



# COLLISION PROTECTION DOLPHINS ON PILES EXPERIENCE FROM RECENT PROJECTS IN DENMARK

SPUNS- & RAMMEDAG 2017: ÅRHUS

## CONCEPT

### Dolphin (Duc d'albe)



*A dolphin is a man-made marine structure that extends above the water level and is not connected to shore*

- **Breasting**
- **Mooring**
- **Housing of navigation aids**
- **Protection**

## CONCEPT

### Dolphin (Duc d'albe)



*A dolphin is a man-made marine structure that extends above the water level and is not connected to shore*

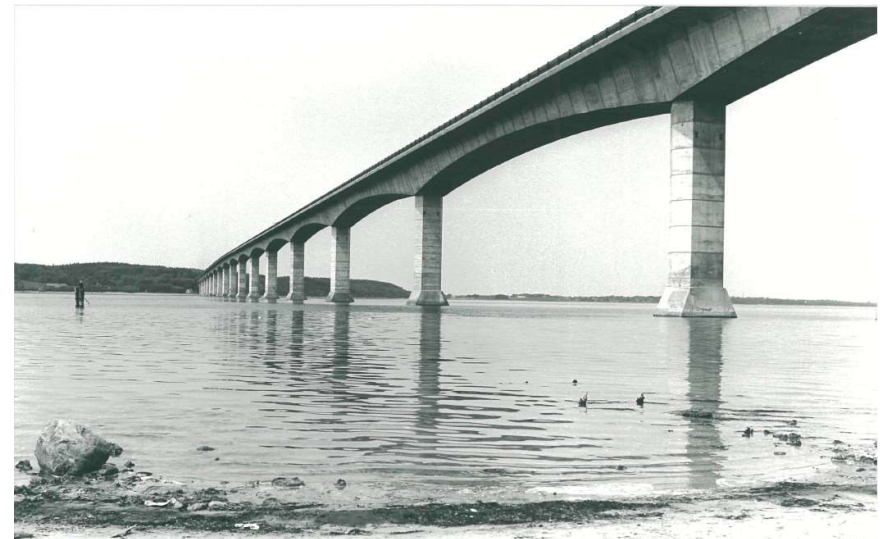
- Breasting
- Mooring
- Housing of navigation aids
- **Protection**

## **RAMBOLL'S RECENT PROJECTS**

### **Protection of bridge piers against collision**

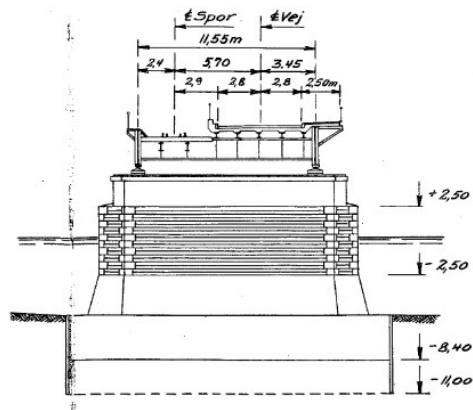
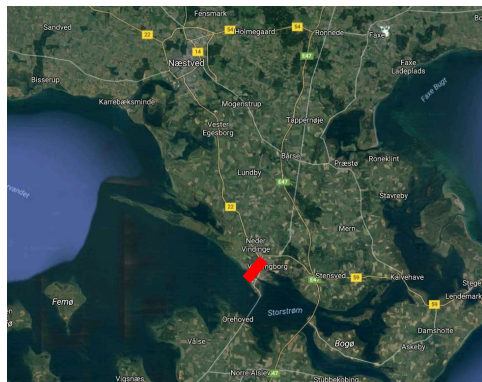
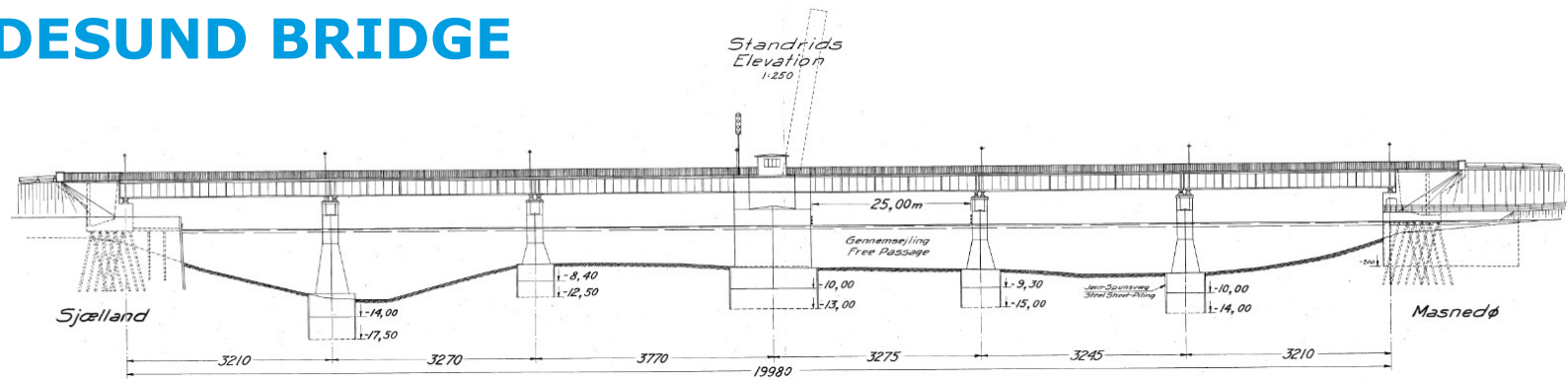


**Masnedsund bridge**



**Sallingsund bridge**

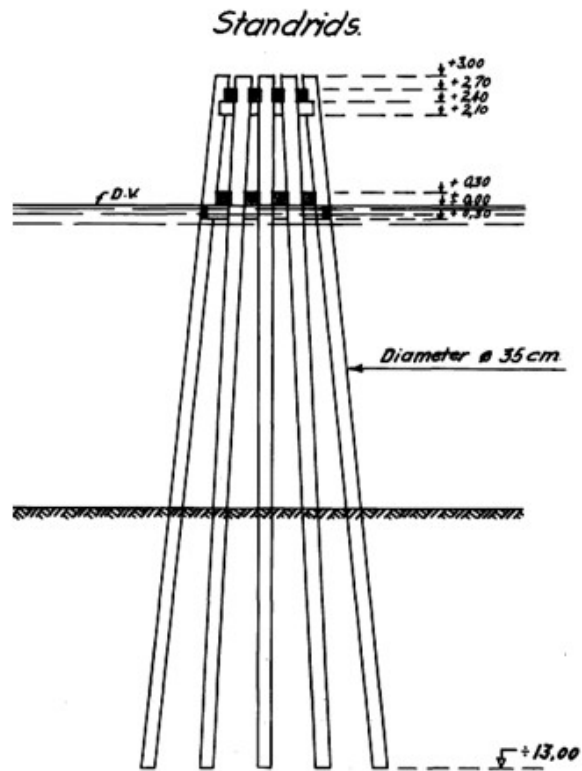
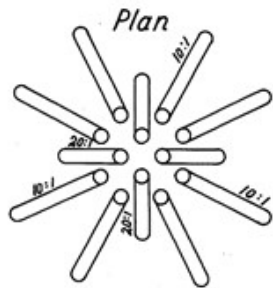
# THE MASNDESUND BRIDGE



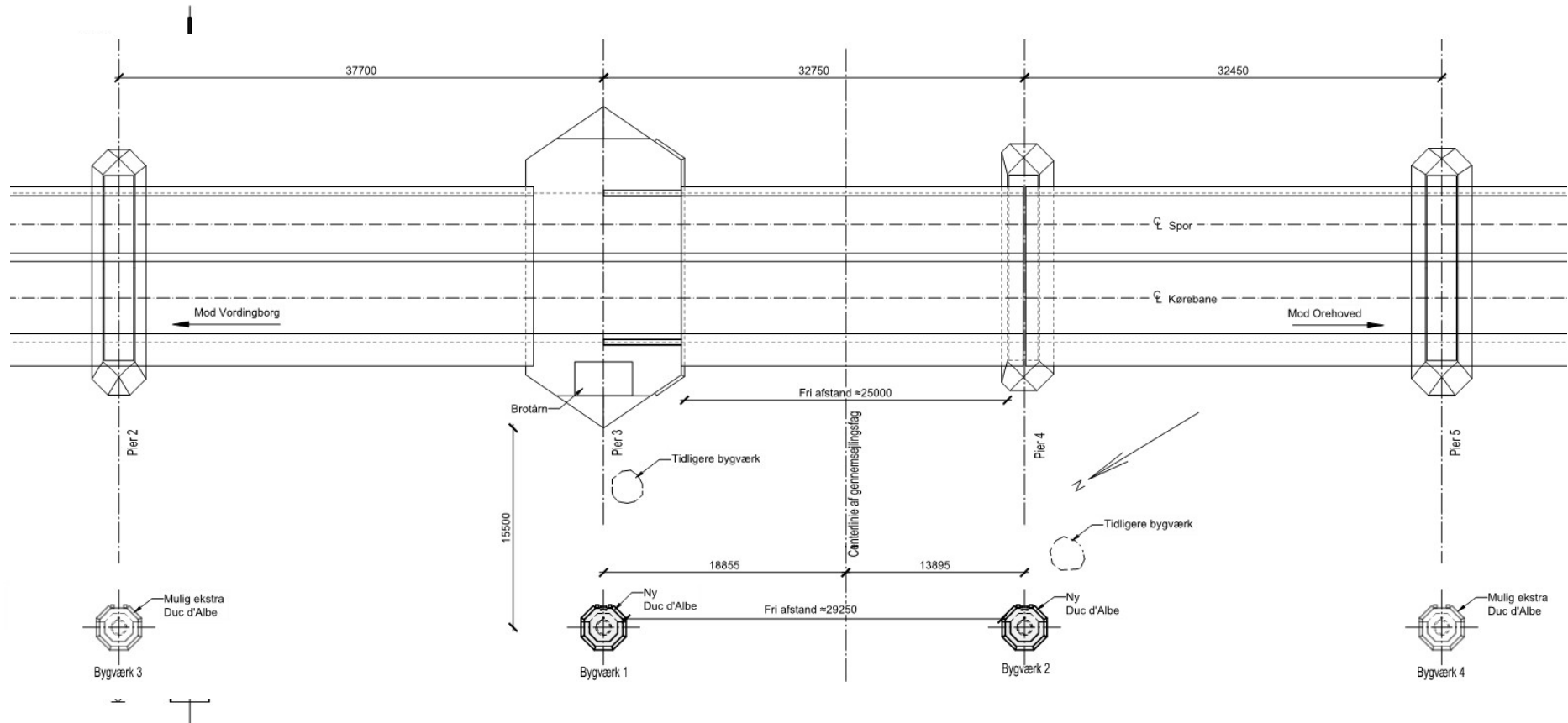
- Completed in 1938.
- Connects south Sjælland and Masnedø
- Total length 200m (6 X 32m)
- Steel deck with combined traffic
- Piers protected with timber-pile dolphins

# THE MASNDESUND BRIDGE

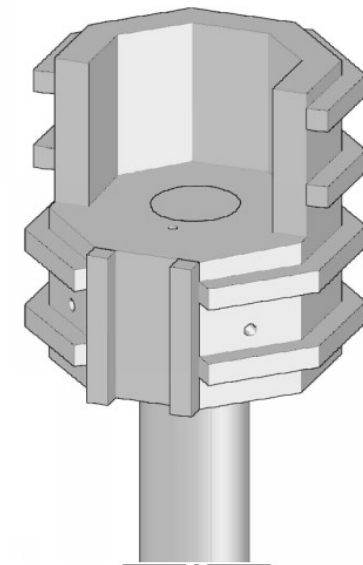
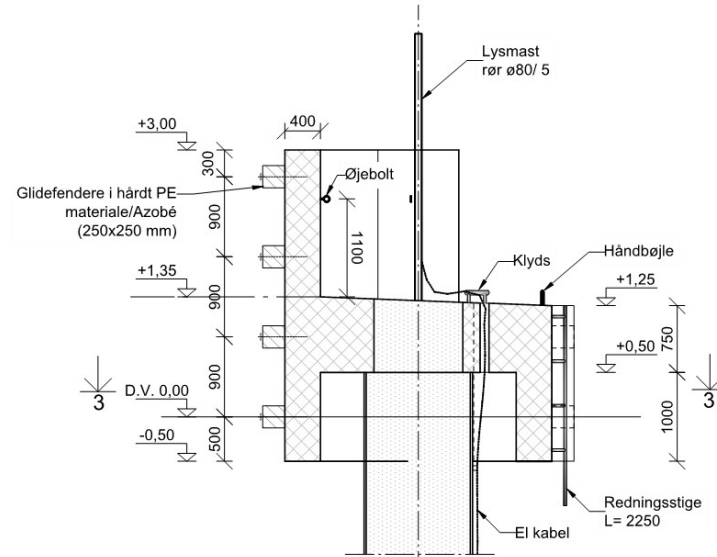
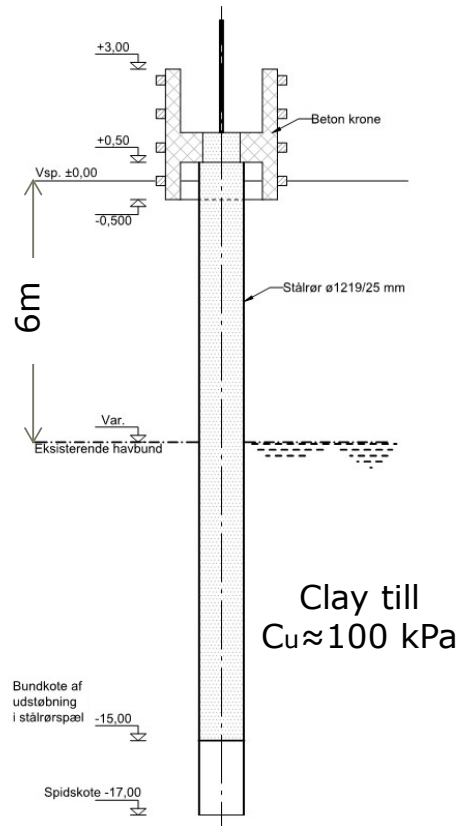
## Existing timber-pile dolphins



# THE MASNDESUND BRIDGE



# THE MASNDESUND BRIDGE

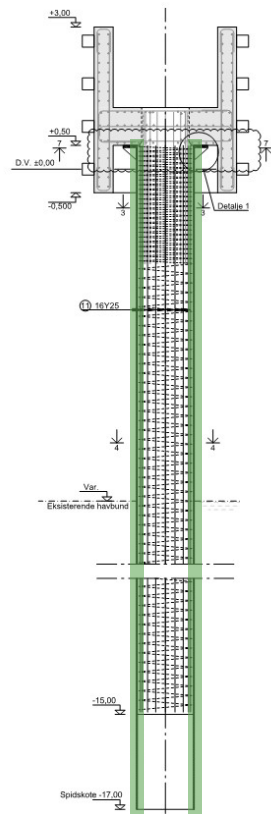


Isometri  
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# THE MASNDESUND BRIDGE

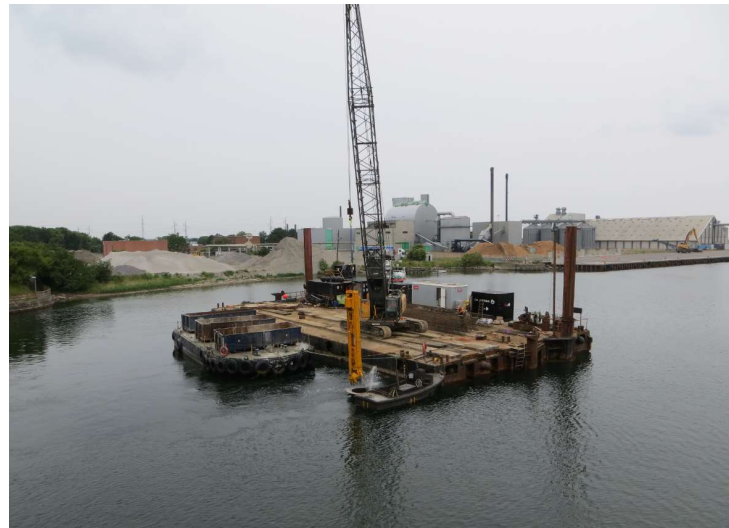
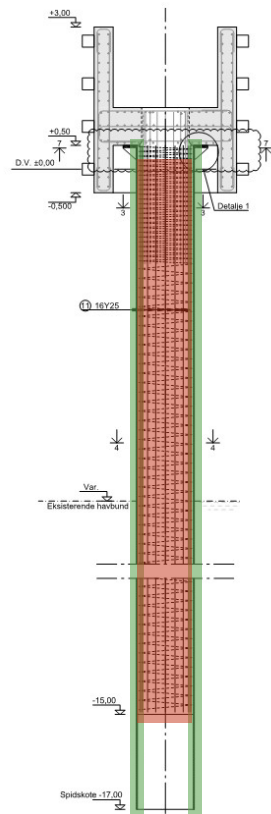
## Construction sequence



Pile driving

# THE MASNDESUND BRIDGE

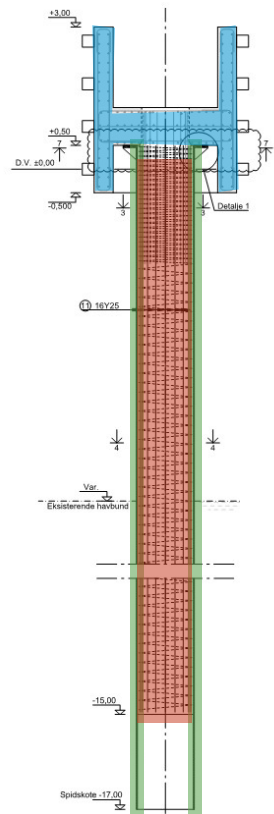
## Construction sequence



Soil excavation and placement of reinforcement cage

# THE MASNDESUND BRIDGE

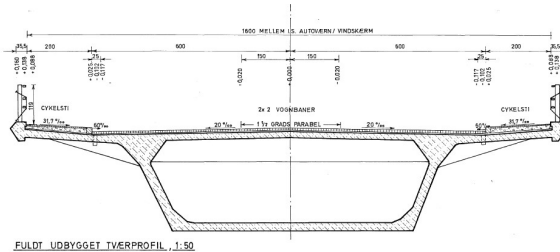
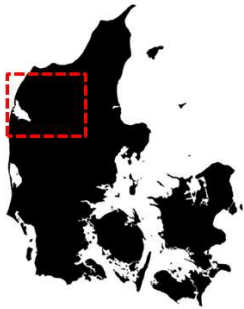
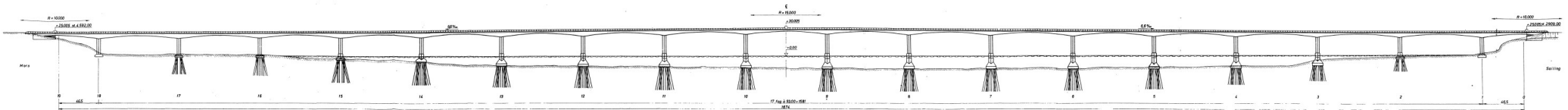
## Construction sequence



## Cap placement and concreting



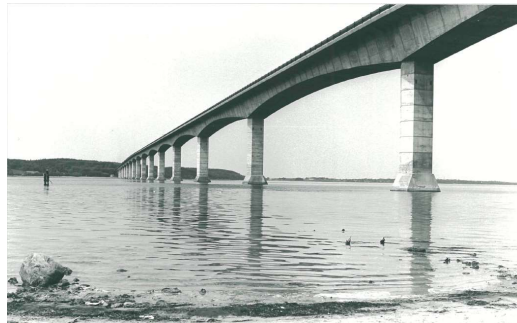
# THE SALLINGSUND BRIDGE



FULD UD BYGGET TVERPROFIL, 1:50

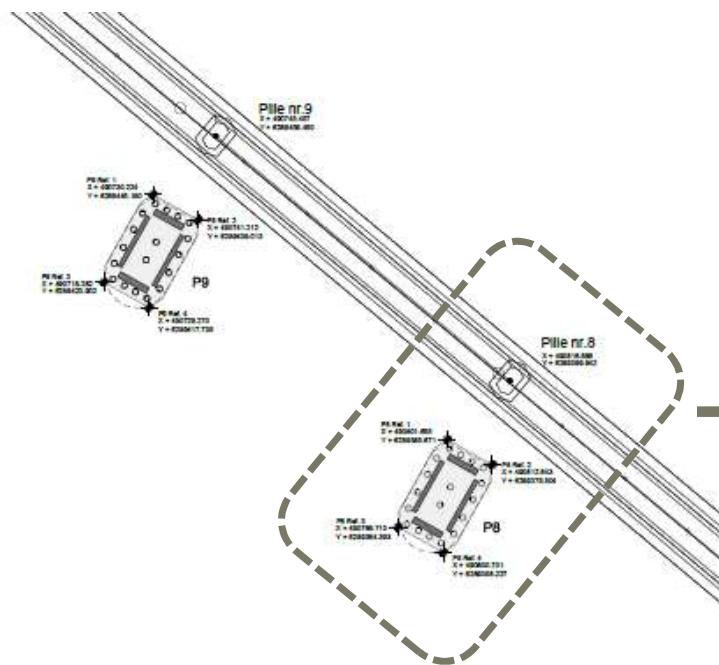
## SALLINGSUND BRIDGE:

- Completed in 1978.
- Connects Salling peninsula and Mors island
- Total length 1700m (17 X 93m + 2 X 46.5m)
- Total width of the deck: 16m
- Vertical clearance to sea: 26m



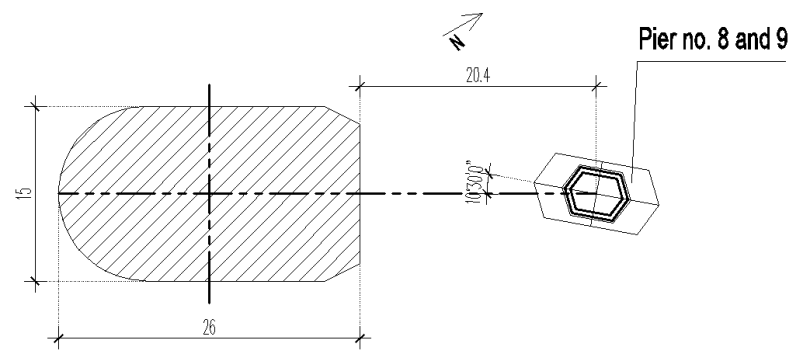
# SALLINGSUND BRIDGE

## Layout of protective dolphins

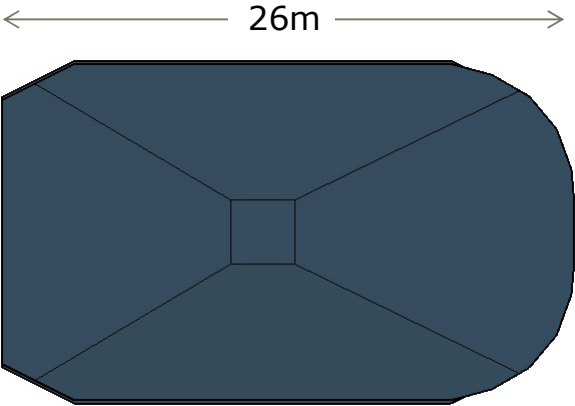


**ACCEPTABLE LEVEL OF PROTECTION:**

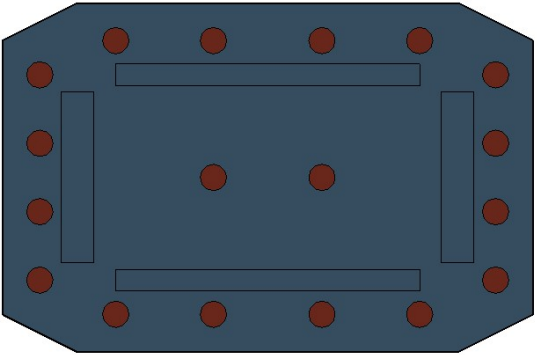
**Two independent protection structures south of piers no. 8 and 9**



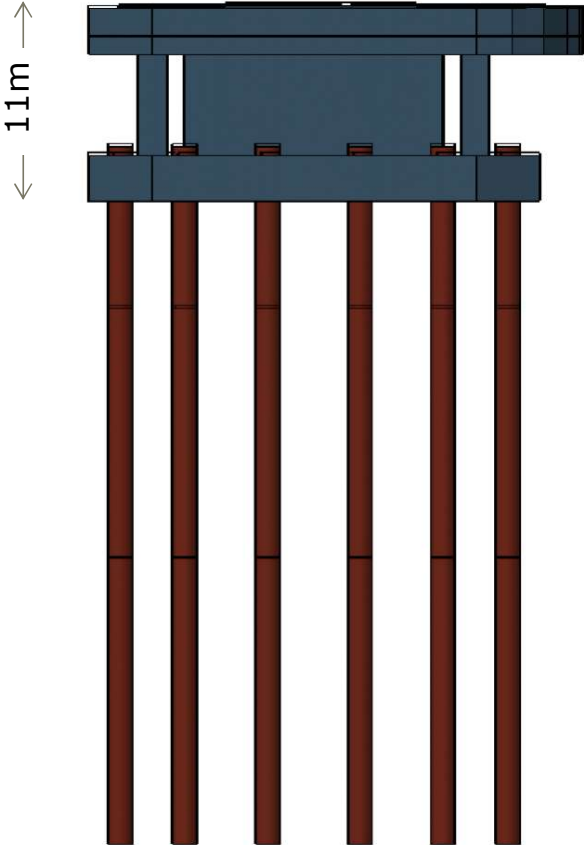
# SALLINGSUND BRIDGE Dolphin geometry



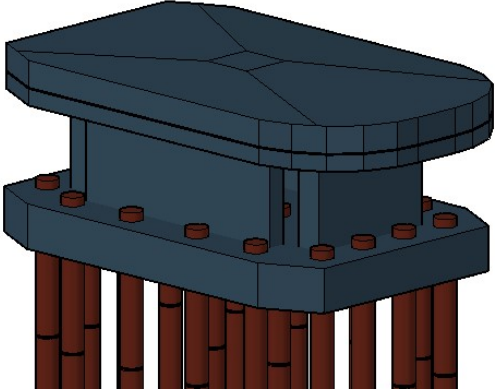
Top slab



Bottom slab



Side elevation



# SALLINGSUND BRIDGE

## Geotechnical conditions

### Gyttja:

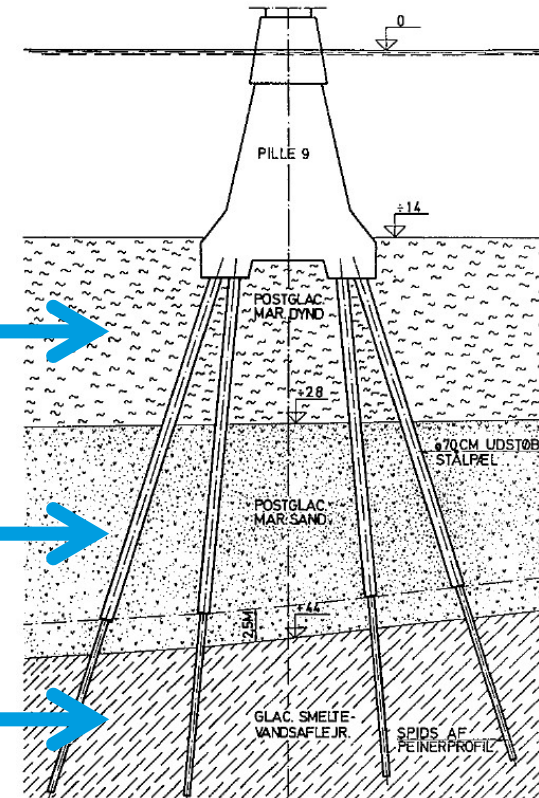
$C_u = 0-18 \text{ kpa}$   
 $\gamma' = 1 - 1.5 \text{ kN/m}^3$

### Marine sand (PG and SG):

$\phi = 33 - 39^\circ$   
 $\gamma' = 9.5 \text{ kN/m}^3$

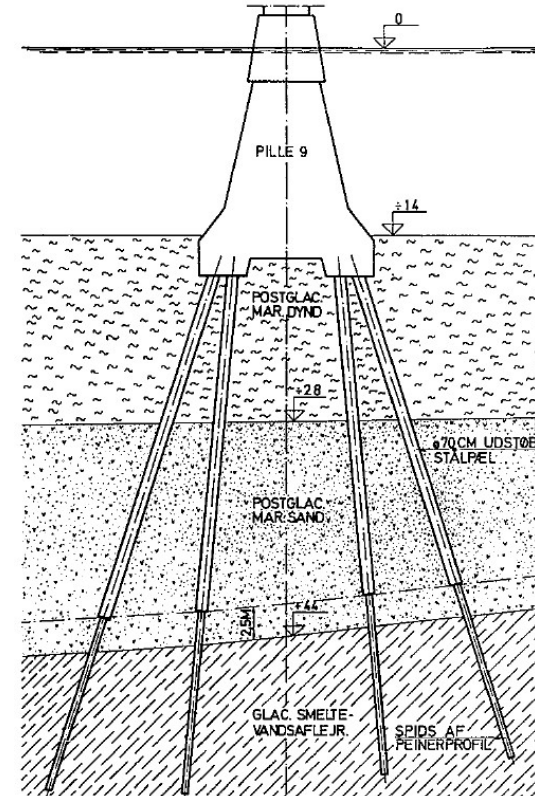
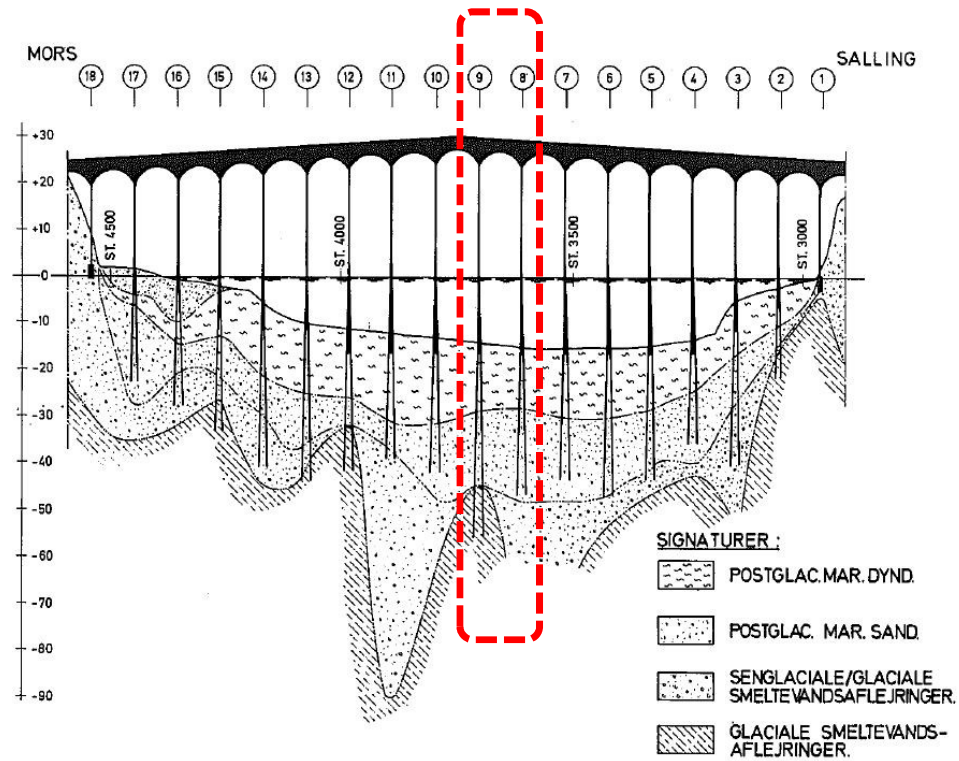
### Glimmerler:

$C_u = 80-130 \text{ kpa}$   
 $\gamma' = 8.0 \text{ kN/m}^3$



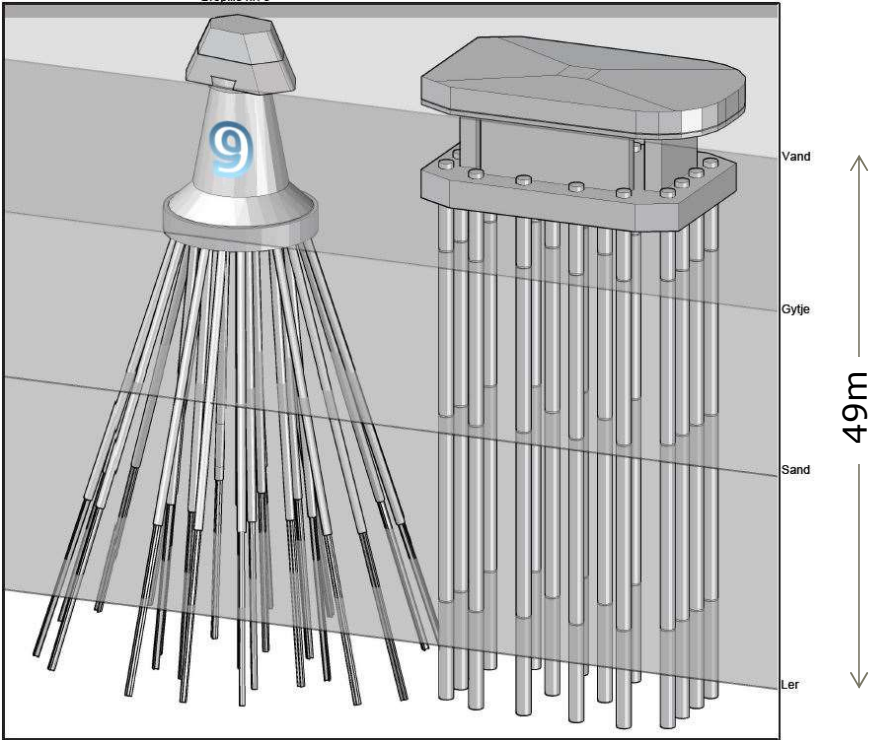
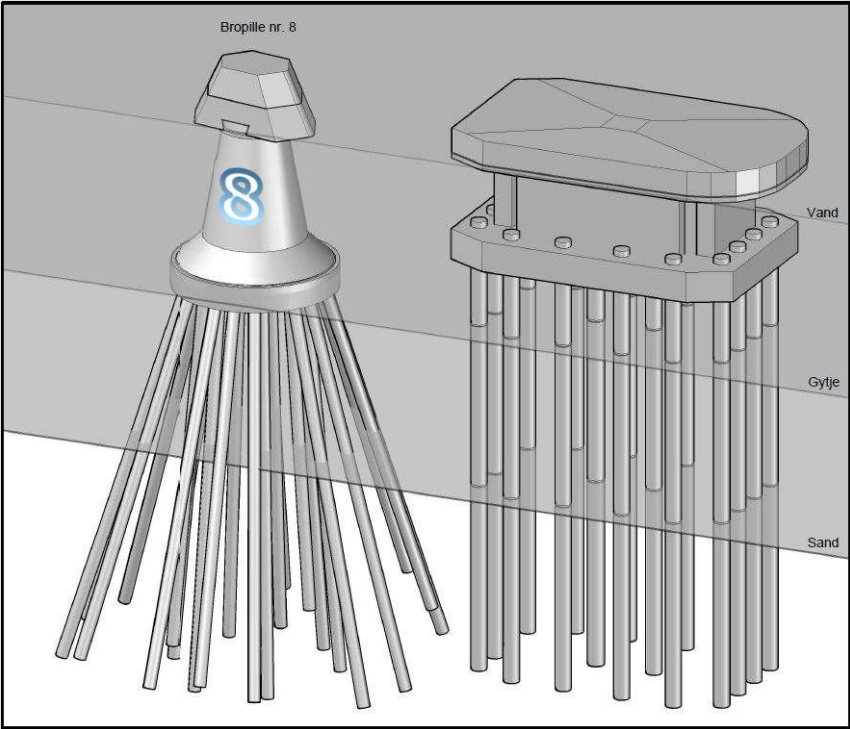
# SALLINGSUND BRIDGE

## Geotechnical conditions





# SALLINGSUND BRIDGE Piles

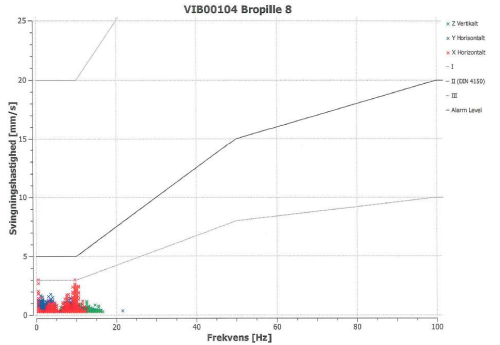
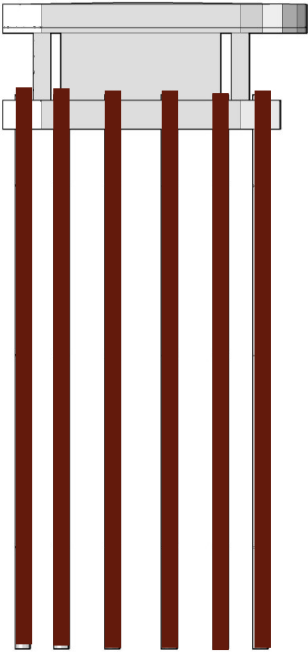


Tubular piles: Ø1220mm / 40(30,20) mm



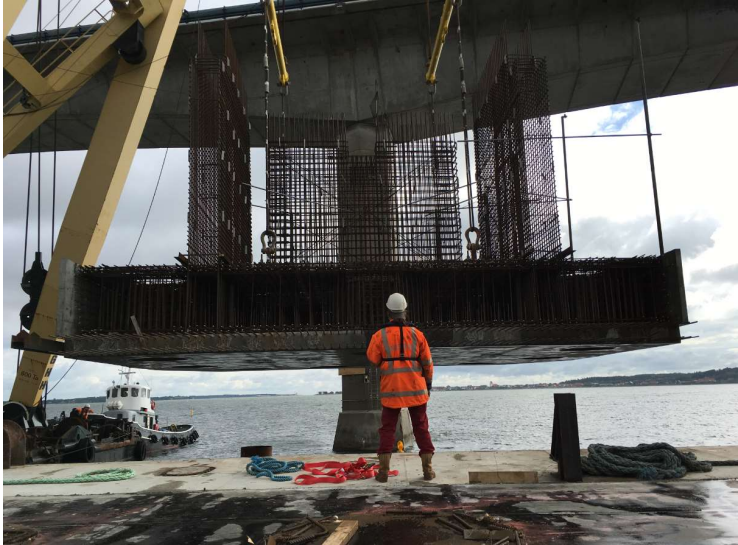
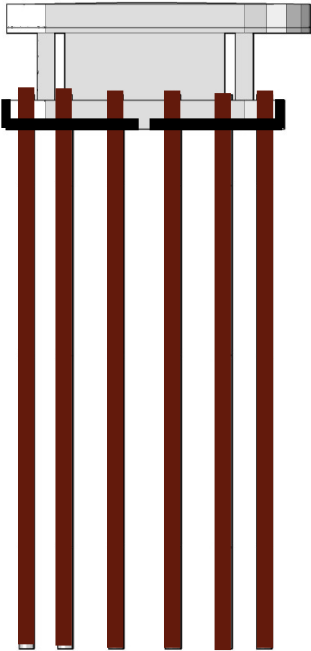
# SALLINGSUND BRIDGE

## Construction sequence – pile installation



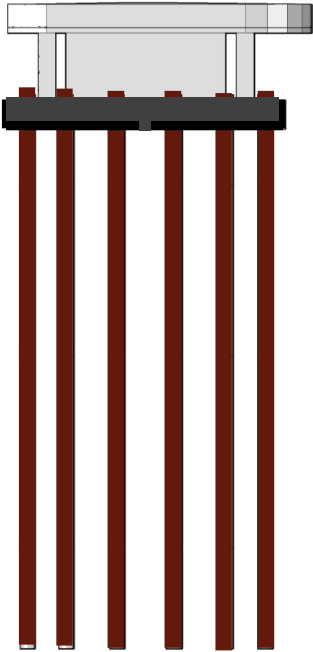
# SALLINGSUND BRIDGE

## Construction sequence – prefab. elements for bottom plate



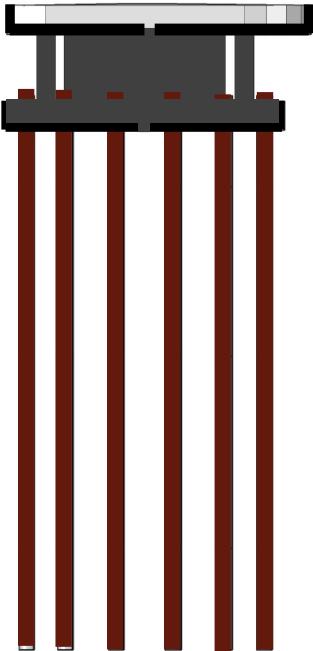
# SALLINGSUND BRIDGE

## Construction sequence – casting of bottom plate



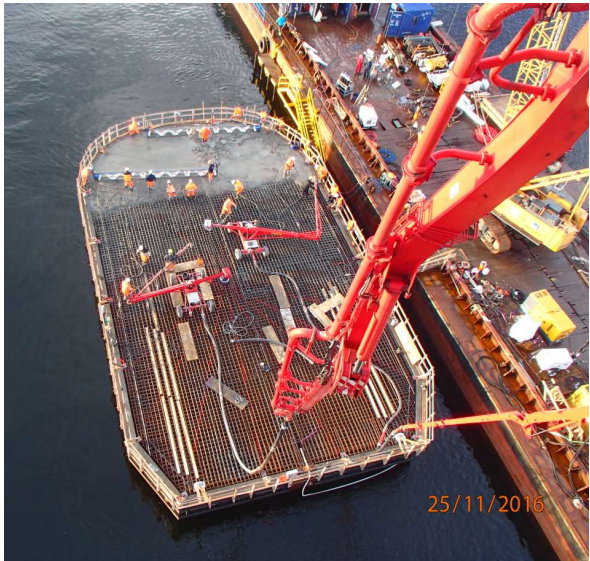
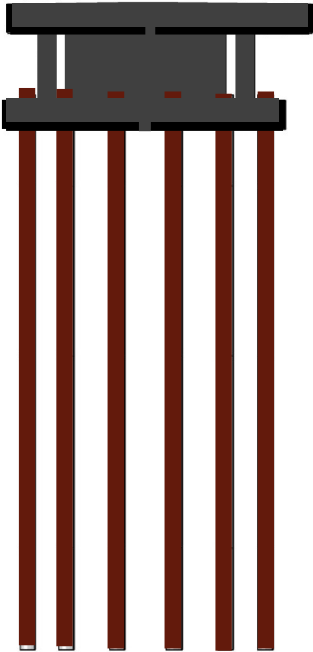
# SALLINGSUND BRIDGE

## Construction sequence – prefab. elements for top plate



# SALLINGSUND BRIDGE

## Construction sequence – casting of top plate

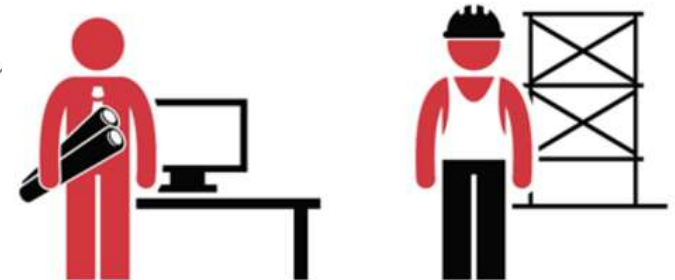


# MARINE STRUCTURES

## Best practice

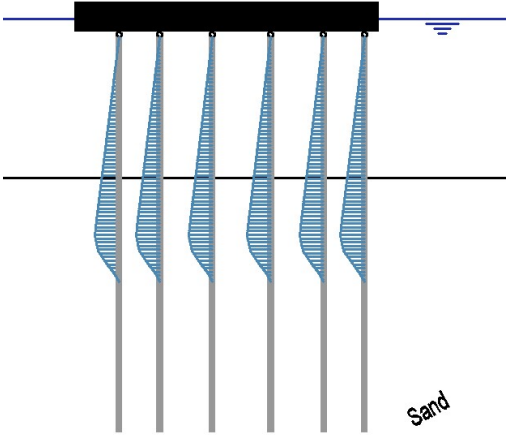
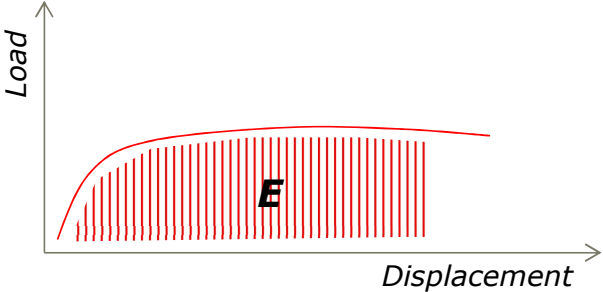
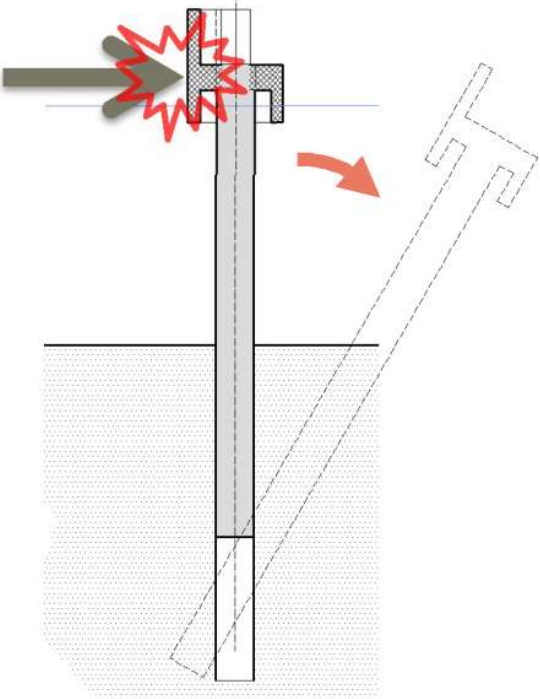
### HOW TO MINIMIZE PROBLEMS:

- Prefabrication
- Minimize diver's works
- Construction sequence detailed during design
- Cooperation between Designer and Contractor



# STATIC SYSTEM

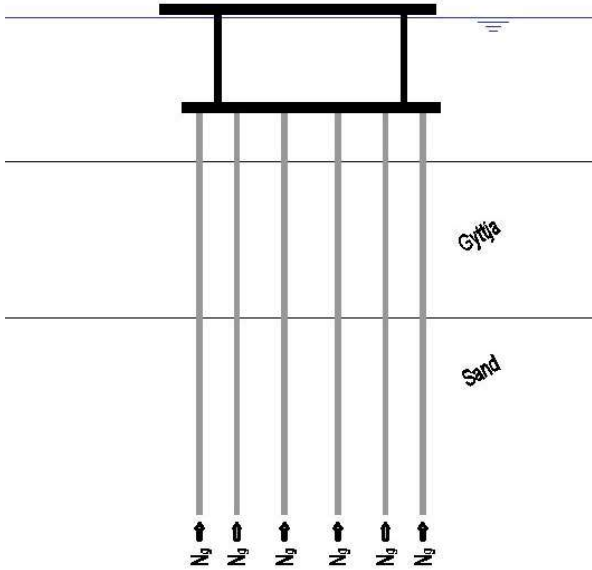
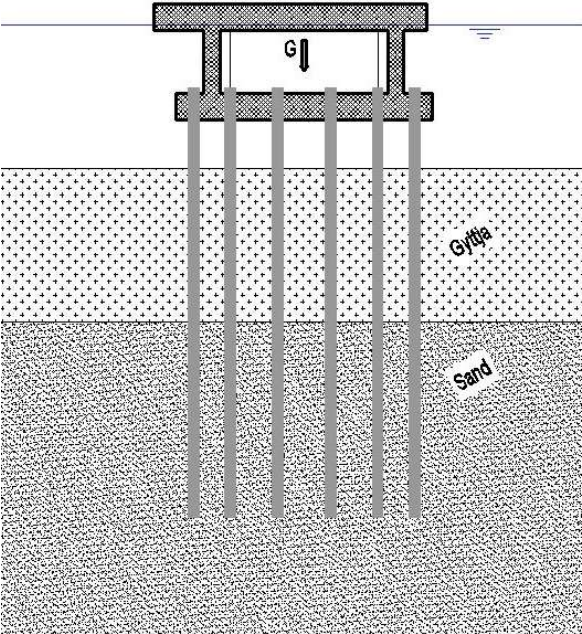
## Typical dolphin





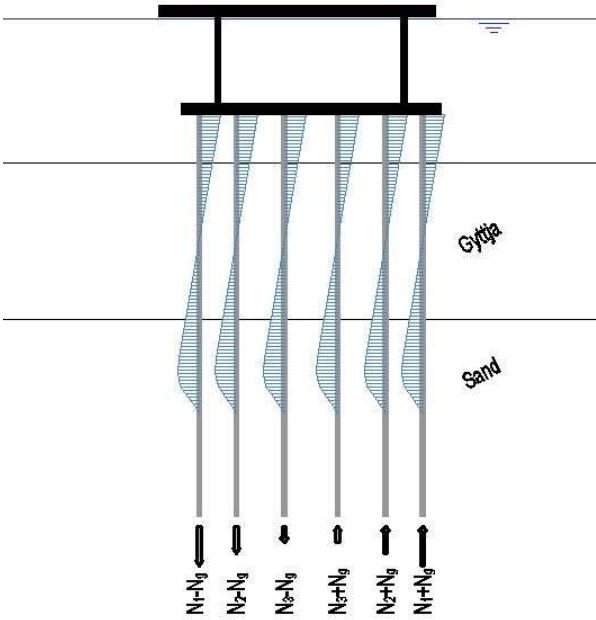
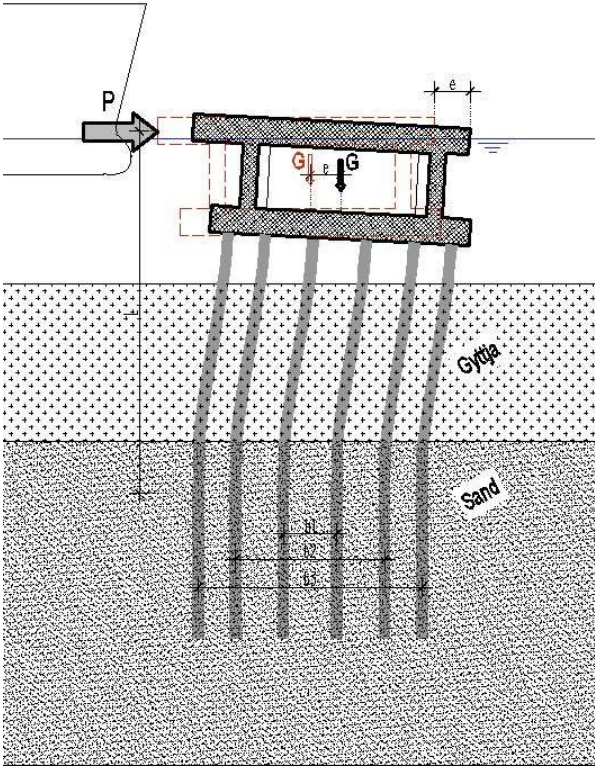
# STATIC SYSTEM

## Sallingsund dolphin



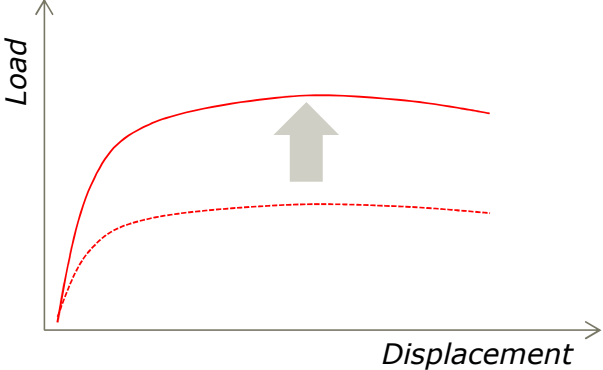
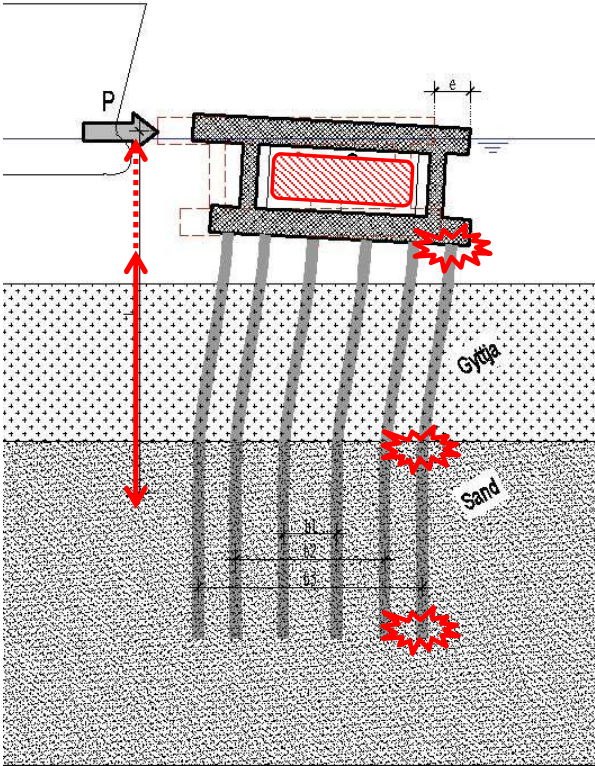
# STATIC SYSTEM

## Sallingsund dolphin



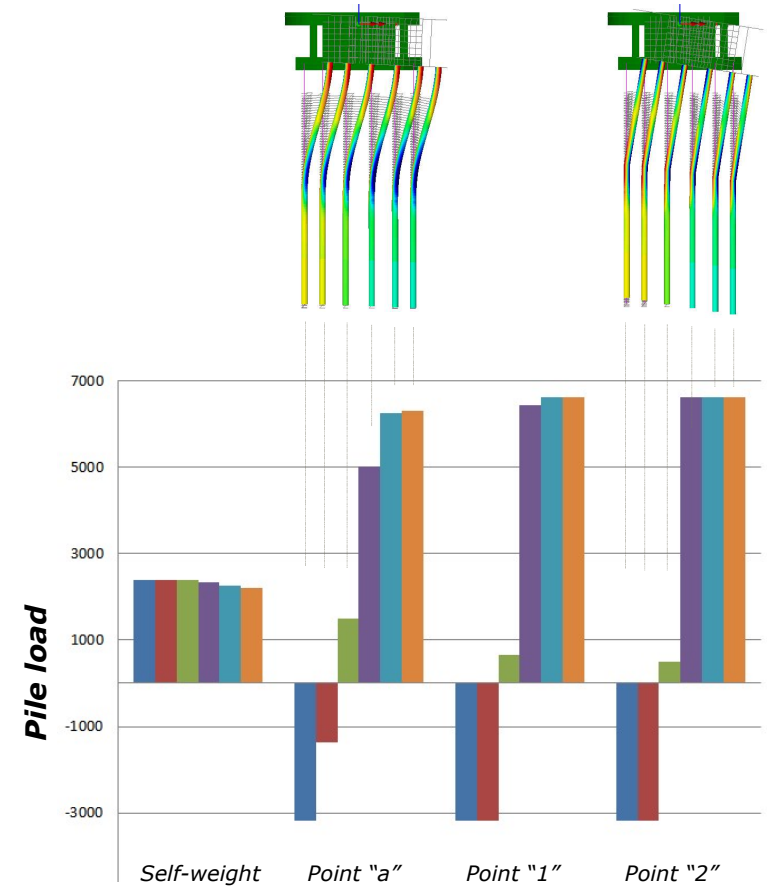
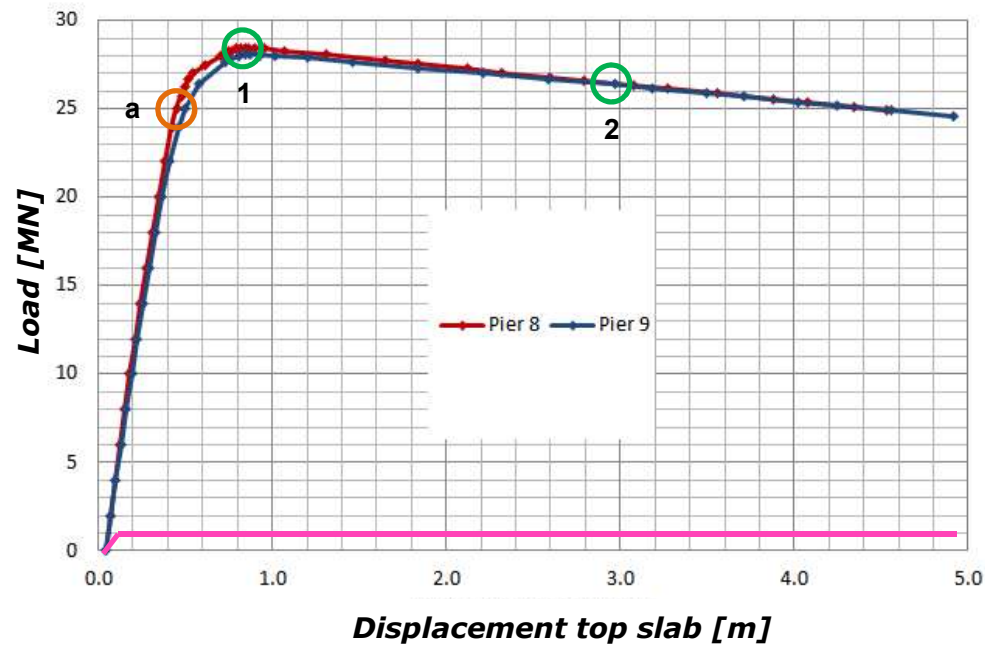
# STATIC SYSTEM

## Sallingsund dolphin

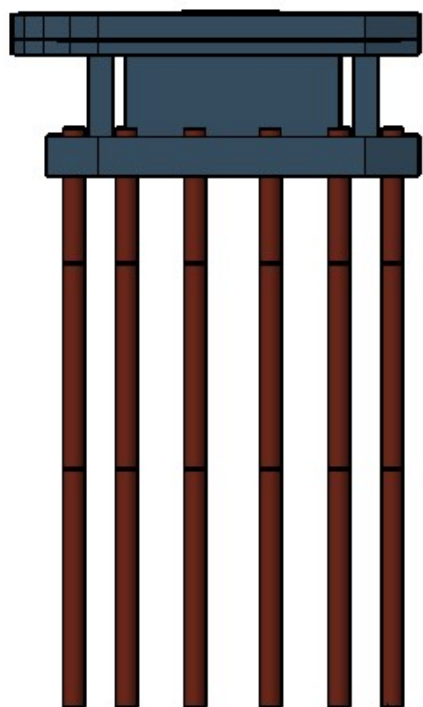


# RESULTS

## Work curve



# COMPARISON



## Sallingsund:

Required stopping energy:

**70 MJ**

Cost per dolphin:

**20.5 MDKK**

Max col. vessel displacement:

**6000 t**



## Masnedund:

Required stopping energy:

**3.5 MJ**

Cost per dolphin:

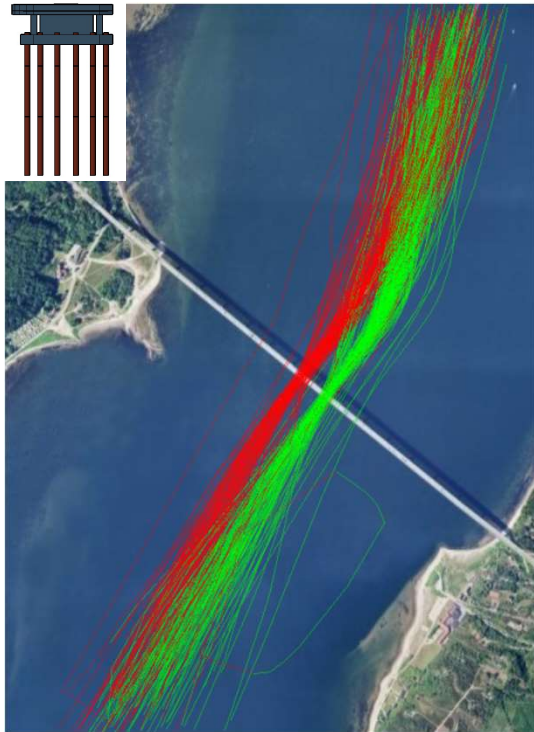
**0.72 MDKK**

Max col. vessel displacement:

**7000 t**



# RISK SCENARIO



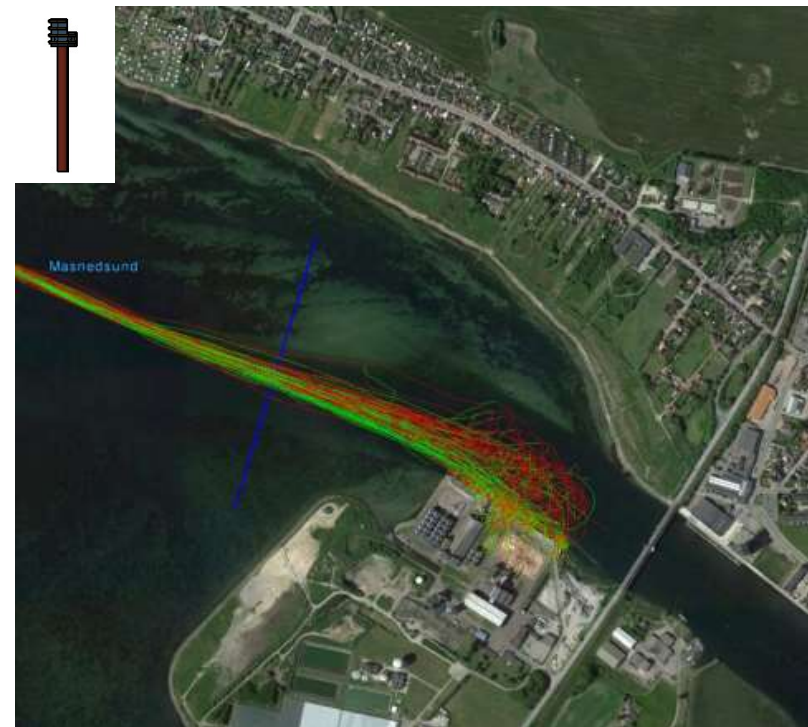
**Design collision speed: 4.8 m/s**



Northbound



Southbound



**Design collision speed: 1 m/s**

# PROTECTIVE DOLPHINS

## DESIGN DRIVING FACTORS:

- **Geotechnical conditions**
- **Water depth**
- **Layout constraints**
- **Collision scenario**

# QUESTIONS ?