A Study on the Variation of PMT Parameters Ratio after Dynamic Compaction of Saturated Sands

ISP’7: 60 Years of Pressuremeter
01/02 May 2015, Hammamet, Tunisia

Babak Hamidi
GFWA (previously Menard)

Serge Varaksin
Apageo (previously Menard)
The terms of reference TC 211 – Ground Improvement period 2013-2017

- Complete and reorganize the TC 211 website (www.tc211.be)
- Continue the issue of a quarterly newsletter
- Participate by dedicated workshops in the international conferences inviting TC members to contribute to the knowledge and develop the themes addressed (XVI ECSMGE Edinburgh 2015,…)
- Introduce as principal theme: “Design, Quality Control and Quality Assurance for ground improvement works”
Rheological Factor ($\alpha$)

- Settlements are a function of the rheological factor

\[ s = (q - \sigma_{vo}) \left[ \frac{2B_0}{9E_d} \left( \frac{B_d}{B_o} \right)^{\alpha} + \frac{\alpha \lambda_c}{9E_c} B \right] \]

- The Rheological factor is a related to $\frac{E_M}{P_{LM}}$

<table>
<thead>
<tr>
<th>Soil</th>
<th>Peat</th>
<th>Clay</th>
<th>Alluvium (silt)</th>
<th>Sand</th>
<th>Sand &amp; gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\frac{E_M}{P_{LM}}$</td>
<td>$\alpha$</td>
<td>$\frac{E_M}{P_{LM}}$</td>
<td>$\alpha$</td>
<td>$\frac{E_M}{P_{LM}}$</td>
</tr>
<tr>
<td>Over consolidated</td>
<td>&gt;16</td>
<td>1</td>
<td>&gt;14 $^{2/3}$</td>
<td>&gt;12</td>
<td>$^{1/2}$</td>
</tr>
<tr>
<td>Normally consolidated</td>
<td>1</td>
<td>9-16 $^{2/3}$</td>
<td>8-14 $^{1/2}$</td>
<td>7-12</td>
<td>$^{1/3}$</td>
</tr>
<tr>
<td>Weathered or disturbed</td>
<td>7-9</td>
<td>$^{1/2}$</td>
<td>$^{1/2}$</td>
<td>$^{1/3}$</td>
<td>$^{1/4}$</td>
</tr>
</tbody>
</table>
Dynamic Compaction
Variation of $\frac{E_M}{P_{LM}}$ before and after Dynamic Compaction

- Previously not researched

- **This study: saturated sands, hydraulically placed or dumped**
  - Abu Dhabi New Corniche Road, Abu Dhabi UAE: hydraulic reclamation
  - Marjan Island Main Road Corridor, Ras Al Khaima UAE: dumped fill
  - Al Nakhilat Ship Repair Yard, Ras Laffan Qatar: hydraulic reclamation
  - Reem Island Causeway, Abu Dhabi UAE: dumped fill
  - WOQOD Fuel Oil Bunkering Facilities, Ras Laffan Qatar: hydraulic reclamation
  - Palm Jumeira, Dubai UAE: hydraulic reclamation
Abu Dhabi New Corniche

- Hydraulic fill by pipeline pumping deposition
- 6 km long
- Up to 300m wide
- 900,000 m²
- Up to 12 m thick
- \( N_{SPT} \): 1 to 10
- High GWL

- Reclamation Specification: less than 10% fines
  - In Reality: Silty layer at bottom of hydraulic fill, generally 0.5 m thick
- Relative density > 80% (not the best)
Setup of Pressuremeter Test using Menard Pressuremeter type geospad 2 with geobox recording and specially designed APAGEO type Apafor 450 drilling rig. Drilling method utilized: either slotted casings directly driven, either pre-drilling by fish tail and bentonite injection.
Marjan Island Main Road Corridor

- Project area = 2,700,000 m$^2$
- Treatment area = 198,000 m$^2$
- Reclamation by land sand tipping
- Reclamation level: +4 m ACD
- Groundwater level: +2 m ACD
- Approximate fill thickness: 7m

**Acceptance Criteria**

- Total Settlement: 25 mm under a uniform load of 20 kPa
- Differential settlement: 1:500 between any two points on the road with a distance of 10 m under a uniform load of 20 kPa
Marjan Island Main Road Corridor

S. Varaksin & B. Hamdi, ISP7, Hammamet 01/02 Mai 2015

TC-102 / TC-211
Marjan Island Main Road Corridor: PMT results

\[ P_{LM} \text{ (kPa)} \]

\[ E_M \text{ (kPa)} \]

\[ \frac{P_{LM\ post\ DC}}{P_{LM\ pre\ DC}} \]

\[ \frac{E_{M\ post\ DC}}{E_{M\ pre\ DC}} \]
• **Total treatment area: 175,000 m²**

• **Ground**
  - Design Platform Level= +3.5 m CD
  - Groundwater Level= +0.5 m CD
  - Seabed Level= -9.1 to -13.2 m CD
  - Hydraulic fill
  - Carbonate sand and gravel
  - Grading
    - Less than 75 mm
    - Less than 10% fines (lenses of silt)

• **Acceptance criteria (not the best)**
  - Minimum Relative Density= 60%
    - Based on Baldi et al.
    - Calcareous sand correction factor= 1.94
Reem Island Causeway

- Dumped fill
- <10,000 m²
- Up to 9 m thick
- High GWL

Acceptance Criteria
- Safe bearing capacity: 120 kPa with a safety factor of 3.
- Total Settlement: 30 mm for the traffic load (conservatively assumed to be 20 kPa).
Reem Island Causeway

S. Varaksin & B. Hamdi, ISP7, Hammamet 01/02 Mai 2015
Reem Island Causeway: PMT results
• **Groundwater level 1-2 m below ground level**

• **13 boreholes**
  - Upper 12 m of ground appeared to be silty sand and gravel with cobbles.
  - Fines content 8 to 23%.
  - SPT
    - Blow counts in all boreholes were generally high and in the range of 25 to 50
    - Layers of 1 to 2 m thick with lower $N$ of 11 to 14 were encountered from depths of 5 to 8 m

• **Acceptance Criteria**
  - Bearing capacity 170 kPa
  - Total settlement 300 mm under a uniformly distributed load of 170 kPa
  - Differential settlement 1:180 under a uniformly distributed load of 170 kPa
WOQOD Fuel Oil Bunkering Facilities

S. Varaksin & B. Hamdi, ISP7, Hammamet 01/02 Mai 2015
WOQOD Fuel Oil Bunkering Facilities: PMT Results

S. Varaksin & B. Hamdi, ISP7, Hammamet 01/02 Mai 2015

TC-102 / TC-211
Palm Jumeira

- Tree trunk
- Crown with 17 fronds
- 3 crescent islands that form an 11 km long breakwater
- 2 smaller islands in the shape Nakheel’s logo
- 94 million m$^3$ of sand
- 7 million m$^3$ of rock
Variation of PMT Parameters Ratio after Dynamic Compaction

\[
R = \frac{\left( \frac{E_M}{P_{LM}} \right)_{after\ DC}}{\left( \frac{E_M}{P_{LM}} \right)_{before\ DC}}
\]

\[
R^{1/4} \left( \frac{P_{LM}}{\left( P_{LM} \right)_{before\ DC}} \right)^{2/3} = 0.0623 \left( \frac{P_{LM}}{\left( P_{LM} \right)_{before\ DC}} \right) + 0.1123
\]
Thank You