Foundation Design Challenges for Basements in Saturated Coastal Plains

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Lantana, August 9, 2022

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1

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Foundation Design Challenges for Basements in Saturated Coastal Plains

Content

- GEOTECHNICAL PARAMETERS AND SOIL PROFILE
- FOUNDATIONS FOR BUILDINGS WITH BASEMENTS
  - Excavations and GWT
  - Intermediate Foundations/Ground Improvement
  - GWT Handling - Dewatering
  - Uplift Pressure Control
  - Geo Construction Approach
- CONCLUSIONS

Professor George F. Sowers
1921 - 1996

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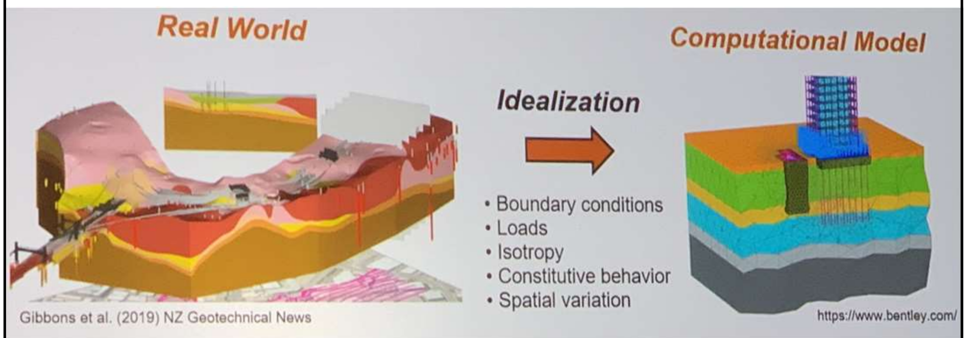
2

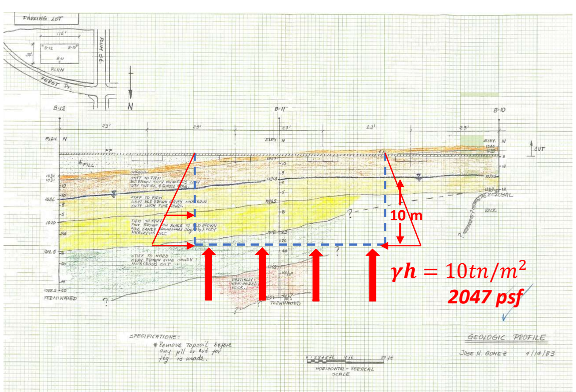
Geotechnical Parameters and Soil Profile



This is Our Challenge!

3

Geotechnical Parameters and Soil Profile
Significant Challenges



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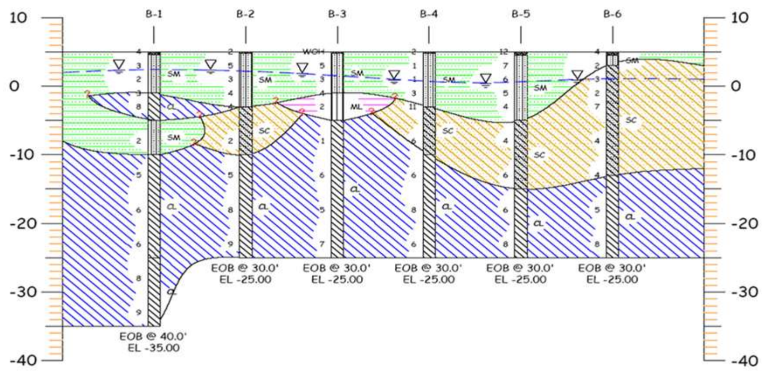
4

Soil Profile



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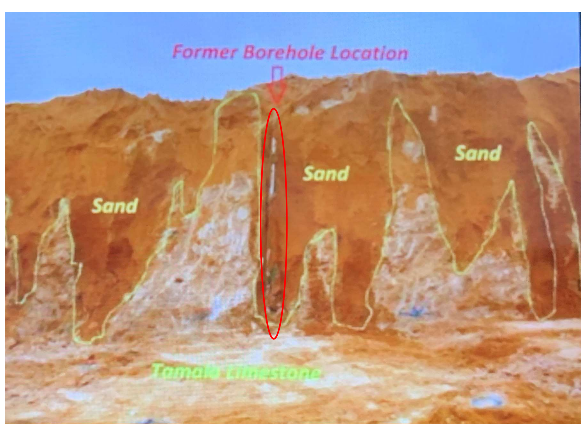
5

How Do We Plan a Geotechnical Exploration?



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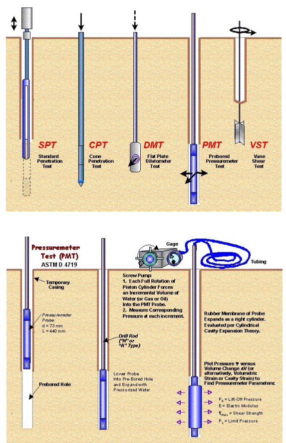
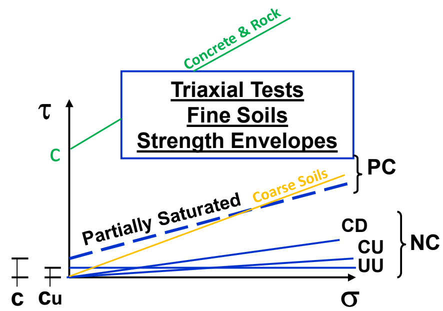
6

Geotechnical Parameters and Soil Profile



http://www.geotechdata.info/geotest/cone-pressuremeter-test.html



$\tau = c + \sigma_n \tan \varnothing$ (PC)

$\tau = \sigma_n \tan \varnothing$ (NC – CD/CU) - Coarse Soils

$\tau = c_u$ ó $q_u/2$ (NC – UU)

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7

Figure 5-2: Bearing Capacity Failure of Silo Foundation
(Vesic, 1975, from Tschebotarioff, 1951)

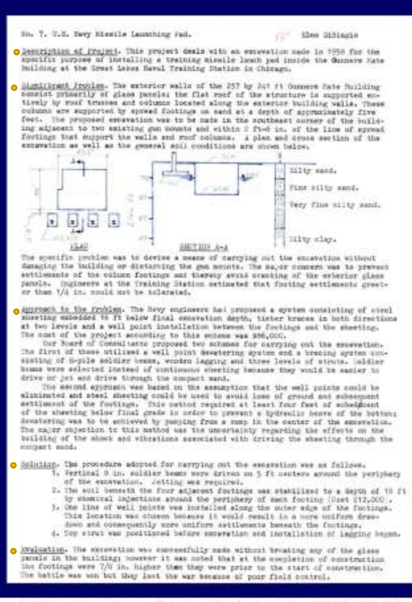
8

Professor Ralph B. Peck

Less is More …

"If you can't reduce a difficult engineering problem to just one 8-1/2 x 11 sheet of Paper, you will probably never understand it." - Peck

9


No. 7. U.S. Navy Missile Launching Pad. Elmo DiBiagio

Description of Project. This project deals with an excavation made in 1958 for the specific purpose of installing a training missile launch pad inside the Gunners Mate Building at the Great Lakes Naval Training Station in Chicago.

Significant Problem. The exterior walls of the 257 by 241 ft Gunners Mate Building consist primarily of glass panels; the flat roof of the structure is supported entirely by roof trusses and columns located along the exterior building walls. These columns are supported by spread footings on sand at a depth of approximately five feet. The proposed excavation was to be made in the southeast corner of the building adjacent to two existing gun mounts and within 2 ft-6 in. of the line of spread footings that support the walls and roof columns. A plan and cross section of the excavation as well as the general soil conditions are shown below.

The specific problem was to devise a means of carrying out the excavation without damaging the building or disturbing the gun mounts. The major concern was to prevent settlements of the column footings and thereby avoid cracking of the exterior glass panels. Engineers at the Training Station estimated that footing settlements greater than 1/4 in. could not be tolerated.

Approach to the Problem. The Navy engineers had proposed a system consisting of steel sheeting embedded 16 ft below final excavation depth, timber braces in both directions at two levels and a well point installation between the footings and the sheeting. The cost of the project according to this scheme was $86,000.

Our Board of Consultants proposed two schemes for carrying out the excavation. The first of these utilized a well point dewatering system and a bracing system consisting of H-pile soldier beams, wooden lagging and three levels of struts. Soldier beams were selected instead of continuous sheeting because they would be easier to drive or jet and drive through the compact sand.

The second approach was based on the assumption that the well points could be eliminated and steel sheeting could be used to avoid loss of ground and subsequent settlement of the footings. This method required at least four feet of embedment of the sheeting below final grade in order to prevent a hydraulic heave of the bottom; dewatering was to be achieved by pumping from a sump in the center of the excavation. The major objection to this method was the uncertainty regarding the effects on the building of the shock and vibrations associated with driving the sheeting through the compact sand.

Solution. The procedure adopted for carrying out the excavation was as follows.
1. Vertical 8 in. soldier beams were driven on 5 ft centers around the periphery of the excavation. Jetting was required.
2. The soil beneath the four adjacent footings was stabilized to a depth of 10 ft by chemical injections around the periphery of each footing (Cost $12,000).
3. One line of well points was installed along the outer edge of the footings. This location was chosen because it would result in a more uniform drawdown and consequently more uniform settlements beneath the footings.
4. Top strut was positioned before excavation and installation of lagging began.

Evaluation. The excavation was successfully made without breaking any of the glass panels in the building; however it was noted that at the completion of construction the footings were 7/8 in. higher than they were prior to the start of construction. The battle was won but they lost the war because of poor field control.

CE 484 GEOTECHNICAL CASE HISTORIES

A typical 1-page summary sheet prepared by students enrolled in Ralph Peck's Geotechnical Case Histories course (in this case, the student was NGI's Elmo DiBiagio).

Students would be presented information as though they were consultants engaged in providing services on a project. The briefing would include the type of information normally known at the beginning of a job. From that point on, the students were required to ask questions, in order to elicit additional information needed to make engineering assessments.

If you cannot reduce a difficult engineering problem to just 8 1/2 x 11-inch sheet of paper, you will probably never understand it. Ralph B. Peck

If you cannot reduce a difficult engineering problem to just 8 1/2 x 11-inch sheet of paper, you will probably never understand it. Ralph B. Peck

10

Building Foundations- Excavations and GWT

Ideal Conditions? ??

https://www.skypumpsest.com/page_english.php?id=2

https://www.groundwatereng.com/blog/2016/03/dewatering-for-basement-construction

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11

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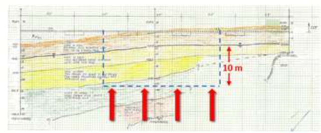
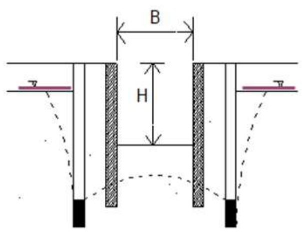
12

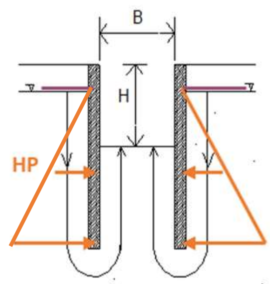
GWT Handling – Dewatering in Granular Soils

Problem: -Soils with medium to high permeability.
-Seepage needs to be controlled to reduce hydrostatic pressure (HP) and uplift force (UF) at excavation bottom.





Well Points / Deep Wells



Deep Wall
(Reduce Hyd. Gradient)

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13

Dewatering System Design

Design Outline

- Soil Profile Definition (o.k)
- Soil Parameters Evaluation and Soil Classification (o.k)
- Aquifer(s) Characterization (o.k)
- Coefficient of Permeability (K, cm/sec) Evaluation
  - Pumping Test
  - Amoozemeter Test
  - Correlations (Grain Size – Sands)
- Dewatering System Alternatives and Selection
  - Conventional Well Points
  - Deep Wells
  - Eductor Wells

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14

Confined/Unconfined Aquifers

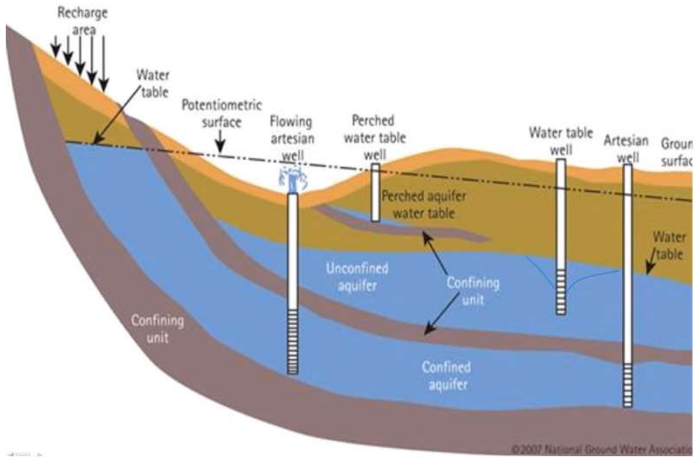


Figure 2. Confined and unconfined aquifer characteristics (National Groundwater Association, 2019).

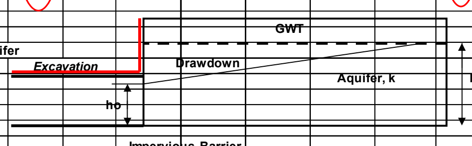
15

Estimation of Total System Discharge Capacity

Drawdown Flow Computation Clay at 8 Mt BGS (26.2 FEET BGS) — Project No. *JNG 09/10/09*

H(ft)	ho(ft)	Wexc	Lexc	ro	R(ft)	k cm/sec	k ft/min	A=(H-ho)	B=(H+ho)	C=(R+ro)	D=(R-ro)	Q ft3/min	Q gpm	Observations
18.5	5	125	200	89	300	0.00092	0.0018	13.5	23.5	389	211	1.67	12	HA-1
18.5	5	125	200	89	300	0.00553	0.0109	13.5	23.5	389	211	10.01	75	HA-2
18.5	5	125	200	89	300	0.00018	0.0004	13.5	23.5	389	211	0.33	2	HA-3
18.5	5	125	200	89	300	0.00435	0.0086	13.5	23.5	389	211	7.87	59	Average In Situ Perms
18.5	5	125	200	89	300	0.0075	0.0148	13.5	23.5	389	211	13.57	102	Pumping Test
18.5	5	125	200	89	300	0.00486	0.0096	13.5	23.5	389	211	8.80	**66**	**Average All**
Well Formula								πk	H^2-ho^2	R/ro	log(R/ro)	**Well Formula, Exc. as Large Circular Well**		
18.5	5	125	200	89	300	0.00435	0.0086	0.026895	317.25	3.36	0.53	7.04	53	Average In Situ Perms
18.5	5	125	200	89	300	0.0075	0.0148	0.04637	317.25	3.36	0.53	12.14	91	Pumping Test
18.5	5	125	200	89	300	0.00486	0.0096	0.030048	317.25	3.36	0.53	7.87	**59**	**Average All**

Q=1.57k(A*B*C)/D "Darcy's law formula"
k=cm/sec x 1.968 to get ft/min
Units: ft3/min, x 7.5 to get gpm
H= Aquifer Thickness (ft)
ho= Drawdown (ft)-From the bottom of the aquifer
Wexc= Width of Excavation (ft)
Lexc= Length of Excavation (ft)
ro= Average radious of exc. bottom
(SGRT W*L/π) - ft
k= Coeficient of Permeability (cm/sec)



Note: This analytical method allows to estimate the approximately flow (Q) required to dewatering a site with geometry W x L, and drawdown ho.

Ref.: Ground Control and Improvement.
Petros P. Xanthakos, et al.
1994 (Wiley)

NOTES:
1. Total System Capacity: 65 gpm
2. Single WP or Eductor Capacity: 1.0 gpm
3. Total System Length: 650 lft (200'x125')
4. Minimum WPs or Eductors Required: 65 units @ 10' centers

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16

Poor Dewatering Outcome

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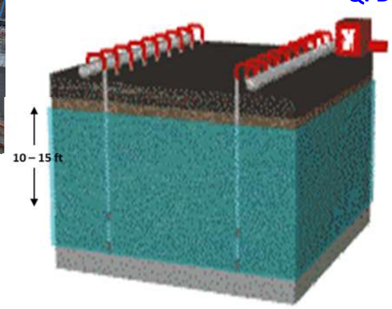
17

Well Point and Sheet Pile Wall Systems



18

Well Point and Sheet Pile Wall Systems

NASA Gantry Impact Basin - 2014

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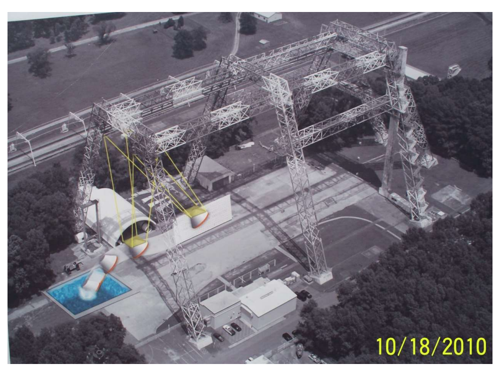
19

NASA Gantry Impact Basin - 2014

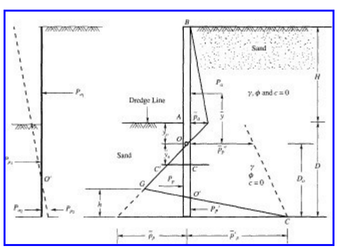


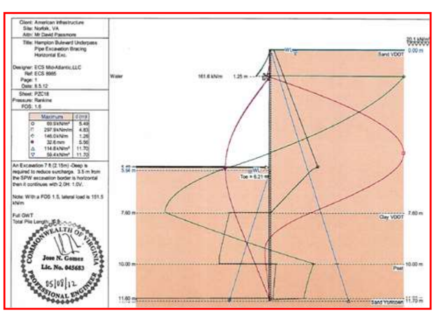
https://www.nasa.gov/centers/langley/exploration/hib.html

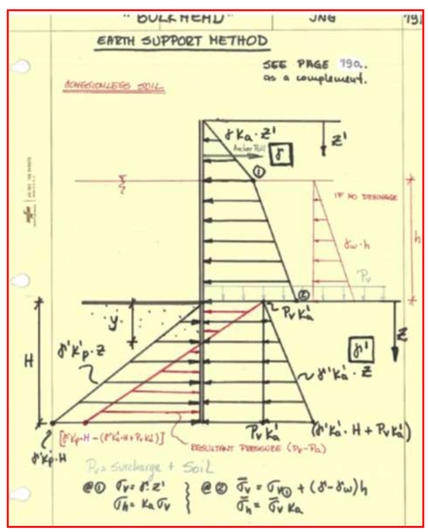
20

21

SPW-Design Considerations







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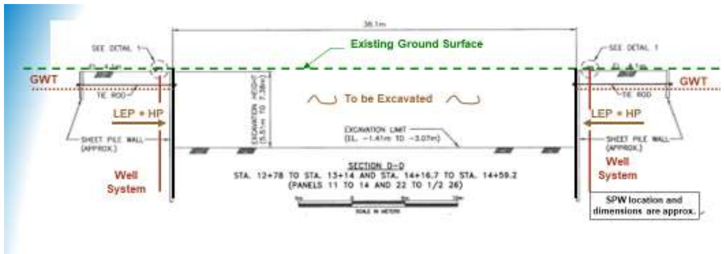
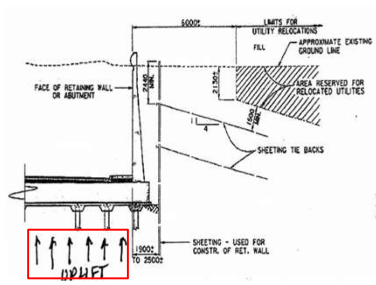
22





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23

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24

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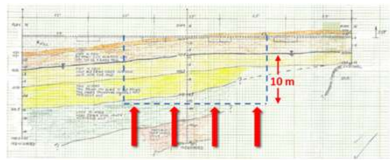
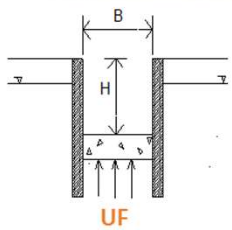
25

When Things Go South

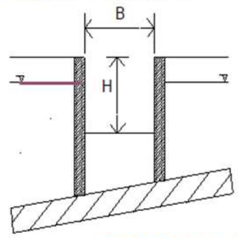
26

GWT Handling – Controlling Uplift Forces in Granular Soils





Bottom/Basement Slab Resists Uplift Force



Check for Aquifer

Walls Embedded in Impervious Layer

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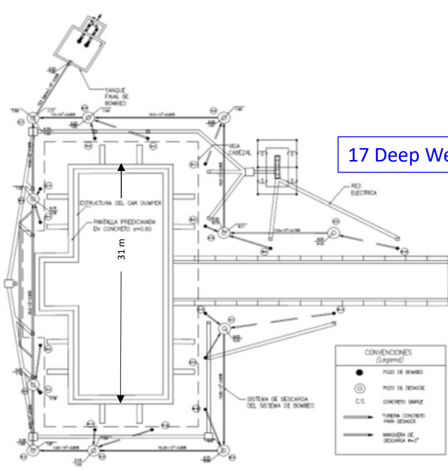
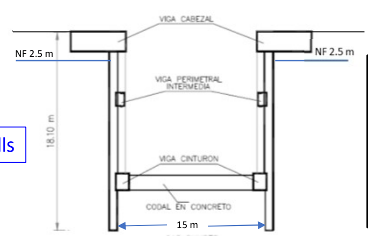
27

Case History of 15-Meter Deep Vault Excavation

"Excavación cajón como estructura para el manejo de carbón: diseño, construcción y comportamiento". XI Jornadas Geotécnicas de la Ingeniería Colombiana (SCI), 2001.

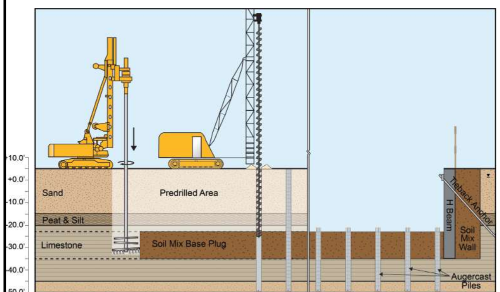


17 Deep Wells



6.5 – 10.0 lt/sec
12,000 m3/day; 85K People

28



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Ground Improvement
Soil Mixing Plug Construction

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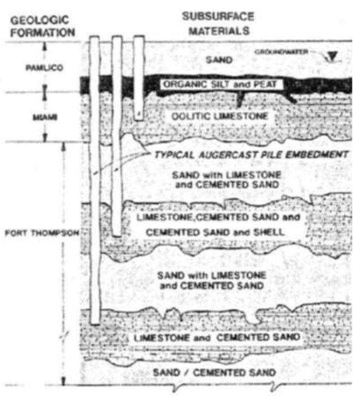
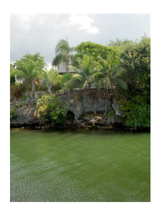
29

Generalized Stratigraphy of South Florida



AUGERCAST PILES - SOUTH FLORIDA EXPERIENCE
By Rudolph P. Frizzi, P.E. and Matthew E. Meyer, P.E. Members, ASCE. (2000)



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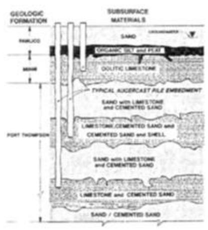
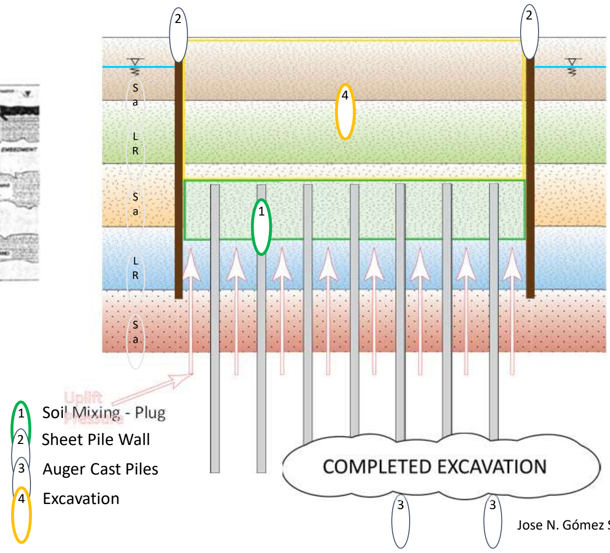
30

Basement Excavation Sequence





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31

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32

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Conclusions

- **When High GWT and Granular Soils with high permeability, hydrostatic uplift pressures are a geotechnical and structural problem.**
- **GWT drawdown systems could be impractical in situations with presence of adjacent structures.**
- **Soil mixing plugs together with an appropriate perimetric pre-excavated wall creates a "bathtub" structure supported with piles to control uplift pressure, as an option in coastal plain geologies.**

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Thank You

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33