

Copenhagen Offshore Wind 2005

Installation – Concepts and Risks



- Reinforced concrete gravity foundation
- A Contractors point of view

Joergen Lisby & Jesper Jacobsen, Per Aarsleff A/S



Overall Planning and Considerations

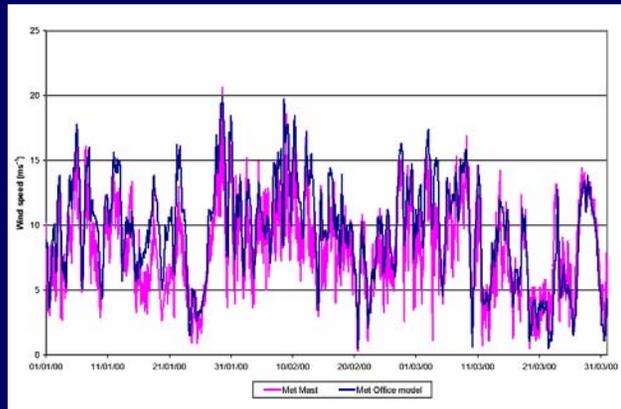
Reinforced Concrete Gravity Foundation

- Site Conditions
- Preliminary Design and Layout
- Design
- Production
- Sea Bed Preparations
- Installation
- Ballasting
- Scour Protection



Site Conditions

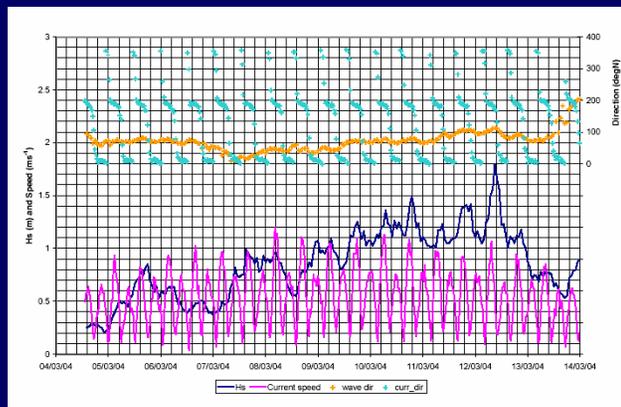
Wind speed



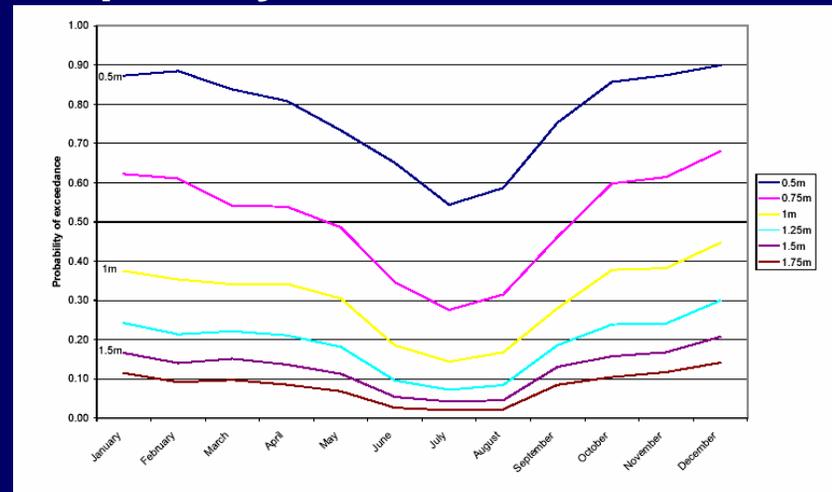
Tides

LAT	0.1m
MLWS	0.9m
MLWN	2.5m
MSL	4.0m
MHWN	5.3m
MHWS	6.9m
HAT	7.6m

Current and Waves



Propability of wave excedence





Preliminary Design and Layout

- **Foundation Level**

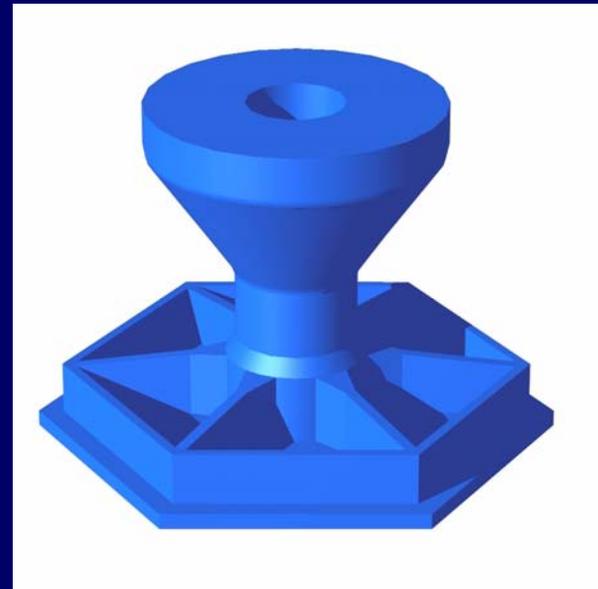
Bearing strata / Weight of foundation / Sea bed preparation

- **Weight Limitations**

Lifting equipment / Type of foundation / Transport

- **Lifting Equipment**

- **Type of Foundation**





Lifting Equipment

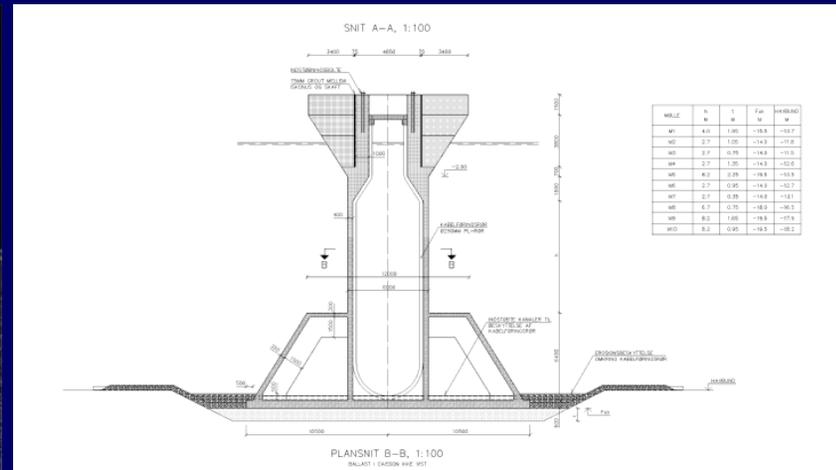
Installation vessel





Type of Foundation

Nysted Foundation. Model

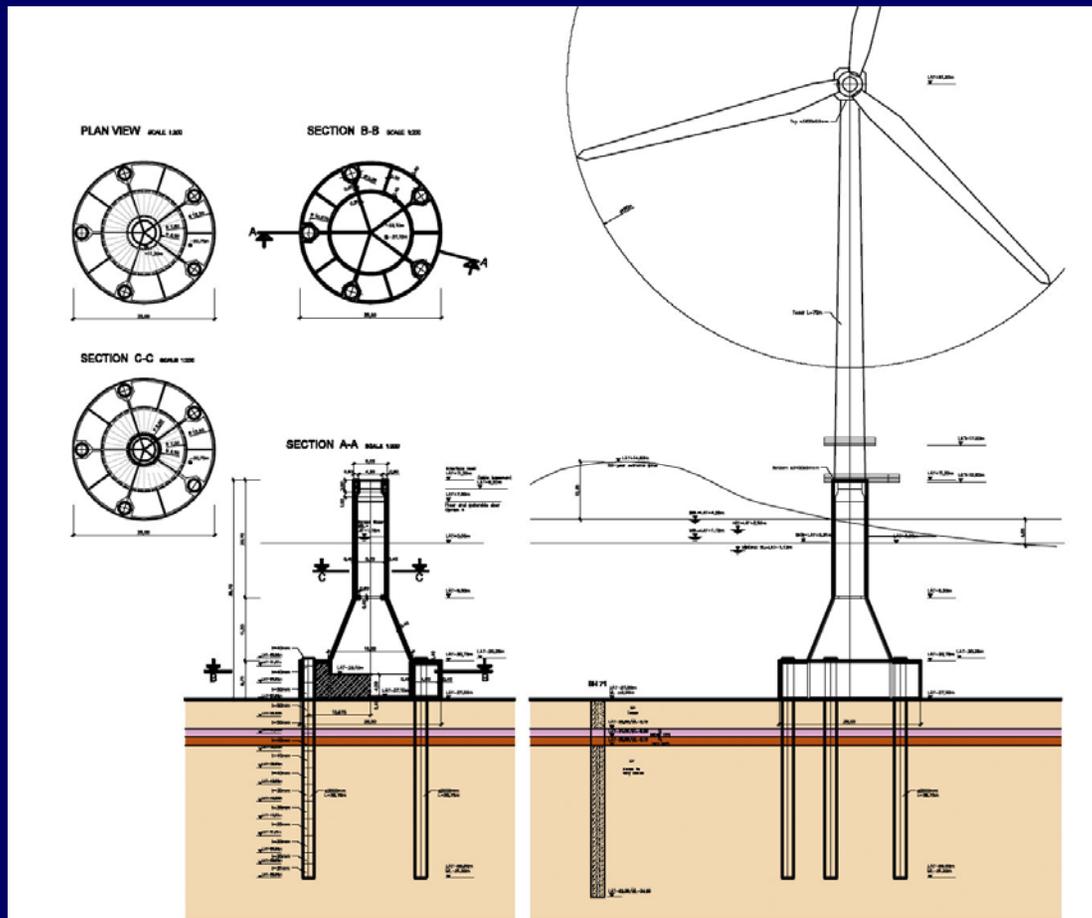


Caisson foundation for floating into position



Type of Foundation

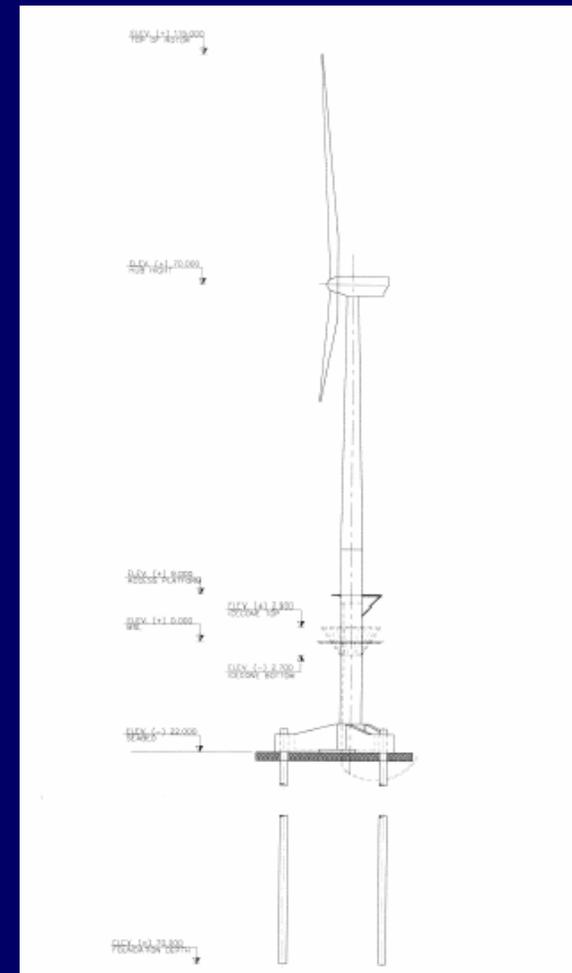
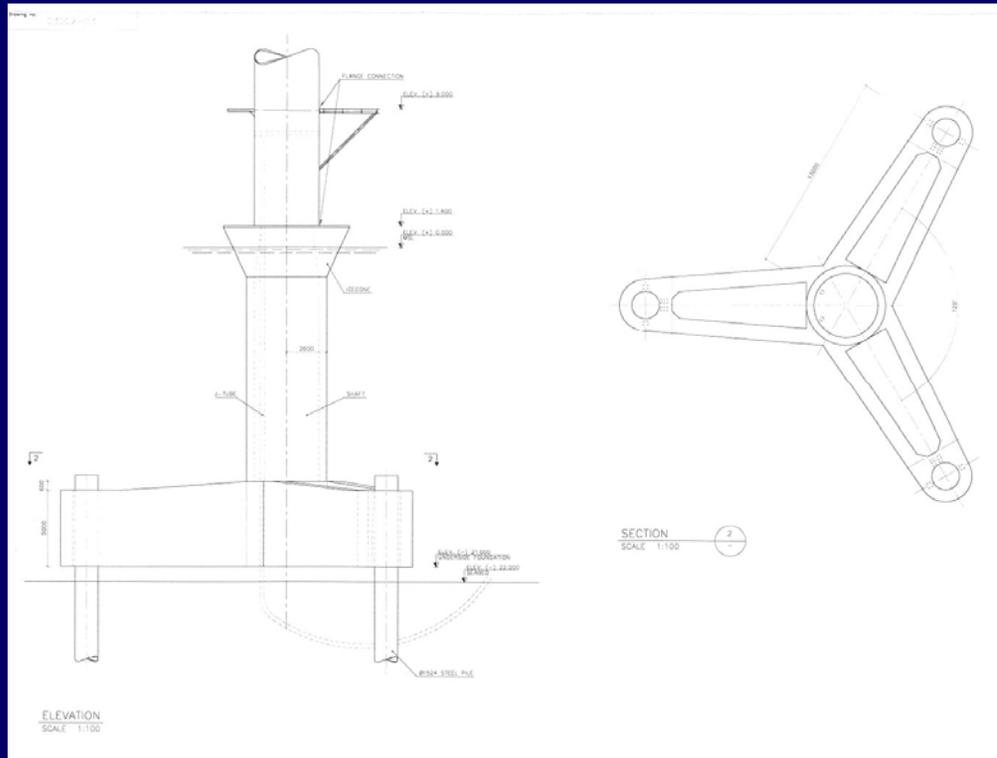
Piled reinforced concrete caisson





Type of Foundation

Reinforced concrete tripod





Design

Design basis | Basic design | Detailed design | Installation design

Design Basis to include:

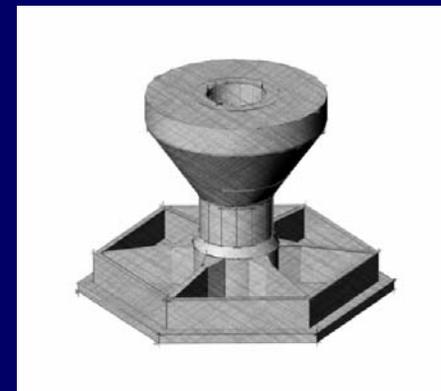
- **Fundamental Codes and Standards**
- **Employer's functional requirements**
- **Loads and load cases for ULS, SLS and FLS (as time series), and ALS**
- **Acceptable natural eigenfrequencies**
- **Hydrodynamic conditions and loads**
- **SN-curves for fatigue calculations**
- **Installation requirements**
- **Design life**
- **Driving analysis**
- **Structural design basis**
- **Geotechnical design basis including variations in all positions**
- **Scour protection and sedimentation design basis (may include physical hydraulic model tests)**
- **Appurtenances (boat landing, working platform and J-tube arrangements)**
- **Structural, geotechnical and hydraulic design methods**
- **Specification of facilities, including software, to be applied in the detailed design**



Design

Basic Design

- Verify the structural design for a typical near "worst case" location
- The basis for the basic design is the Design Basis.
- The Basic Design Report shall include:
 - Summary of design conditions
 - Basic Geotechnical Design, including calculations
 - Basic Structural Design, including calculations
 - Basic Scour Protection Design, including calculations
 - Specification of material design properties
 - Limited number of drawings
 - Quantities
 - Appurtenances (boat landing, working platform and J-tube arrangements) in basic design.





Design

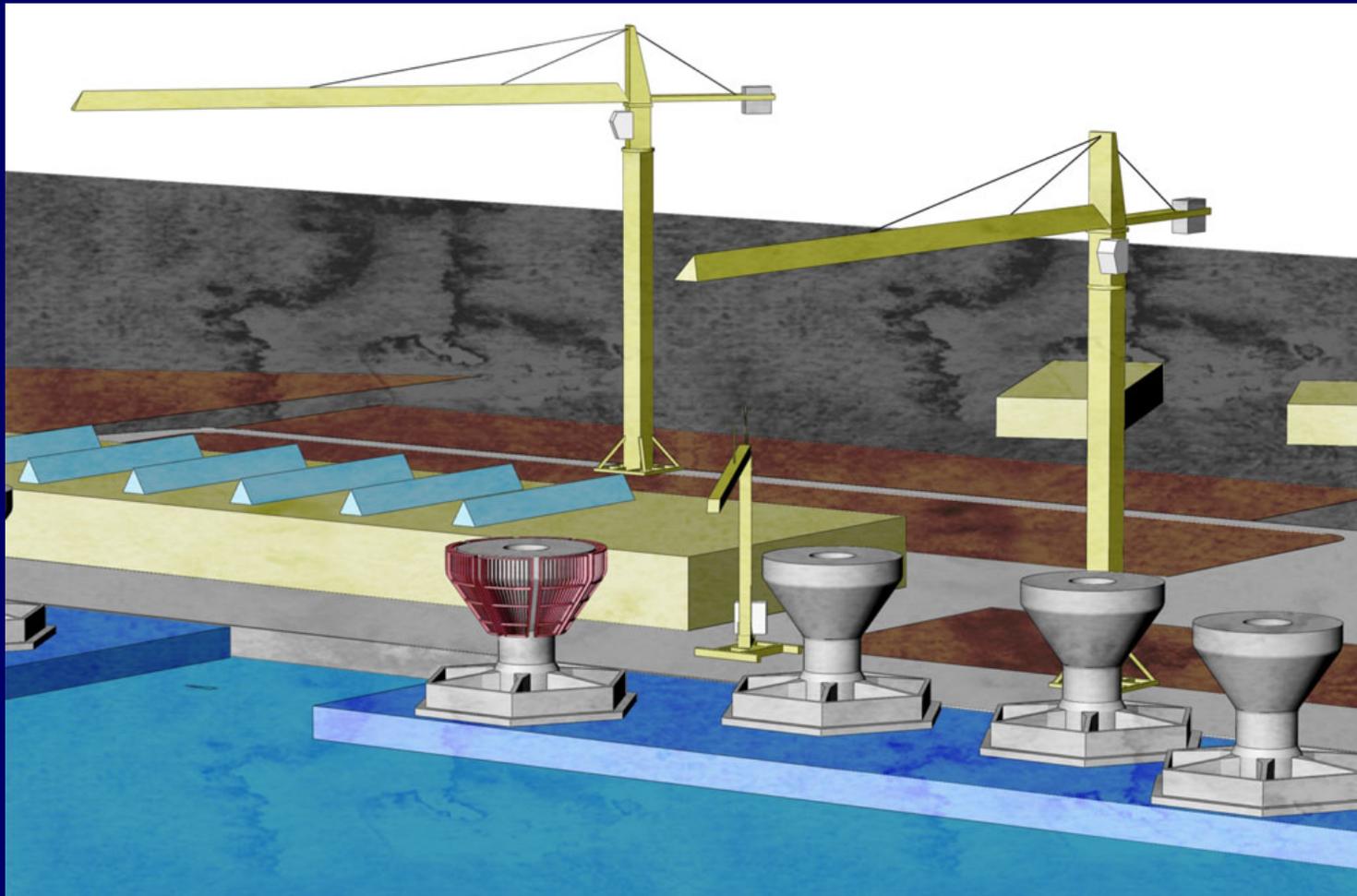
Detailed Design

- Final Design Basis (incl. Physical Hydraulic Model Tests)
 - Detailed Basic Design (General)
 - Detailed Foundation Design (Each or similar positions)
 - Detailed Appurtenances Design
 - Certification from Independent Verification Bureau
 - As-built documentation
-
- **Design Installation Issues**



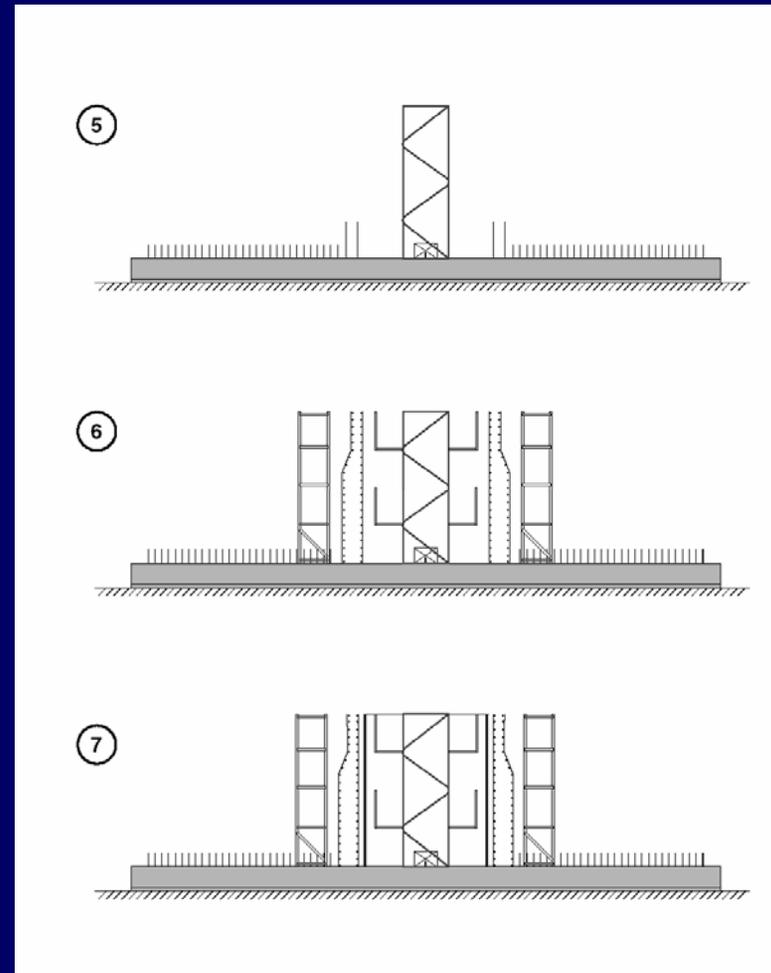
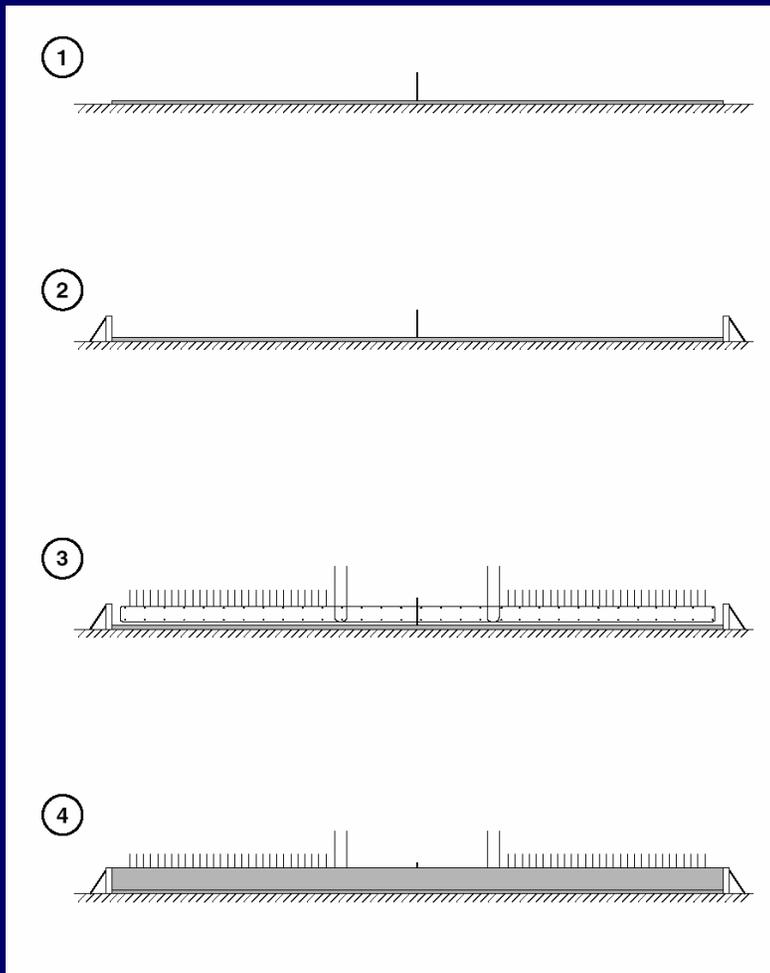
Production

Concrete | Reinforcement | Form works | Site | Lifting/floating | logistics | Work force | Materials | Appurtenances | Equipment



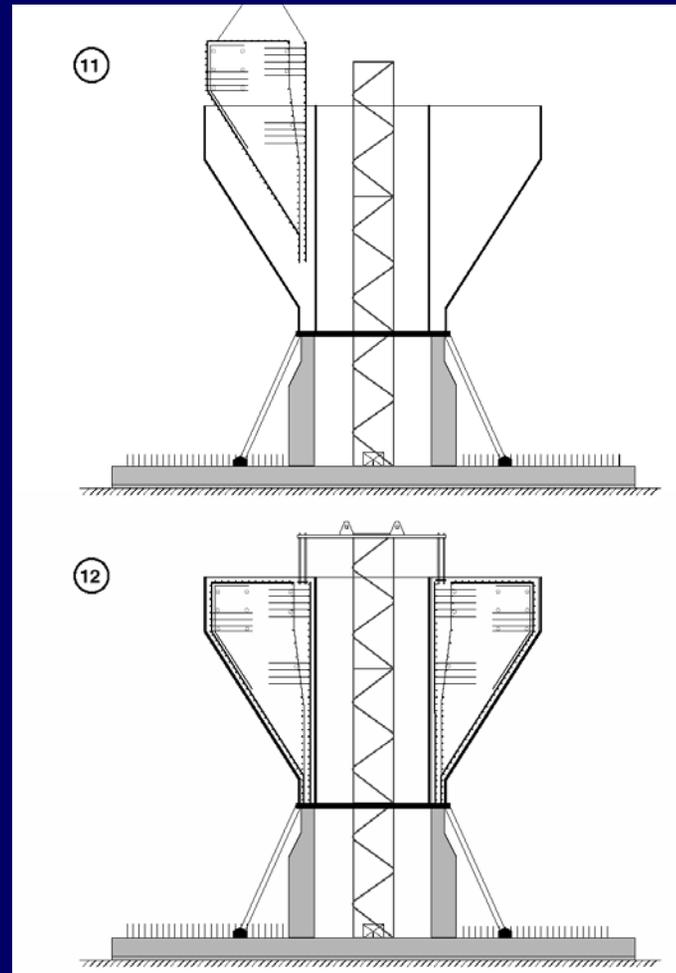
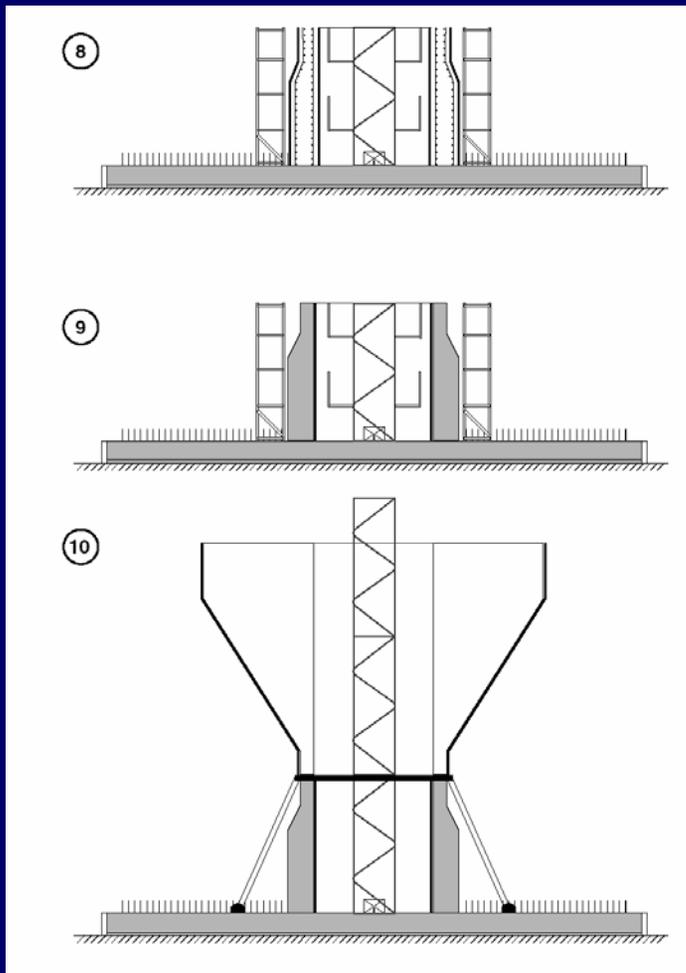


Production phases



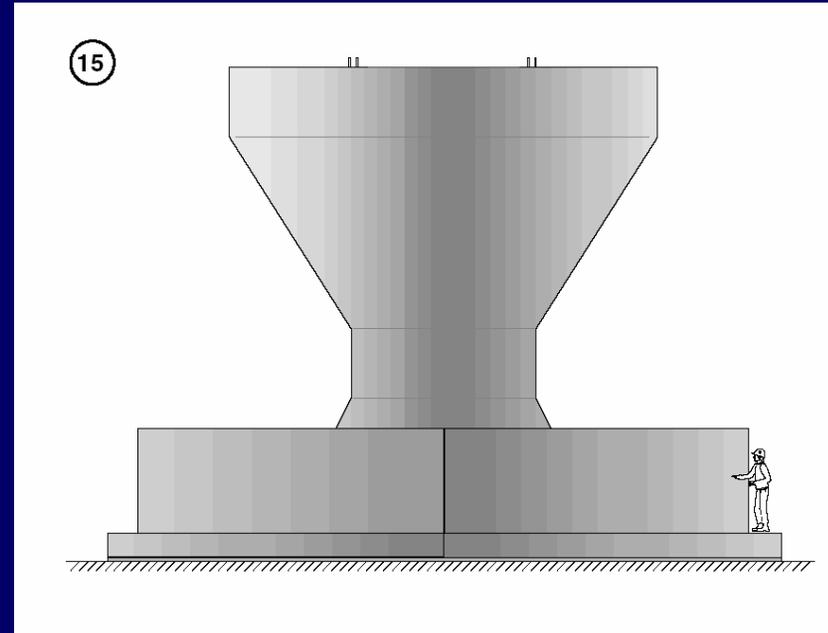
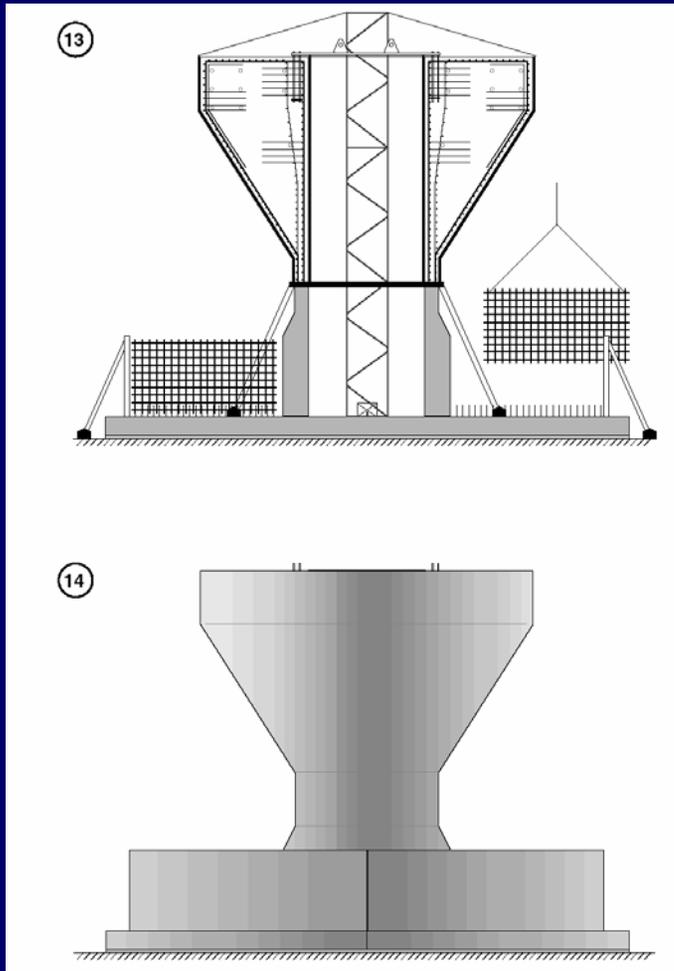


Production phases





Production phases



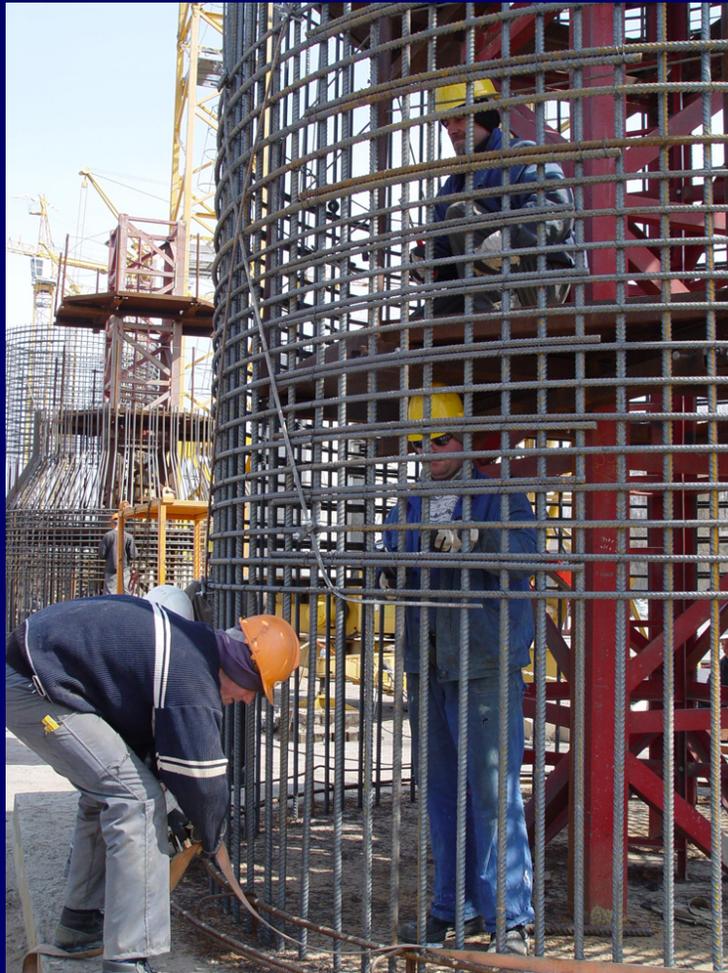


Production Concrete





Production Reinforcement





Production Reinforcement

Top of ice cone during concreting





Production Form Works

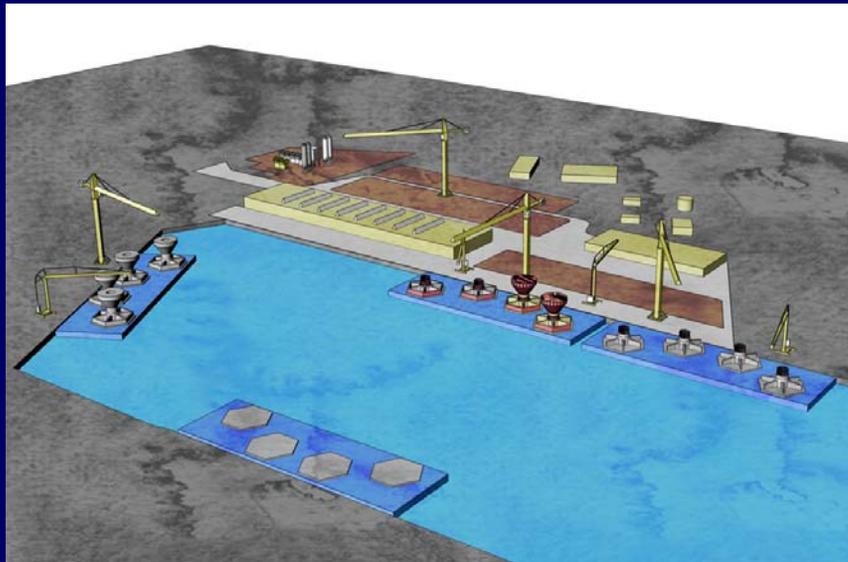


Concreting Nysted foundation in Poland





Production Site



No lifting on Site as foundations are produced on barge deck



Appurtenances



Boat landing installation



Railing installed

Placing of scour protection

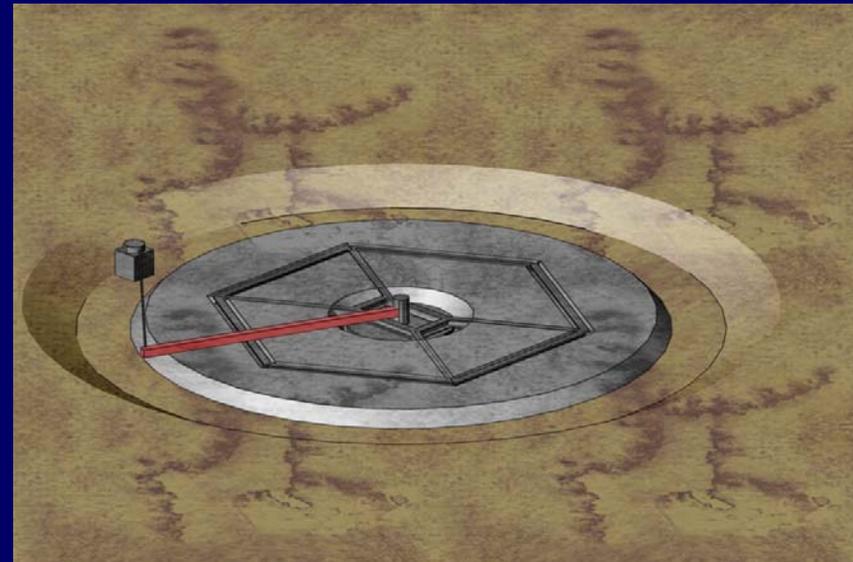


Sea Bed Preparation

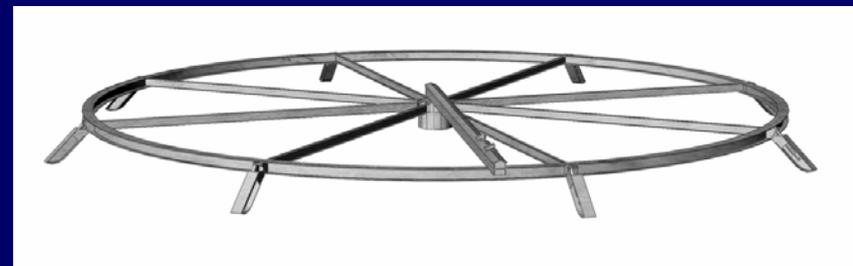
Dredging | Dumping license | Spill monitoring | Silation | Stone bed | Tolerances | Equipment



Dredging with back hoe



Stone bed preparation



Levelling frame



Transportation

Almost ready to leave production port





Installation

Lifting | Tolerances | Weather windows | Operational conditions | Logistics

Eide 5 lifting





Installation

The Placing sequence: Example

- EIDE V places itself on the side of the Transport Barge in front of the Foundation to be placed and is moored to the barge.
- The Sea fastenings on the Foundation are removed and at the same time the lifting Yoke is engaged with the lifting points on the Foundation. The Yoke is equipped with a, centrally operated hydraulic system, activating and securing the connection of the Yoke to the Foundations lifting points.
- The Foundation is lifted from its place on the transport Barge that is continually ballasted to keep its trim.
- EIDE V leave for the position of the foundation and on arrival linked to pre-positioned anchors. Using the anchors and the Spud the exact position is secured.
- The Foundation is lowered into place on the prepared Stone Bed. (See below) During the lowering operation the position is constantly monitored and if required will be corrected by use of the anchors.
- After touch down and subsequent transfer of the weight of the Foundation onto the Stone Bed the position and level of the Foundation is controlled before the lifting Yoke is disengaged hydraulically and EIDE V can leave the position for its next operation after having lifted the Yoke above water level.
- The flexible part of the Cable pipes, are then extended from the Foundation onto the sea bed ready to receive the cables.



Installation

Foundation installed





Ballasting

Materials | Equipment | Weather windows | Operational conditions | Logistics

Materials

Olivine 0 - 80mm		Approximate gradation curve (weight percentage)			
Expected dry density 2.25 Ton/m3					
Norit 50 - 775 kg designated by weight					
Expected dry density 1.86 Ton/m3					
Limit definition, Wy (kg)					
Extreme lower	Lower	Upper	Extreme upper	Effective mean weight	
y < 2%	0% < y < 10%	70% < y < 100%	97% < y	min.	max.
25	50	775	1100	350	500

Ballast inside shaft is Olivine if necessary.

If sufficient sand are used.

In outer chambers Norit 50 – 775 kg are used.



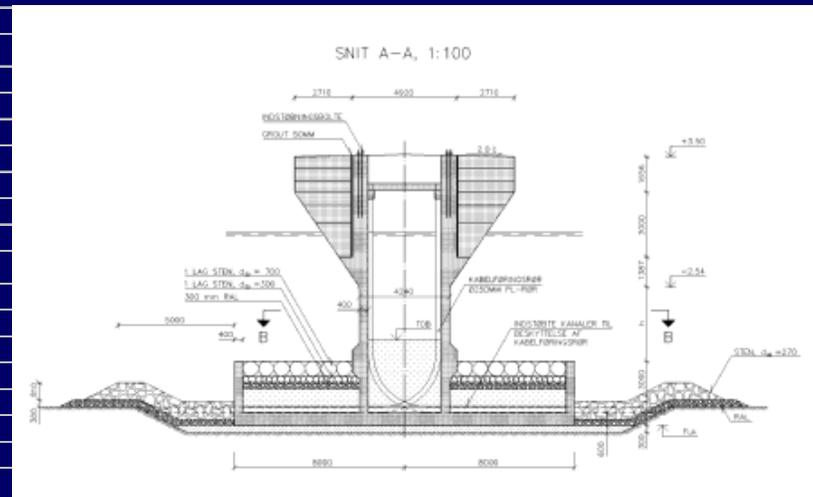
Scour Protection

Materials | Placing | Equipment | Weather windows | Operational conditions | Logistics

Materials

Norit 50 - 775 kg designated by weight					
Expected dry density 1.86 Ton/m ³					
Limit definition, Wy (kg)					
Extreme lower	Lower	Upper	Extreme upper	Effective mean weight	
y < 2%	0% < y < 10%	70% < y < 100%	97% < y	min.	max.
25	50	775	1100	350	500
Armour stones 60-300kg					
Expected dry density 1.60 Ton/m ³					
Limit definition, Wy (kg) (Ciria 83 / Cur 154)					
Extreme lower	Lower	Upper	Extreme upper	Effective mean weight	
y < 2%	0% < y < 10%	70% < y < 100%	97% < y	min.	max.
30	60	300	450	130	190
Stone bed material and Filter 20 - 100mm					

Scour protection design





Risks

- Bearing strata level within the single foundation varies more than can be foreseen.
- ***Surplus dredging to be performed and original bearing strata level shall be created by a surplus compacted stone bed.***

§

- Abnormal conditions through the installation period. Costs can raise and time extension can be necessary. High waves and current can cause siltation in the dredged foundation pit.
- ***Heavier equipment less sensitive to waves.***

§

- Waves, current and tides during installation
- ***Safe anchoring of transport barges. Safe sea fastening of foundations. Short installation time to fit within weather windows. Suitable equipment.***