Water: The Enemy of Construction

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August 10, 2015
AASHTO SOC Meeting, Little Rock Arkansas
Overview

Compaction

Expansive Soils

Drilled Shaft Foundations
Compaction
Compaction

- Dry Unit Weight, $\gamma_d$
- Molding Moisture Content, $w$
- Zero Air Voids $f(G_s)$

Graph showing the relationship between dry unit weight and molding moisture content, with points marked at different values.
Dry Unit Weight, $\gamma_d$

Molding Moisture Content, $w$

$\gamma_d = 120$pcf

$w = 19.6\%$

$w_{\text{opt}} - 2$ to $5\%$

$w_{\text{opt}} + 2$ to $5\%$

Zone of Acceptance

95% $\gamma_{d \text{ max}}$

Zero Air Voids $f(G_s)$
Compaction

Zero Air Voids
$f(G_s)$

Dry Unit Weight, $\gamma_d$
Molding Moisture Content, $w$
Zero Air Voids

1 2 3 4 5

Molding Moisture Content, $w$
Compaction

Dry Unit Weight, $\gamma_d$

Molding Moisture Content, $w$

105±5°C
16-24 Hours
Compaction

- Acceptable Zone Based on Shear Strength
- Modified Energy (ASTM D1557)
- Zero Air Voids $f(G_s)$
- Overall Acceptable Zone
  - Acceptable Zone Based on Hydraulic Conductivity
- Dry Unit Weight, $\gamma_d$
- Molding Moisture Content, $w$
- $k >$ Regulatory Limit
- $k \leq$ Regulatory Limit
- 75 or 50% of Standard Energy (ASTM D698) by Reducing Blow Count
- Acceptable Zone Based on Shear Strength
- Standard Energy (ASTM D698)
Expansive Soils
Matric Suction, $\psi$, [kPa]

Volumetric Water Content, $\theta$, [m$m^3$/m$m^3$]

- In-situ Sensing Measured Data
- Remote Sensing Measured Data
- Fitted SWCC using van Genuchten (1980)
- Laboratory Obtained SWCC (CS-229 and TDR)
- Remotely Sensed SWCC (RADAR and LAST DAB)
- Conceptual Data
Thunder Scientific (2014)
SWCC Curve
Parameters ($\alpha, m, n$)

\[ \psi_m \]

\[ \theta_v \]
The diagram shows the CS-610 TDR Probe Waveform with the following key points:

- Reflectance Ratio, $R = -2.660x + 54.084$
- Reflectance Ratio, $R = -0.156x + 2.973$
- $L_a/L = 4.05$
- $K_a = (L_a/L)^{0.5} = 16.4$
- $L_a = 1.21m$
- $R = -0.156x + 2.973$

Legend:

- Probe Head
- Unshielded Leads
- Reflection off Probe Tip

Campbell Scientific (2014)
Reservoir

Large cap for easy closure with leak-proof seal

Hermatically Sealed Gauge

Air-Free Gauge Chamber

IRROMETER Body
Constructed of tough Butyrate plastic

Ceramic to Plastic Connections are permanently leakproof

Ceramic tip - porous

\[ \psi_m \pm 1 \text{ kPa} \]

0-100 kPa

10-2500 kPa

\[ \theta_v \]

\[ \pm 1 \text{ kPa} \]
\[ I = I_1 I_2^* = A_1 e^{i \phi_1} \cdot A_2 e^{-i \phi_2} = A_1 A_2 \cdot e^{i(\phi_1 - \phi_2)} = A \cdot e^{i \phi} \]
\begin{align*}
\sigma^0(dB) &= 10 \times \log(\sigma^0)(m^2 m^{-2}) \\
m_s(t) &= \frac{\sigma^0(40,t) - \sigma_{dry}^0(40,t)}{\sigma_{wet}^0(40,t) - \sigma_{dry}^0(40,t)} \\
m_v &= m_{v,0} + 0.042(\Delta \sigma^0|dB| - \Delta \sigma_{0}^0|dB|) \\
m_v &= \frac{\sigma^0 - i}{8.56 - 1.56i} \\
i &= \frac{\sigma_{0}^0 - 8.56m_{v,0}}{8.56 - 1.56i}
\end{align*}
\[
\sigma_{qq}^0 = 8k^4 h^2 \cos^4(\theta) W(2k \sin(\theta)) |\alpha_{qq}(\theta)|^2 \\
W(2k \sin(\theta)) = \sum_{n=1}^{\infty} \left( \frac{1}{n} \right)^2 \left[ 1 + \left( \frac{kl}{n} \right)^2 \right]^{-1.5} \\
\alpha_{HH}^0 = \frac{(1 - \varepsilon')}{\left( \cos(\theta) + \sqrt{\varepsilon'-\sin^2(\theta)} \right)^2} \\
\alpha_{VV}^0 = \frac{(\varepsilon'-1)\sin^2(\theta) - \varepsilon'(1+\sin^2(\theta))}{\left( \varepsilon' \cos(\theta) + \sqrt{\varepsilon'-\sin^2(\theta)} \right)^2}
\]
1857 MW Coal Fired Facility

Full Scale Wetlands

100 x 100 Test Section

Treatment Soil Stockpile

V Transmit Antenna

V Receive Antenna

Field Computer

GPRI-II

ψ

θ

v

ψ_m

θ_v
Upward Movement (Top of BLC)
Downward Movement (Bottom of BLC)

South 1.2m DSF
Center 1.8m DSF
North 1.2m DSF
Axial Load, $R$, [MN]

<table>
<thead>
<tr>
<th>Location</th>
<th>FB-Deep MODOT Mean (N)</th>
<th>FB-Deep MODOT 30% (N)</th>
<th>FB-Deep MODOT Silt (N)</th>
<th>SHAFT MODOT Mean (N)</th>
<th>SHAFT MODOT 30% (N)</th>
<th>SHAFT MODOT Silt (N)</th>
<th>SHAFT MODOT Combined (N)</th>
<th>SHAFT UofA Mean (N)</th>
<th>SHAFT UofA 30% (N)</th>
<th>SHAFT UofA Silt (N)</th>
<th>SHAFT UofA Combined (N)</th>
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<tbody>
<tr>
<td>South 1.2m DSF</td>
<td>N=blow count</td>
<td>$\phi$=friction angle</td>
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<td>Center 1.8m DSF</td>
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<tr>
<td>North 1.2m DSF</td>
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</table>

Movement, $\delta$, [cm]
Collapsed Excavation

Ground Surface

CLAY

SILT

SAND

Initial Temporary Casing 7.0m

Idealized Collapsed Volume = 19.93m³

Estimated Collapsed Volume = 3.82m³

Final Temporary Casing 14.0m

Approximate Soil Level After Excavation Collapse

Rebar Cage Placed into the Excavation 15.2m Below Ground Surface

Modified Predictive Model

SG 10 2.4m

SG 9 4.9m

SG 8 7.3m

SG 7 9.8m

SG 6 12.2m

SG 5 14.0m

SG 4 16.5m

BLC 18.9m

SG 3 19.4m

SG 2 20.4m

SG 1 22.9m

CLAY

SILT

MODELED AS SAND (METHOD 1)

OR

SILT (METHOD 2)

6.1m

9.1m

MODELED AS ADDITIONAL SILT (METHOD 3)

12.1m
Conclusion

Compaction

Expansive Soils

Drilled Shaft Foundations
Perform Additional Laboratory Tests
Develop Zone of Acceptance (based on $k$, $c_u$)
Perform Field Verification
Rework/Reject Locations Outside of Zone
Laboratory Techniques to Measure Expansive Soils
Remote Sensing Instruments to Measure Expansive Soils
Need for Unsaturated Soil Parameters
Need for Additional Full-Scale Load Tests
Slurry Density/Viscosity is Important
Plan for Contingences