Guidance for good practice in bored pile and diaphragm wall design and construction for marine structures
Contents

• Introduction
• Recent developments
• Diaphragm wall finish
• Cage detailing practice
• Tremie concreting practice
• Panel stability
• Improvements in safety
• conclusions
Introduction
Introduction
Introduction
Introduction
Introduction
Why concrete at London Gateway?

- Illustrative design based on combi wall
- Safer installation of DWall on dry land
- Risk of driving into very dense Thanet Sand mitigated
- Dwalls will act as foundations for the gantry cranes
- Steel prices high and volatile in 2007
- Much reduced steel content in DWall
Design of Diaphragm Wall

- Key challenges
- Relatively high retained height (ca. 28m lowest dredge)
- Changing ground conditions
- Complex soil-structure interaction
- Tight displacement criteria - limit permanent change of gauge ca. 14.75 mm
- Complex load cases involving tidal lag, crane, vessel berthing and mooring
- Crack widths limited to 0.24 mm (SLS) in the splash zone
London Gateway Port – Typical Section
Recent developments - deeper CFA

Soil Mech SF50

Fundex F3500

CFA pile reach limited by mast height and pull back winch capacity
• Dia. 300 to 1500mm
• Length max 32 metres
Recent developments – cased CFA secant walls
CFA - Secant wall examples
Cased CFA - Secant wall examples
Diaphragm walls – new horizons

- 100m+ wall depth
- 1800mm thickness
- Verticality 1 in 300
- C60 concrete
Diaphragm wall - Hydrofraise

- Guide Frame
- Inclinometer
- Mud Pump
- Rotary drum cutters
- Mud return into the trench after treatment
- Mud to the desanding plant
Excavation verticality control

Hydraulically operated verticality control pads
Diaphragm wall – Grab versus Hydrofraise comparison

- - - - Theoretical position of wall

- - - - Specified limits of deviation

Grab

Hydrofraise

Re-excavate to correct alignment

Adjust alignment as excavation proceeds
Diaphragm wall – What does a finished Dwall look like?
Diaphragm wall – What does a finished Dwall look like?
Diaphragm wall – What **can** a finished Dwall look like?

- Bleed channels
- Mud inclusion
- Mattressing
Diaphragm wall – Latest design and execution practice?

- Careful mix design
- Pre-start concrete trials
- Monitor concrete production facility
- Observe good cage detailing practice
- Follow good tremie practice
- Slump and strength are not sufficient testing eg. bleed and stability tests
Diaphragm wall – latest guidance on cage detailing
Diaphragm wall – Latest guidance on cage detailing

• Final clear horizontal distance on vertical bars at least 100 mm
• Can be reduced at laps to 80 mm
• Multiple layers of vertical bars to be lined up behind each other
• Final clear vertical distance on horizontal bars at least 150 mm provided max aggregate is 20 mm
• 3D model may be required in areas of high congestion to avoid clashes
• Minimum distance between cages 200 mm
• Ensure nominal cover is sufficient to achieve required design cover, to satisfy durability requirements, allowing for construction tolerances
Diaphragm wall – Latest guidance on tremie practice
Diaphragm wall – Latest guidance on tremie practice

• At start of pour tremie to the panel bottom and raise <200 mm
• Prior to first discharge install effective separator ie. ball or vermiculite volume to create plug length at least 2x tremie diameter
• Discharge to all tremies simultaneously until at least 3 m depth of concrete
• Thereafter keep difference in concrete level to a minimum
• Avoid repeated raising and lowering of the tremie (surging)
• Minimum tremie embedment 3 m (may be reduced to 2 m if concrete level accurately known)
• Excessive tremie embedment to be avoided (preferably less than 10m)
• Remember the first concrete which enters the tremie will not usually reach the top of the pour
Trench instability
How do we check trench stability?

OVERALL STABILITY
• Limit Equilibrium Method
• Finite Element Model
• Limit Analysis

FoS required:
1.1 to 1.3
Trench stability example
Trench stability considerations

- Add 20KPa surcharge
- Guidewall depth
- Potentially unstable
- 1.0m drop in bentonite level
How to improve trench stability in poor ground

**Standard measures**

- Slurry level min 1.5m higher than groundwater level
- Reinforcement continuity along guide wall sections
- L-shaped guide walls
- Careful consideration of where to position the plant
- Use short panels (single bite)

**Additional measures**

- Elevated guide walls (no more than 500mm)
- Increased density of support fluid
- Lower groundwater
- Ground improvement
Horizontal to vertical - Tandem lift D-wall
Temporary works rebar – very important

Additional rebar to ensure safe:
- Fabrication
- Transportation
- On and off loading
- Storage
- Lifting from horizontal to vertical
- Hanging
- Splicing

All elements require design e.g. bars, welds and connectors
Horizontal to vertical lift – tandem lift

Tandem lifting points
@ top of z bars and cathedral bar
• Were developed to splice ropes, not reinforcement bars

• Must use lowest tested strength and robust procedure due to high variation of tensile strength results

Cage splicing - Bulldog grips
New cage splicing systems - Superlatch™

- Size of superlatch varies with cage weight
- No fingers in cage
- Expensive but safe
Improvements in safe working – platforms and barriers
Conclusions

• Cast in situ concrete diaphragm and secant pile walls have many potential applications in marine works
• Diaphragm walls in particular have been used on many quay wall projects
• Plant and material developments have brought opportunities and risks
• Recently published industry guidance designed to achieve better outcomes in terms of quality and safety
• Good practice should be shared by all