The geotechnical performance of Deep Penetrating Anchors in calcareous sand

Mark Richardson, Conleth O’Loughlin & Mark Randolph
ISFOG 2005
DEEP PENETRATING ANCHOR (DPA)

Deep Penetrating Anchor

- Installation line
- Release unit
- Permanent mooring line
- Chain
- Anchor
- Seabed
- Drop height, typically 30-40 m
- Penetration depth

10-15 m
300-3000 m

THE GEOTECHNICAL PERFORMANCE OF DPAs IN CALCAREOUS SAND
Mark Richardson (richardson@civil.uwa.edu.au)
TEST ARRANGEMENT & MODEL ANCHOR

Tests conducted at 200 g

Model anchor:

\[ D = 6 \text{ mm}, \quad L = 75 \text{ mm}, \quad m = 14.9 \text{ g} \]
Sand recovered from seabed in vicinity of North Rankin platform
Sieved to max particle size of 0.3 mm
Saturated in centrifuge strongbox
Placed on vibrating table for ~ 1 hour
Strength increase during testing in Box 3 ? optimum strength & density condition after several ramp up/down cycles

<table>
<thead>
<tr>
<th>Specific Gravity, $G_s$</th>
<th>Min. Dry Unit Weight (kN/m³)</th>
<th>Max. Dry Unit Weight (kN/m³)</th>
<th>Min. Void Ratio, $e_{\text{min}}$</th>
<th>Max. Void Ratio, $e_{\text{max}}$</th>
<th>Porosity, $n$ (%)</th>
<th>Friction Angle, $\phi$ (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.73</td>
<td>7.5</td>
<td>10.1</td>
<td>1.65</td>
<td>2.59</td>
<td>62 - 72</td>
<td>40</td>
</tr>
</tbody>
</table>
At similar impact velocities embedment approximately 50% of that in normally consolidated clay? 0.7 - 1.5 times anchor length

Good agreement with field data - embedment 1.25 times anchor length (Medeiros, 2001)
Theoretical vertical pullout capacity:

\[ F_v = W_s + N_q \sigma_v A_p + \beta \sigma_v A_{shaft} \]
DPA padeye resembles vertically loaded plate anchor during pullout

\[ \beta = 0.03 - 0.15 \text{ for driven piles at North Rankin (Randolph, 1988)} \]

Cyclic degradation of shaft friction due to nature of pile installation (White & Lehane, 2004)
Static resistance profile

\[ F_s = N_q \sigma_v A_p + \beta \sigma_v A_{shaft} \]

Anchor deceleration

\[ m \frac{d^2z}{dt^2} = W_s - R_f F_s \]

Biscontin & Pestana, 2001

\[ R_f = \left( 1 + \lambda \log \frac{v}{v_s} \right) \]

CPT tip resistance in Box 3 used to deduce average \( N_q = 32 \) \( \beta = 0.42 \)

Back analysis using \( \beta = 0.3 \) (pullout) \( N_q = 35 \)

\( \beta \) values back-calculated from measured embedments:

(i) Measured static resistance \( \Rightarrow ? \sim 0.6\% \)

(ii) Formulated static resistance \( \Rightarrow ? \sim 2\% \)

Clay \( ? = 5 - 20\% \)
>> CONCLUSIONS

- Prototype embedments of up to 1.5 times the anchor length were achieved with impact velocities approaching 24 m/s
- Good agreement with field test data of 1.25 times anchor length
- Maximum vertical capacity of approximately 2 times the anchor dry weight
- Embedments and subsequent capacities in calcareous sand significantly less than those in normally consolidated clay at similar impact velocities
- Potential for higher embedments and capacities with higher impact velocities
- Possible to predict embedment depth of DPAs in calcareous sand from static resistance profile
- Low back-calculated values demonstrate minimal strain rate effects in calcareous sand
- DPA has potential for use as an anchoring system in calcareous sediments
THANK YOU