Geodetic Infrastructure and Positioning for the Fehmarnbelt Fixed Link

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Agenda

Short overview of the Fehmarn project

Geodetic Infrastructure:
- Organisations involved
- Permanent GNSS stations and reference frame
- Mean sea level
- Realization of new height system
- Geoid model
- Map projection
- Coordinate transformations
- GNSS RTK service

Concluding remarks

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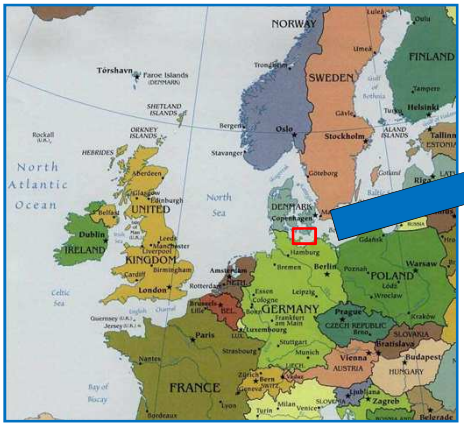
The Fehmarnbelt



Stretch of water between Germany and Denmark

18 km wide

Map from www.huntingdon.edu

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The Fehmarnbelt Fixed Link

Realises a fixed link between Scandinavia and continental Europe

The link is considered important for European economy

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The Fehmarnbelt Fixed Link

- Geotechnical, geodetic and environmental preparations almost complete and early works on land has started
- Construction work on the tunnel is planned to commence in 2016
- The fixed link is planned to open in 2021
- Will be 18 km long immersed tunnel, consisting of four-lane highway and double railway track

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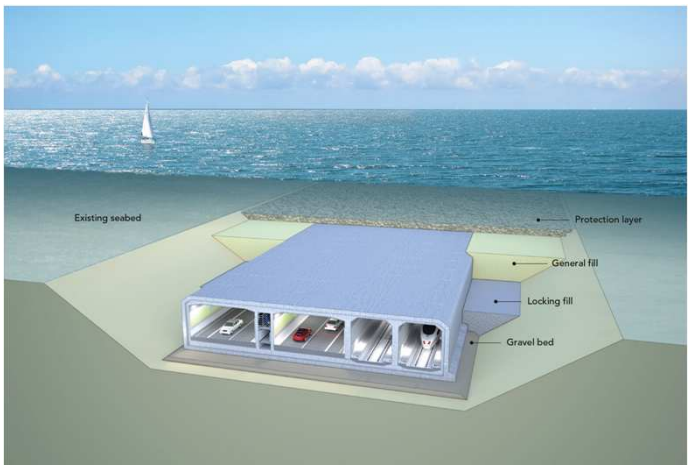
The Fehmarnbelt Fixed Link



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Organisations involved

Builder:	Femern A/S
Adviser, geodesy and positioning:	Rambøll Arup TEC JV
Contractor, positioning:	AXIO-NET GmbH
Sub contractor:	Allsat GmbH and others

Consultants, geodesy:

Germany: "Bundesamt für Kartographie und Geodäsie" and "Landesamt für Vermessung und Geoinformation Schleswig-Holstein"

Denmark: "National Geodata Agency", "National Space Institute" and "National Road Directorate"

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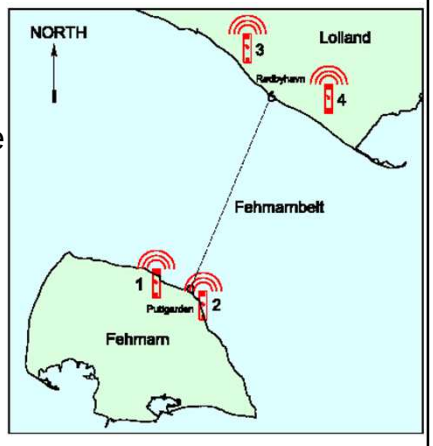
Permanent GNSS stations

Permanent geodetic grade GNSS stations established to form basis for the geodetic reference frame and for the RTK service

Coordinates of the stations are re-processed at regular intervals to monitor stability



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Permanent GNSS stations

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Permanent GNSS stations

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Geodetic reference system and reference frame

The ITRS is used as the geodetic reference system with the ITRF2005 reference frame

Coordinates for the four permanent stations were determined with seven days of GPS-data and the Bernese software to form the local realisation of the reference frame

Coordinates were determined relative to international IGS–stations coordinated in the ITRF2005

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Mean sea level

Analyses of 20 years of water level data from Puttgarden in Germany and Rødbyhavn in Denmark used for estimation of mean sea level

Zero level in new height system defined to be mean sea level in Rødbyhavn 2010

New height system realised by hydrostatic levelling and by precise motorized levelling

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Realization of new height system

- In 1987 a hydrostatic levelling was carried out across Fehmarnbelt between Puttgarden and Rødbyhavn
- In 2009 control levelling carried out to verify stability of existing benchmarks
- Then, levelling was done on both sides to connect; tide gauges, end points of the hydrostatic levelling, and levelling bolts at the four GNSS stations
- Hydrostatic levelling used to transfer height over Fehmarnbelt

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Precise motorized levelling

All levelling has been carried out by the Danish Geodata Agency using precise motorized spirit levelling

A priori standard deviation: 0.6mm/√km

Supplemented with foot levelling where necessary

Photo: National Geodata Agency, Denmark

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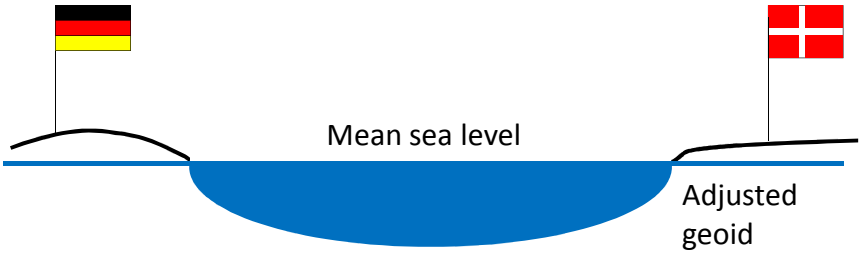
Geoid model



Gravity data was collected, a geoid model was derived and fitted to mean sea level and to the reference frame in the GNSS stations

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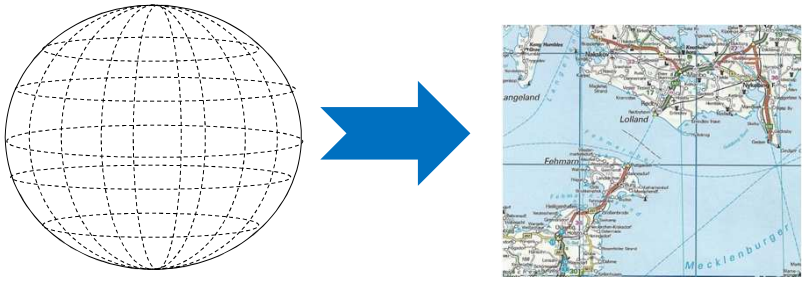
Map projection



A map projection has been defined with minimum distortion inside the construction area

Transverse Mercator with central meridian at 11° 20’

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Coordinate transformations

In both Germany and Denmark realizations of the ETRS89 are used a the national reference frames

For the Fehmarnbelt ITRF2005 is used as reference frame

Coordinate transformation parameters have been derived between both of the national reference frames and the Fehmarnbelt reference frame

Transformation software has been developed by the Danish Geodata Agency, including the geoid model

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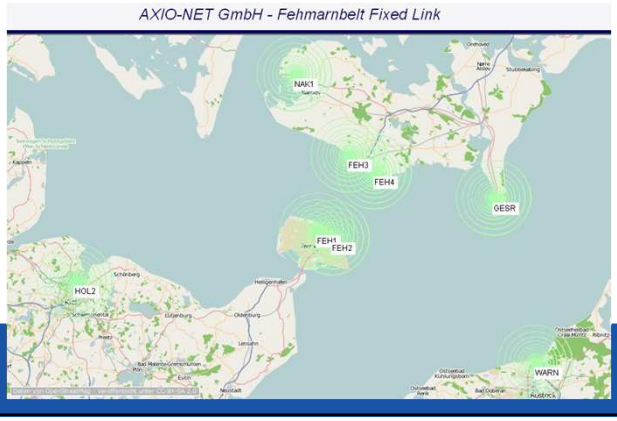
GNSS RTK-service

RTK correction data generated from the four new Fehmarn GNSS stations, supplemented with GNSS data from four secondary GNSS stations further away



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GNSS RTK service

- Network RTK service
- Based on GEO++ software
- Operated by AXIO-NET GmbH
- RTK data distributed via UHF radio or mobile internet

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RTK service - redundancy

- The RTK service is a network based approach, with single station RTK as back up
- A three carrier concept is used for data communication between GNSS stations and control centres
- Two redundant control centres at two different addresses in Germany
- RTK data is distributed both via UHF radio from each GNSS station and also via mobile internet using the NTRIP protocol

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RTK service - performance

Positioning with the RTK service is carried out with an uncertainty of 0.8 cm in the horizontal and 1.5 cm in the vertical (one sigma – 68%)

The numbers are valid under normal operating conditions and with the network RTK solution

Several tests have been carried out and do e.g. reveal that the RTK service can be used with both Leica, Trimble, Topcon and Javad user equipment

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Concluding remarks

The geodetic infrastructure for the fixed link across Fehmarnbelt has been established well in advance before construction work commences. This has provided good opportunities for testing

Upgrade of RTK service to include Galileo when feasible

Disclaimer: The opinions and conclusions presented in this presentation do not necessarily cover the opinions and conclusions of Femern A/S.

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