Contents of presentation

• Introduction
• Project Artificial islands North Caspian Sea
  • Design of Perimeter wall
  • Ice loads and standards
• Project Yamal Russia
  • Design of Ice Protection Structures

Part 1 - Arctic engineering

Project North Caspian Sea
Civil design works Caspian Sea

- civil design for manmade islands
- fully protected and semi protected islands

Facts and figures

- project start 1998
- W+B designed appr. 13 sites, man-made islands mostly
- exploration by mobile rig, submerged on berm, with active ice management and ice protection
- 2 major hubs with 40 year lifetime and manned, of which 1 is constructed (complex D)
- multiple drilling / production islands, temporary manned
- appr. 10 sites constructed
- First oil 2013…

Design of island perimeter wall
Island layout – Combiwall design

Combiwall ice load performance

Measures taken for best ice load performance:
1. Combiwall pile with concrete fill
2. Intermediate sheetpile with strong interlocks
3. Intermediate sheetpile flange at island side
4. Conical anchors

Analysis performed:
• Plaxis 2D global ice load performance
• Plaxis 3D local ice load performance

Experience:
• Kashagan Complex D barrier heads

Combiwall ice load performance

PZC sheetpile laboratory test:
• Simulation of local ice load
Combiwall ice load performance

Conical anchors – principle
- Waling and anchor plates fixed
- Tie rod can move free from waling
- Central load introduction

Plaxis 2D and 3D local ice load - deformations

3D analysis cofferdam local and global ice load
Standards, manuals, research

- ISO Code 19906
- Rock Manual
- Field testing and data collection

Definitions of exposure level

- consequence category:
- life-safety category:
- exposure level:
- classification system to define the requirements for a structure based on consideration of life-safety and of environmental and economic consequences of failure

Reliability concept

- Ultimate limit state (ULS - ELIE)
- Abnormal (Accidental) limit state (ALS - ALIE)
- Serviceability limit state (SLS)
- Fatigue limit state (FLS)

Design ice actions

- Ice scenarios (see table)
- Limiting mechanisms
- Ice failure modes
- Structural configuration
- Operation scenarios
Active Ice Management:
active processes used to alter the ice environment with the intent of reducing the frequency, severity or uncertainty of ice actions

Field testing and data collection
- meteorology
- oceanography
- geotechnical conditions
- ice conditions
  - ice thickness
  - ice drift
  - ice formations (type)
  - ice strength
  - ice structural interaction
  - seabed scours

Land fast ice or mobile ice
18 December 2002
22 December 2002
19 January 2003

Grounded stamukha in 8m water scour on seabed
Strength testing on ice

Project Yamal Russia

Design of IPS
- Ice Protection Structures:
  - Breakwaters
  - Caissons
  - Piles
  - ...

Failure modes breakwater
- Failure mechanisms, load cases
  - LC1: edge failure (local)
  - LC2: deep slide failure (global)
  - LC3: global slide failure (global)
  - LC5: decapitation (frozen cap)
- Methodology
  - Interaction scenarios and loads defined together with ice experts
  - Simulation of ice and soilrock in Plaxis (FEM)
**Breakwater stability verification under ice loading**
- Local failure (acceptable?)
- Global failure (not acceptable)

**Global failure mode of trial berm**
- Height 6m
- Footprint 30x50m
- Seabed survey after actual failure

**Selected concepts**
- Shallow section A+C: rubble mound IPS and reused dredged material
- Deep section B+D: two optimized prefab caisson IPS with sloping side walls
- Rubble mound construction on sandy layers
- Foundation level caisson IPS in dredged trench
- Piperack combined with south IPS

**Два профиля, выбранные из разреза 22**
- СК4966 (мелководье, разрез А,С)
  - ИГЭ-3 (песок) на -2 м БС
  - ИГЭ-6 на -6 м БС
  - ИГЭ-12 на -10 м БС
- СК4936 (глубоководье, разрез В,Д)
  - ИГЭ-4 (ил/глина) на -5 м БС
  - ИГЭ-2 на -10 м БС
  - ИГЭ-12 на -15 м БС
NW Section A
- concrete block mat
- reused dredged material
- rubble mound IPS, outside slope 1:3
- bunds

NE Section B
- concrete caisson with 45° sloping sides
- ballast by hydraulic fill
- reused dredged material
- gravel layer

SE Section D
- concrete caisson with 60° sloping sides
- reshaped slope
- reused dredged material
- concrete block mat

Ice parameters and loads (ISO19906)
- Initial bending loads 0.1 to 0.4 MN/m
- Rubbling load on rubble mound 0.8 to 1.5 MN/m
- Rubbling load on caisson 0.9 to 1.3 MN/m

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<th>Ice and ice rubble physical parameters</th>
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<td>Density</td>
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<td>Parameter</td>
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<td>Ice to ice friction coefficient</td>
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<td>Ice to rubble friction coefficient</td>
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<td>Rubble to soil friction angle</td>
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Спасибо за внимание - Вопросы
Part 2 - Earthquake engineering

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Carolina Sigaran
Floris Besseling

Geological quick-scan

Proposed Project
(tender/feasibility)

Desk-geology

Tectonic setting

Geohazards
(e.g. winds, landslides, tsunamis, floods, mud volcans, difficult arks)

Contents

- 1) Introduction
- 2) Geological quick-scans
- 3) Seismic design

Site location: Taman Port, Russia
Site location: Taman Port, Russia

Geological quick-scan

- Proposed Project (tender/feasibility)
  - Desk-geology
  - Tectonic setting
  - Geohazards
    - E.g. seismos, landslides, volcanic hazards, faults, subsidence, diffused ash
  - Recommendations for SoW and geotechnical design
    - Geomodels
      - Physical tests: in situ (SPT, DMT, CPT), laboratory, geophysics, field reconnaissance
    - Seismic assessment for design
      - Liquefaction, ground deformation, stability, failure

Seismic assessment for design (performance-based)

- Earthquake loads
  - E.g. operating, contingency levels (ULS, DL, LEL)

- Pseudostatic ("simplified")
- Displacement-based (Newmark, "simplified dynamic")
- Site response ("dynamic")
  - Equivalent linear
    - Nonlinear (e.g. FEM/FDM)

- Stability
  - Internal forces: threshold info
- Deformation
  - Displacements: threshold info

Site response ("dynamic")

- Input:
  - Geotechnical characterization
  - "n" seismic records (corrected, filtered, scaled)

- Approaches:
  - Equivalent linear (e.g. Shake, Matlab)
  - Nonlinear (e.g. Plaxis)

- Outputs, e.g.:
  - Site response (t-f domain)
  - Deformations
  - Stresses/ductility
  - Stability
**Pseudostatic: QW Taman Port, Russia**
- Deltares-sheetpiling (winkler model)
- Plaxis (FEM)

- 12 quay s
- Lengths: 400-1187 m
- Total length: 9355 m

**Dynamic: QW Taman, Russia**
- Lower displacements then for pseudostatic
- Displacements in both directions
- Soil improvement at toe is effective

**Pseudostatic: BW Taman Port, Russia**
- Deltares-Stability(Slip circle)
- Plaxis (FEM)

- 6 sections
- Total length: 7500 m

**Dynamic: BW Taman, Russia**
- Lower displacements then for pseudostatic
- Displacements in both directions
- Soil improvement at toe is effective
Nonlinear: Dike Kapuk-Naga, Indonesia

- design of three offshore islands
- dredging plans (50 million m$^3$ reclamation)

Dynamic: Dike Kapuk-Naga, Indonesia

- Displacements
- FoS
- Shear strains
- Liquefaction potential

Seismic soil-structure interaction

- Sea of Marmara, Turkey
- Basic design
- Oil and chemical jetty, LNG tanks
- 30 m soft soil (class E)

Jetty’s

- MSc thesis Floris Besseling
- Soil – Structure interaction
- Performance based seismic design (focus on displacements and ductility)
Case study project

- Concrete deck with steel tubular piles
- Soft soil deposit (20 m. depth, two clay layers) overlying dense sand, overlying bedrock
- Typical situation of large end-bearing shafts
- Structural model, high deck stiffness and plastic hinge locations

Thesis project

- Jetty structure for transfer of oil and chemicals (high risk structure)
- High seismicity area (L1 EQ_apeakbedrock = 0.7g, L2 EQ_apeakbedrock = 1.02g)
- Izmit 1999 earthquake, Mw = 7.6, 17,000 fatalities, 43,000 injured, 120,000 buildings damaged

Contents

- Case study project
  - Seismic/dynamic jetty analysis
    - Simplified dynamic analysis
      - Pushover analysis and laterally loaded piles
    - Uncoupled dynamic analysis
    - Coupled dynamic analysis
    - Comparison of uncoupled/coupled results
  - Conclusions
Seismic dynamic jetty analysis methods

Simplified dynamic analysis
Uncoupled dynamic analysis
Coupled dynamic analysis

$u_{\text{max}}, M_{\text{max}}$
$u(t), M(t), u_{\text{residual}}$
$u(t), M(t), u_{\text{residual}}$

Pushover analysis and laterally loaded piles

- Literature: Reese and van Ympe and NCHRP Report 461
- Plaxis 3D as a tool to establish equivalent Winkler foundations

Simplified dynamic analysis

- N2 - Single mode capacity spectrum method, Fajfar (2000)
- Pushover curve to determine capacity and estimate fundamental frequency
- Transformation to equivalent SDOF system
- Response spectrum approach (displacement demand)

Uncoupled dynamic analysis

- Input from free field site response at levels along the pile
- Structure dynamic analysis with structural model
- Near field lateral interaction covered by non-linear p-y springs
  - Static p-y spring stiffness
  - Added viscous dashpots
Dynamic analysis of slice of soil including the jetty structure

Aspects of preliminary model calibration:
- Pushover analysis
  - Structure modelling, interfaces etc.
  - Soil parameters and constitutive modelling
  - Group effects (soil slice thickness, 2.5*D)
- Free field dynamic analysis
  - Mesh element size (<1.00 m)
  - Boundary disturbances and dynamic viscous boundaries (soil slice width, 300 m)
  - Soil parameters (incl. damping) and constitutive modelling
- Computational demands
  - Duration of a single run: 2 days
  - Model calibration: weeks

Similar results for uncoupled and coupled dynamic analysis
Residual displacements can only be determined by non-linear site response analysis (Plaxis)

Earthquake loads
Seismic ground response (1D Shake, 2D Plaxis)
Liquefaction potential
Seismic stability (Pseudostatic, Newmark, Plaxis)
Structure response and soil-structure interaction (Response spectrum + pushover, Uncoupled and coupled dynamic analysis)