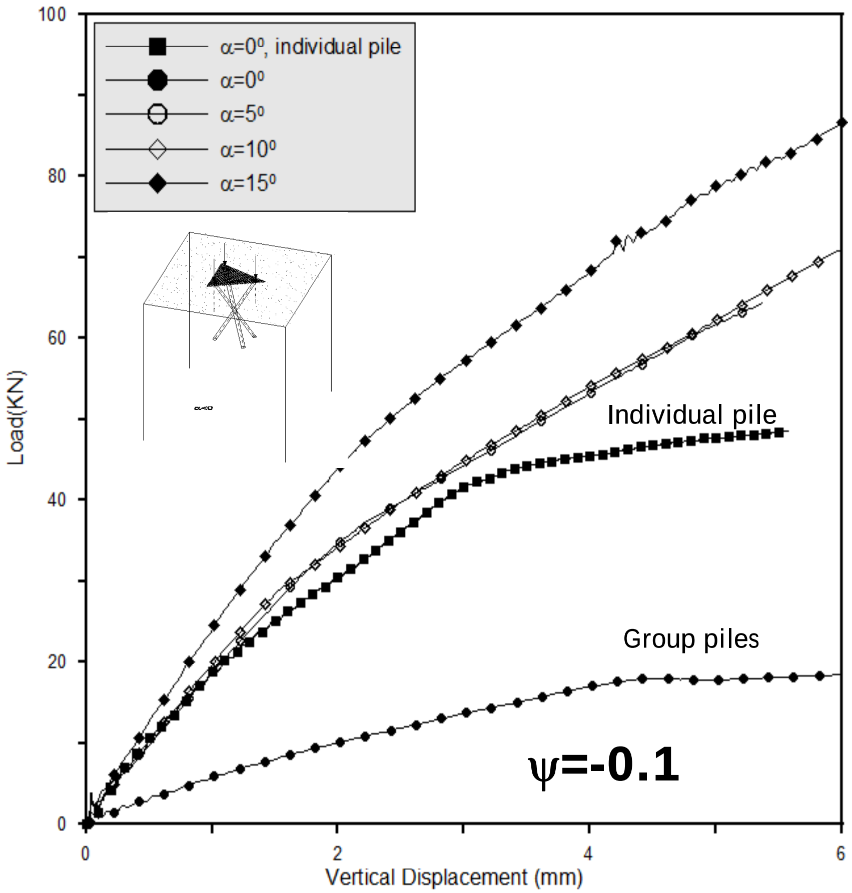
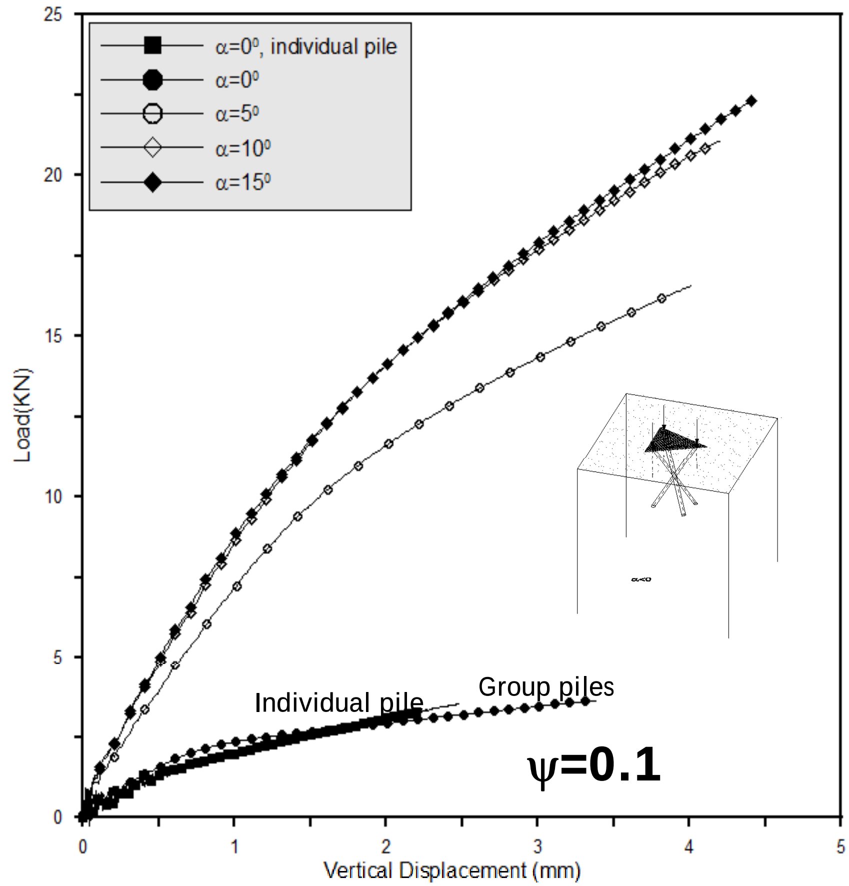
SIMULATION OF NETWORK OF MICROPILES





Tip Resistance

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CONCLUSIONS

- Group effect and network effect are contributed by both stress overlapping and dilatancy.
- For dilative sand, ultimate shaft resistance of both individual vertical pile and network piles is less than that of vertical group piles. However, the behavior is opposite for piles installed in contractive sand.
- The tip resistances of inclined piles are always larger than those of vertical piles for both contractive sand and dilative sand.
- Group effect of side resistance of micropiles installed in dilative sand is positive, but becomes negative when they are installed in contractive sand. Tip resistance group effect is negative in dilative sand but there is no obvious group effect in contractive sand.

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CONCLUSIONS

- Network and group effects: types of installation, sand state, pile spacing, ratio of length over diameter, properties of pile-sand interface. Therefore, it is difficult in practice to compare the performance of micropiles and groups from one test program to other without consideration of the sand state.
- Pile installation selection should be considered to increase sand dilatancy to get positive group and network effects.
- The FLAC3D model developed here is a useful means of quantifying the effects of sand state.

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THANK YOU

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