

## NOTE

17 January 2011

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**To:** Whom it may concern

**From:** Femern A/S

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## Geotechnical Investigations Activities Overview

### 1. General

The overall purpose of the geotechnical investigations is that Femern A/S at any time during the project development can supply the necessary information about the ground conditions to authorities, consultants and contractors involved in the project.

Preliminary geotechnical investigations for the Fehmarnbelt Fixed Link were performed as part of the feasibility study in 1995/96, for the German and Danish ministries of transport.

The project geotechnical investigations are performed over the years 2008-2012 by Femern A/S, the state owned Danish organization responsible for the preparatory work for the link.

Following the EU procurement procedure, Femern A/S has appointed Rambøll Arup Joint Venture as geotechnical consultant. The investigations are performed by this organization and investigation contractors, selected according to the EU procurement procedures.

These investigations are designed to meet the design and construction requirements of a fixed link, covering both a bridge solution and a tunnel solution. The investigation corridor covers a wide area in Fehmarnbelt east and west of the existing ferry harbours. In 2009 and 2010, the geotechnical investigations have focussed on a corridor east of the existing ferry route between Rødbyhavn and Puttgarden.

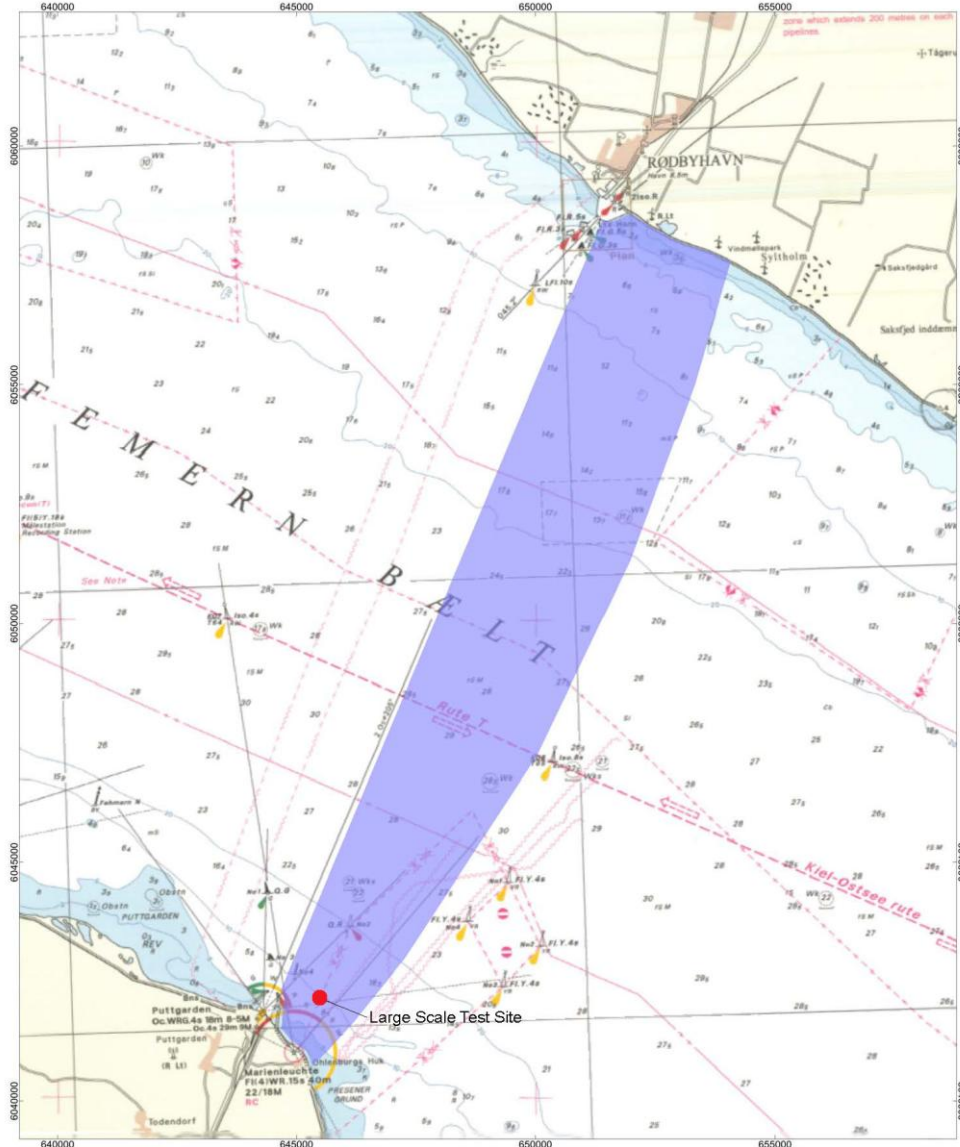
The main elements of the project investigations are:

- Organizing the existing and new information in a state-of-the-art geo information system
- Establishing a project specific positioning system
- Geophysical surveys
- Geotechnical boring campaign
- Advanced laboratory testing

- Large scale on site testing

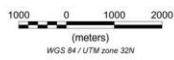
Eventually, during construction, the contractors are anticipated to perform detailed control investigations for all parts of the selected project and thus verifying the basis established during the project investigations.

# Femern Sund ≈ Bælt



  
Corridor

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(G.7-98)  
\*KAN IKKE ANVENDES TIL NAVIGATION\*



**Femern A/S**  
Investigation Corridor  
Rev. B 2010-07-14



## 2. Geo Information System

All geo-related information has been installed in the Geo Information System, comprising Geo Database and Geo Archive. This new system includes modern facilities for web-access and searching.

The system is installed on servers at Femern A/S and access will be given to relevant stake holders according to their role in the project.

This system is regularly updated.

## 3. Positioning System

Modern GPS is available to anyone and high accuracies may be achieved by including signals from existing reference stations, correcting local errors. Such systems are named Differential Global Positioning System (DGPS).

In order to limit the necessary number of radio frequencies and for improved reliability and accuracy, Femern A/S has established a project specific Global Navigation Satellite System (GNSS) with four reference or relay stations around the project area. These stations are transmitting signals to a control centre that is transmitting Real Time Kinematic (RTK) data to surveyors working in the project area.

This facility comprises:

- *The Positioning Reference System*, i.e. the theoretical geodetic basis, established in cooperation with Kort og Matrikelstyrelsen (KMS) in Denmark and Bundesamt für Kartographie und Geodäsie (BKG) in Germany.
- *The Positioning Reference Frame*, i.e. the physical establishment in the form of GNSS-stations at 2 locations in Denmark and 2 in Germany, all located close to the shores. Furthermore, the reference frame comprise equipment and instruments for transmission systems, rover stations etc.

Establishment, operation and maintenance of the Positioning Reference Frame has been entrusted to a specialist firm, AXIO-NET GmbH in Hannover.

This system was commissioned in August 2010.

## 4. Geophysical Surveys

### **General**

The purpose of geophysical surveys is to improve the geological understanding by identifying the various soil layers and the nature of the seabed and any objects hereon.

Furthermore, these surveys contribute to archaeological and environmental knowledge.

These surveys have been performed by the consultant in 2008 and supplemented in 2010.

### **Offshore**

Vessels surveyed the entire Fehmarnbelt in 2009.

In the vicinity of the ferry route, the survey works were intensified with lines across the belt with a spacing of only 25 m.

The survey comprised multi beam echo sounder, side scan sonar, different reflection seismic, and magnetometer. Receiving hydrophones were towed in a streamer behind the vessel. Objects of interest were inspected by remotely controlled video cameras.

### **Onshore**

These surveys were carried out during the summer and autumn 2008, following the completion of the harvesting season.

On Fehmarn, the survey area extended from the shore and 2 km inland and 1 km on either side of the road/railway connection to the ferry harbour and to the west of Marienleuchte.

On Lolland, a similar corridor with centreline approximately 1 km to the east of the ferry harbour was investigated, likewise extending 2 km inland and 2 km wide.

The surveys comprised:

Reflection seismic profiling performed by a medium size off road vehicle, towing a vibration trailer and a 250 m long cable streamer with geophones mounted on small sledges. This profiling preferably takes place on existing roads.

MEP (Multi Electrode Potential), using a light transport vehicles (i.e. 4 wheel motor bike) and light hand carried measuring equipment. Preferably on virgin land.

## 5. Boring Campaign

### **General**

The purpose of the boring work is to obtain information on all soil layers to a depth of 50-100m below the seabed.

Borings Type A were carried out by continuous coring, aiming at obtaining full sample coverage of the entire depth penetrated.

In addition to sampling, the borings enable measuring of soil properties, geophysical bore hole logging and laboratory classification testing.

Borings Type B were carried out next to borings Type A. These Type B borings are meant for in situ strength measurements in the form of Cone Penetration Testing, CPT.

All borings were properly grouted after completion.

In order to fully benefit from relevant experience, correlation borings were carried out at the old Lillebælt Bridge and at the Fehmarnsund Brücke. These two bridges have similar ground conditions and their performance has been monitored for 75 and 45 years respectively.

The boring work was performed by a specialized boring contractor, Fugro Engineers BV, Holland.

### **Offshore**

A jack-up platform was performing geotechnical borings in the project corridor. In total say 30 (double-)borings.

The platform was assisted by tug-boats and guard ships, facilitating smooth cooperation with other ships.

A drill ship performed CPTs from the seabed and until a depth of 25 metres.

### **Onshore**

Truck mounted drill rigswere performing the geotechnical borings. In total say 5 borings in Germany and 5 borings in Denmark.

On Fehmarn, some 30-40 CPTs were performed from terrain and to 25 metres of depth.

Stand pipes for continuous groundwater monitoring were established in wells under protected covers as agreed with relevant authorities.

The boring campaign was completed in December 2010

## **6. Advanced Laboratory Testing**

On selected samples from the boring campaign, advanced laboratory testing is being performed for determining the soils deformation and strength characteristics.

This testing is carried out by a specialist firm, GEO, Denmark.

The samples are handed over to GEO in refrigerated containers in Rødbyhavn and transported to the laboratory.

In the laboratory, the samples will undergo advanced testing. Firstly, the samples will be restored by repeating their load history and hereafter the samples will be exposed to conditions, simulating the effects of the coming construction.

## **7. Large Scale Testing**

The purpose of large scale testing in the project area is to measure ground properties and construction element's performance in a scale comparable to real life structures. Likewise, time effects may be studied over several years.

The test field is located at the seabed northeast of Fehmarn.

The test field enables the investigation of such important issues as settlements and swelling, pile bearing capacity, ground anchor capacities, plate load tests etc.

The large scale testing has been entrusted to the Danish contractor Per Aarsleff A/S.

With respect to the pile testing, Femern A/S has entered a research and development program headed by the Norwegian Geotechnical Institute concerning the time effects on pile bearing capacity. This program runs in parallel to the Large Scale Testing.

## 8. Time Schedule

The activities described above will time wise be organized as a top down process, starting with overall understanding and finishing with all necessary facts.

ACTIVITY	Year 2008	Year 2009	Year 2010	Year 2011	Year 2012	Year 2013
<b>Geo Information System</b>	■					
<b>Positioning System</b>		■	■			
<b>Geophysical Surveys</b>	■		■			
<b>Boring Campaign</b>		■	■	■		
<b>Advanced Laboratory Testing</b>			■	■		
<b>Large Scale Testing</b>			■	■	■	■