

February 10, 2021

# Current status and Concrete requirements for the Fehmarnbelt Fixed Link

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18 km

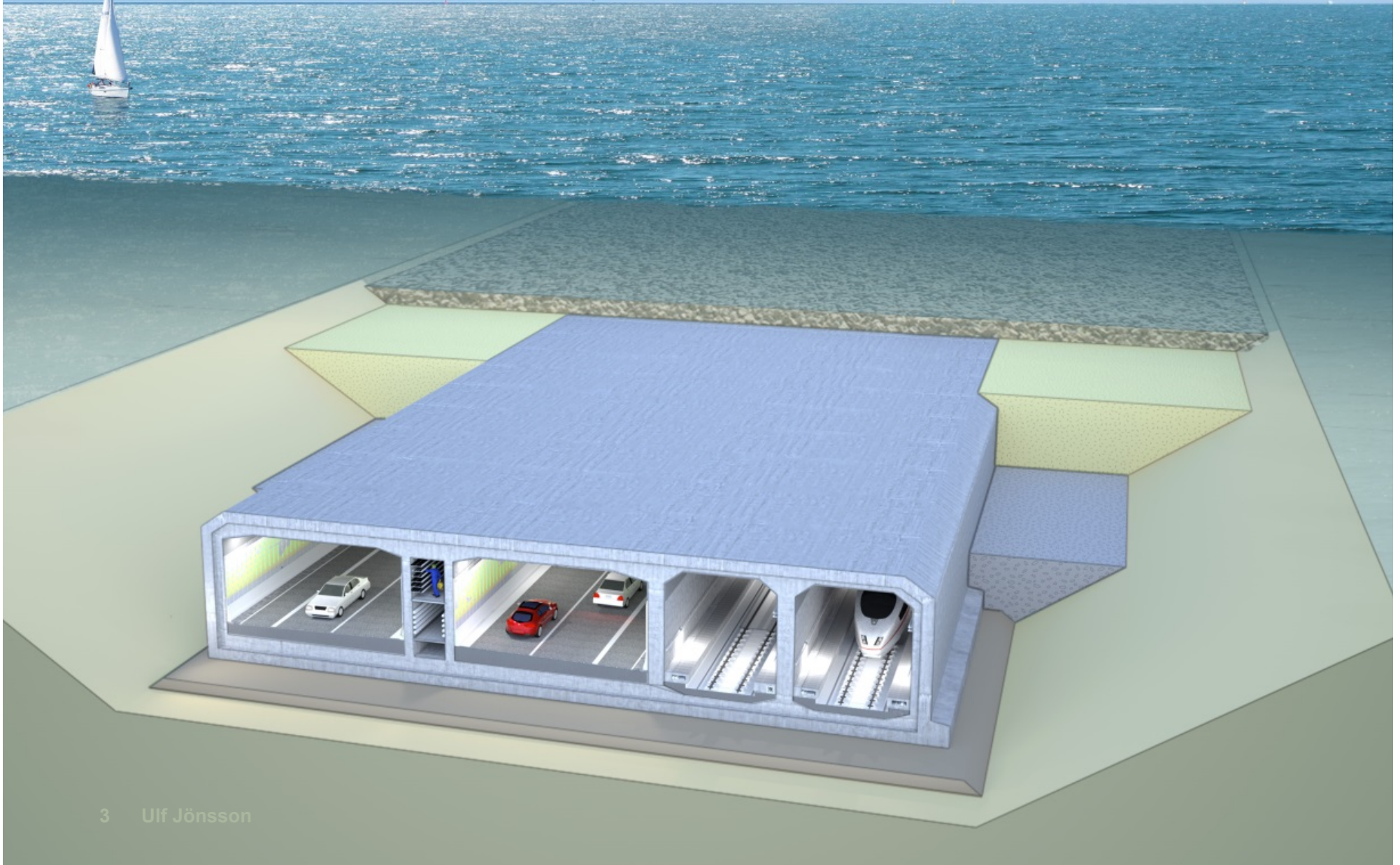
**Femern**  
*Sund ≈ Bælt*

# Connecting Central Europe and Scandinavia

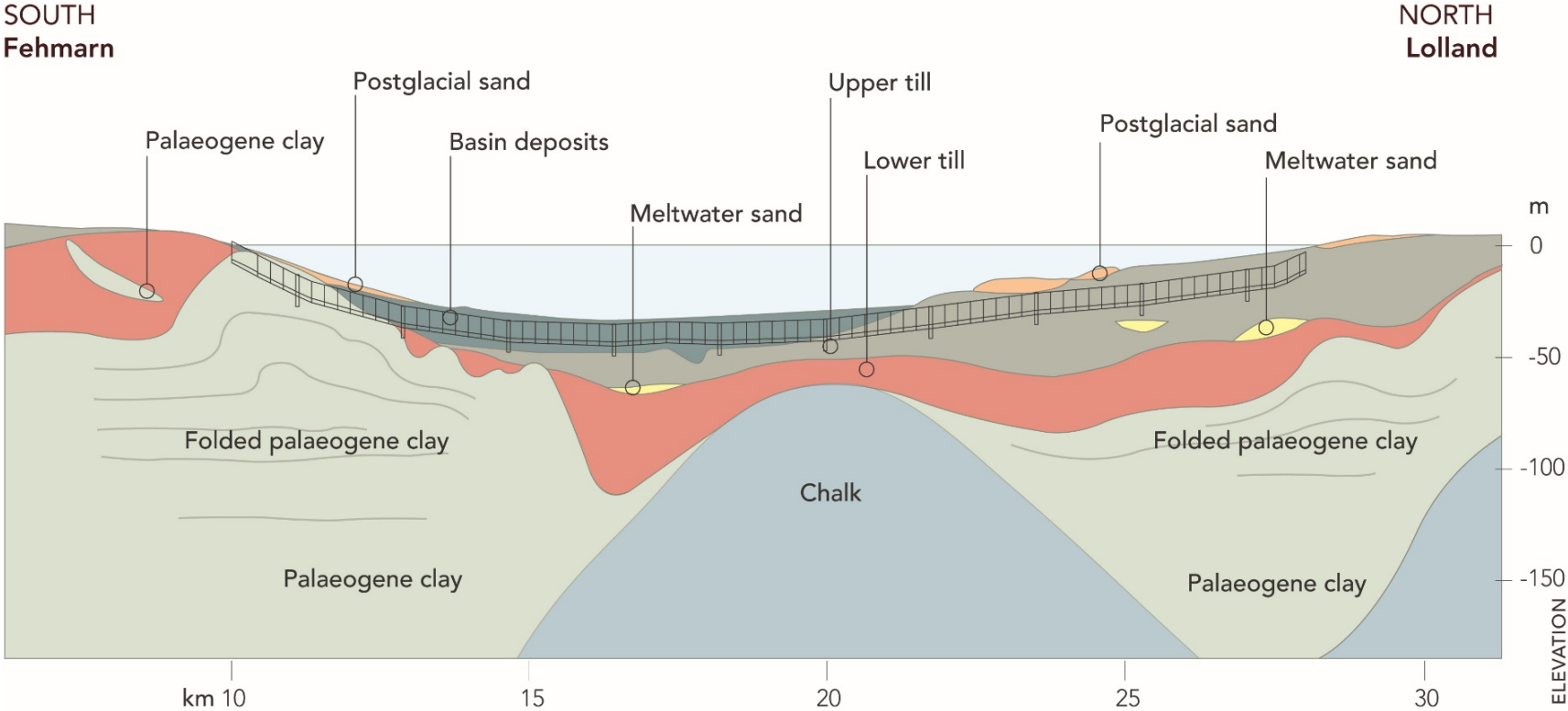




# An immersed tunnel with two tubes for a four-lane motorway and two tubes for a dual-track railway



# The tunnel consist of 89 elements all below current seabed.







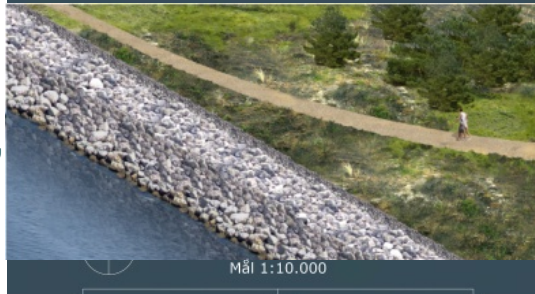
Tunnel portal on Fehmarn,  
Germany



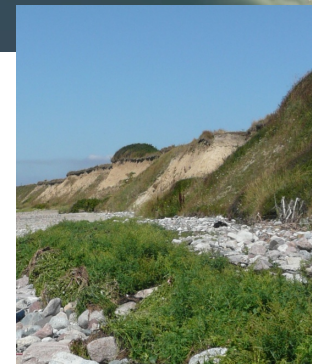
# Beaches, lagoon and channel



# Coastal protection, foot/cycle path

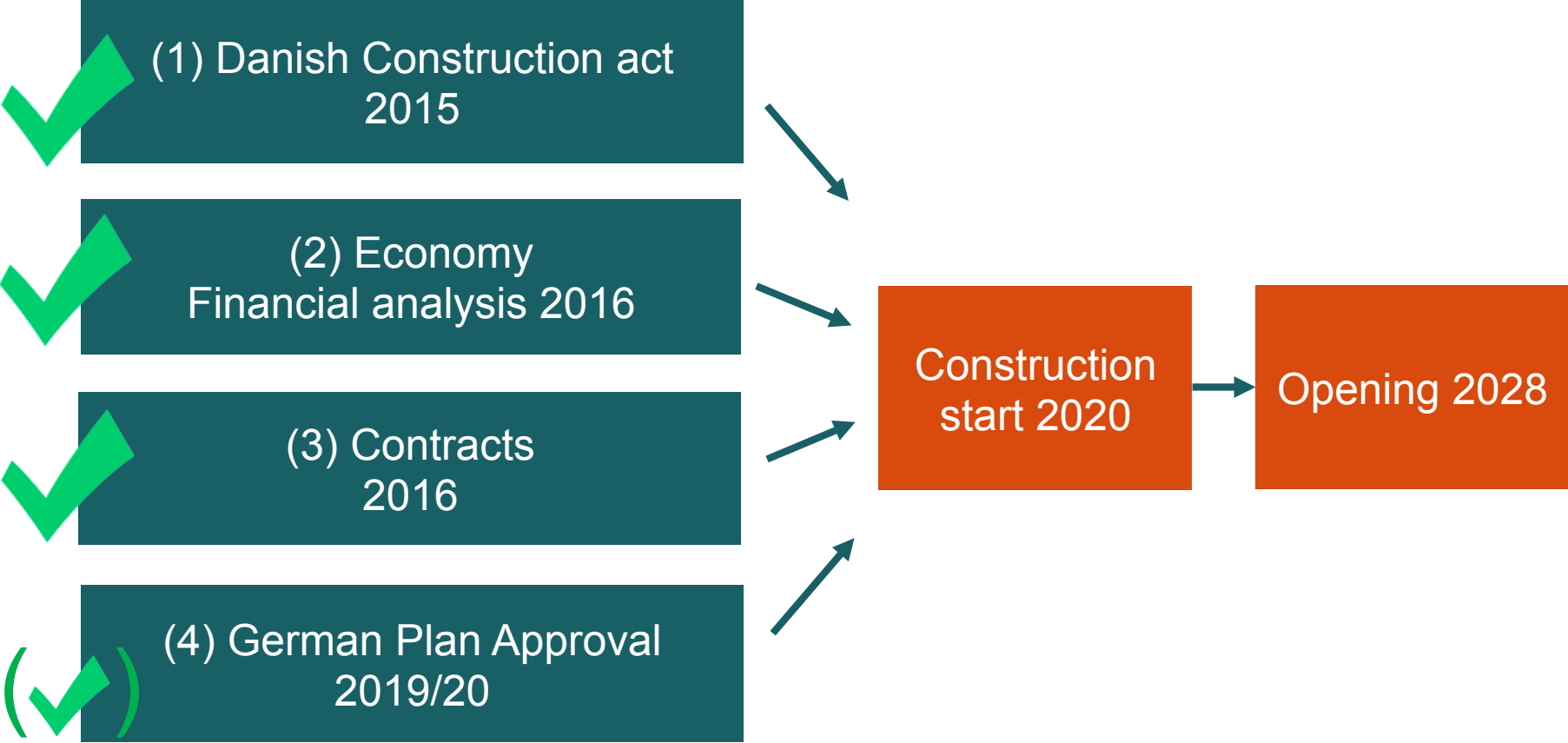


Wetland lagoon





# Status – the tunnel project

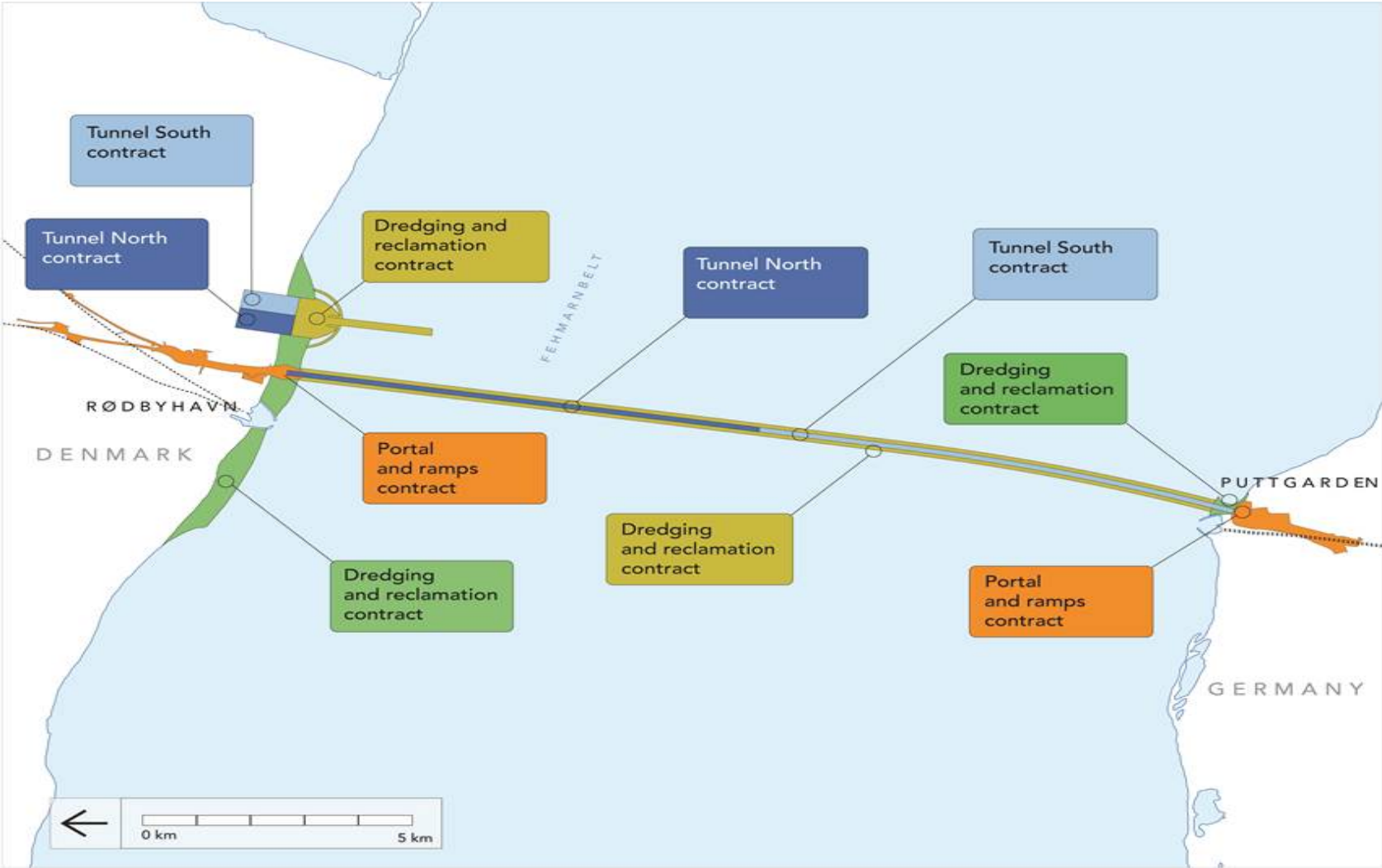


# Approval process in Denmark and Germany

Denmark	Germany
<b>2008:</b> Denmark and Germany sign the State Treaty	
<b>2009:</b> Ratification in the Folketinget (97 % yes, 3 % no)	<b>2009:</b> Ratification in the Bundestag (80% yes, 20 % no)
<b>2013-14:</b> Environmental Impact Assessment hearing process: 1,600 pages and 43 responses	<b>2013-15:</b> Plan approval application hearing process: 10,000 pages and 3,100 responses
<b>2015:</b> Adoption of the final Construction Act in the Folketinget	<b>2015:</b> A new public hearing round was decided in Germany
	<b>2016:</b> Renewed public hearing: 14,000 pages
	<b>2018:</b> Final plan approval decision (Administrative decision)
	<b>2019-20:</b> Court cases



# The Civil Works Contracts



# Contingent Contracts signed 2016

## Tunnel North/South



## Portals & Ramps



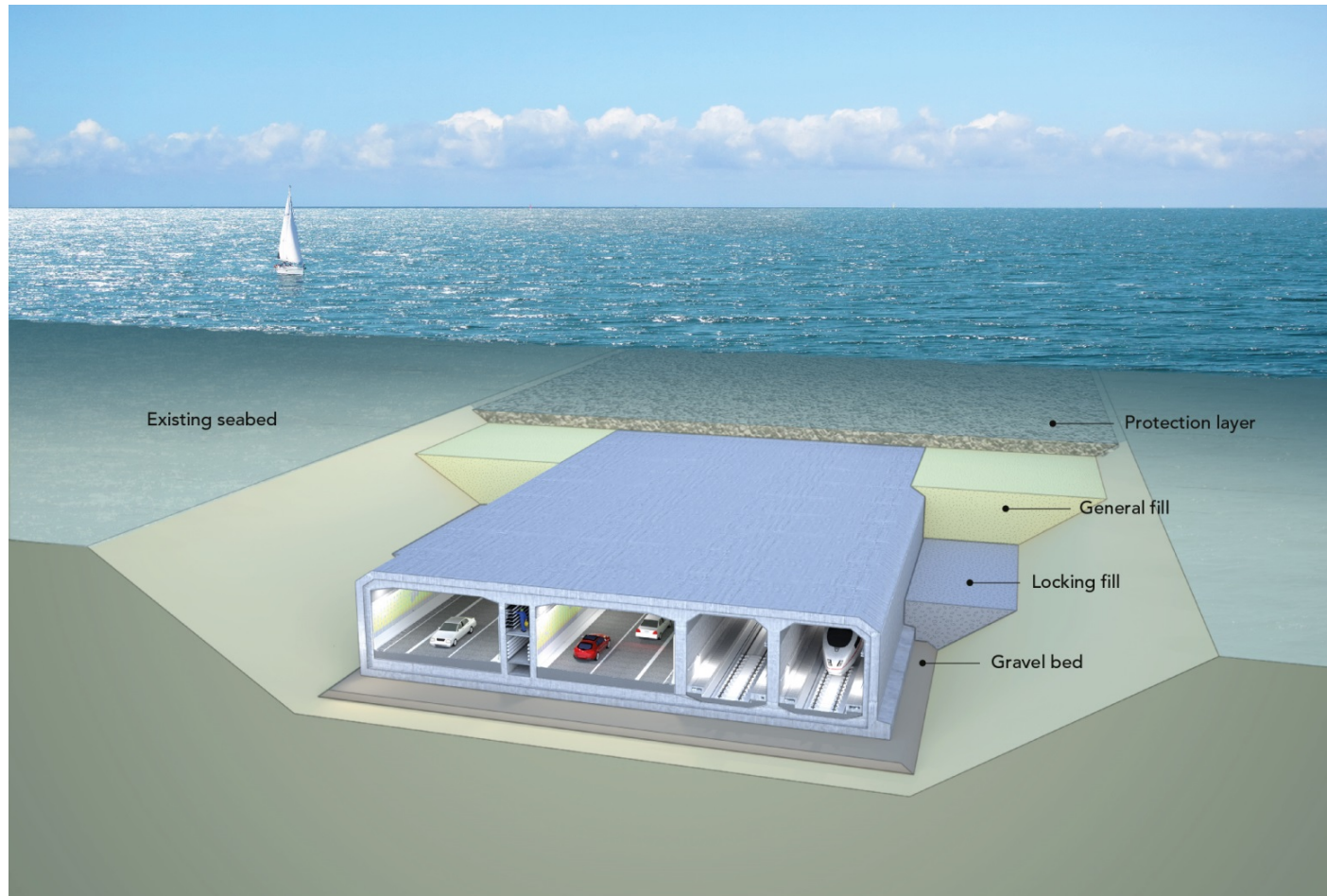
## Dredging & reclamation





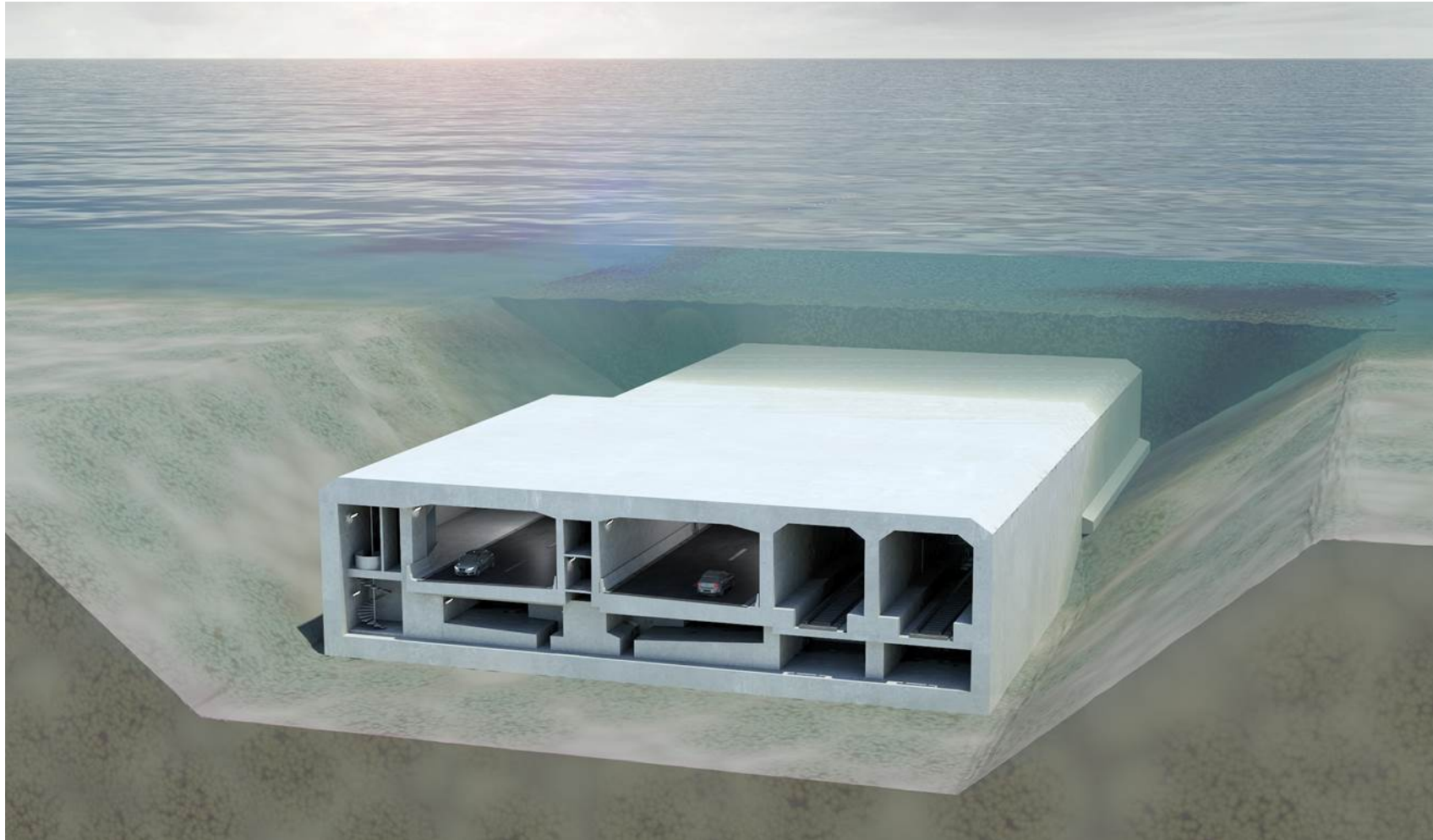
# Immersed tunnel – one of the 79 standard elements

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# One of the 10 special elements

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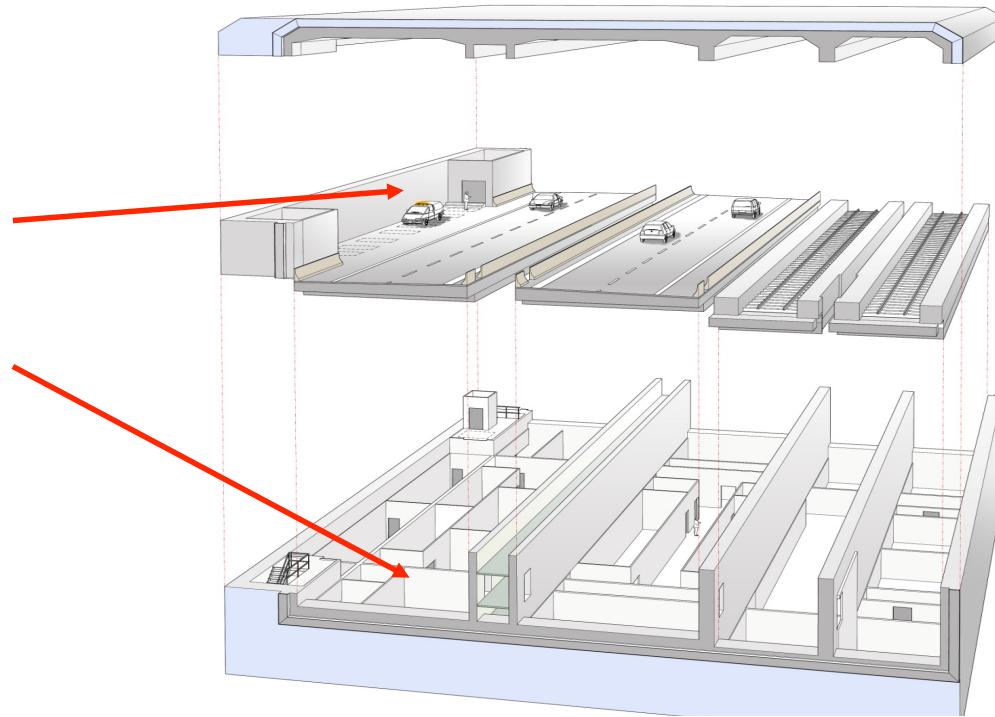


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# Special element

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- 10 special elements
- O&M access
- Access to installation rooms and the different tubes
- Transformerstations
- Electrical switchboards
- Pumpsumps
- Prepared for future safety systems



# Fourth generation – Tender proposal

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FEMERN LINK CONTRACTORS



# Femern A/S exposure site

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- Installation in Rødbyhavn April 2010
- Collection of data for check of the requirements
- Long term data collection for knowledge build-up
- Follow up of contractors mix designs in the construction phase
- Part of the monitoring of performance during the operation phase
- Platform for research activities



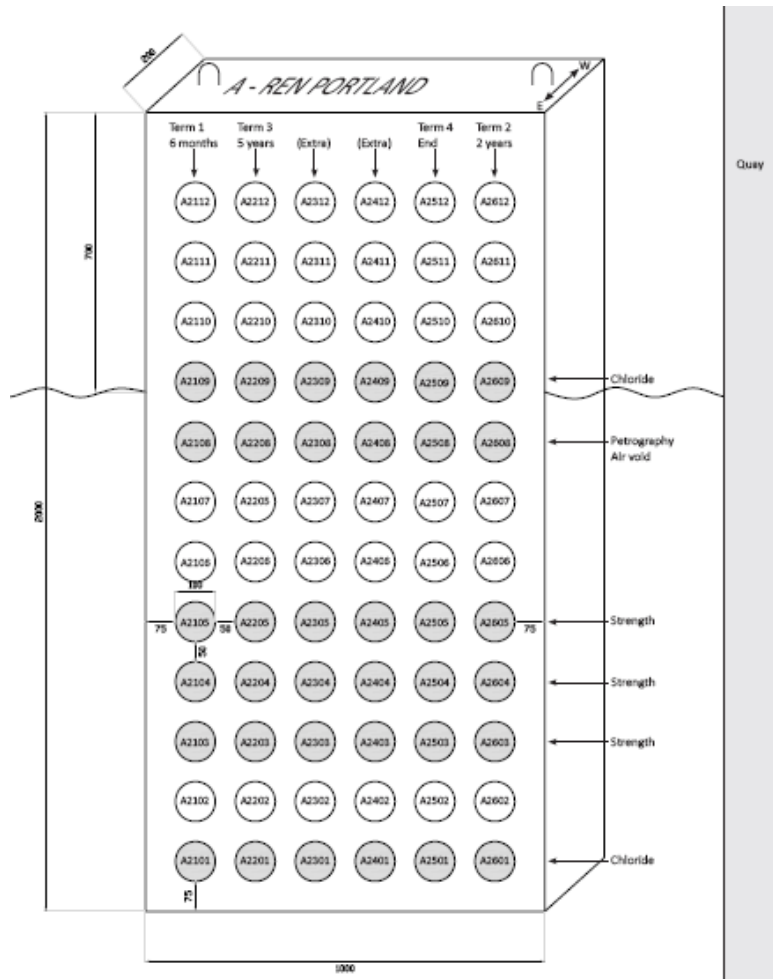
# Concrete Blocks

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- Small block 1.0 x 1.0 x 0.2 m
- Large block 2.0 x 1.0 x 0.2 m
- Cast indoors as "high wall"
- Poker vibrated (except SCC)
- Demoulding after 24 h
- Curing by sealed plastic bag
- Maturity monitored by cast in sensors
- Large blocks exposed at 40-46 mdays



# Testing programme: drilled cores from large blocks



- Petrographic analysis and evaluation (0.5, 2, 5, and 10 years exposure)
- Air void analysis (6 months exposure) (EN 480-11)
- Compressive strength development and density (0.5, 2, 5, and 10 years exposure) (EN 12390-3, EN 12390-7)
- Chloride penetration (submerged zone and splash zone) (0.5, 2, 5, and 10 years exposure)



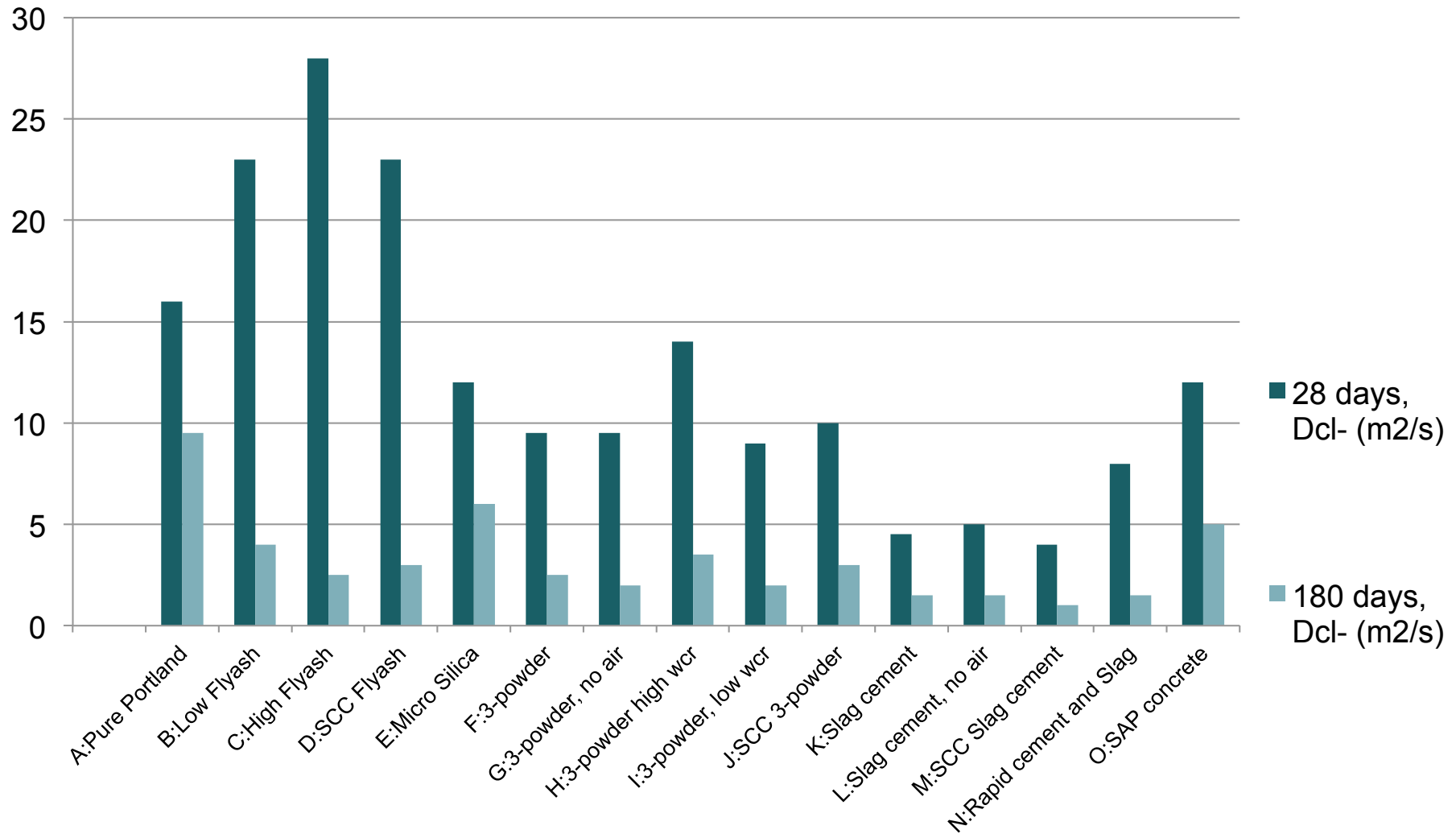
## 5 year snap shot

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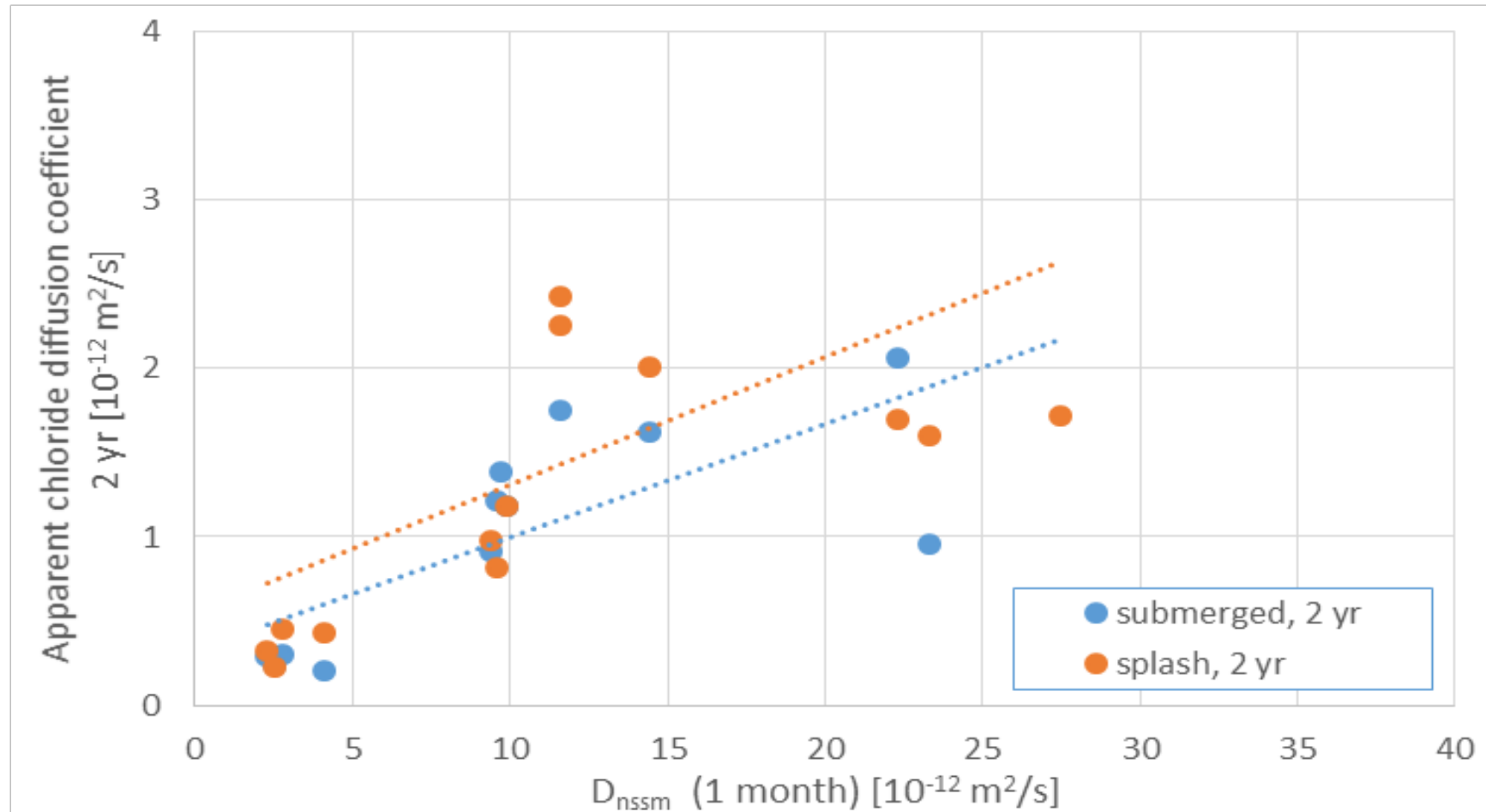




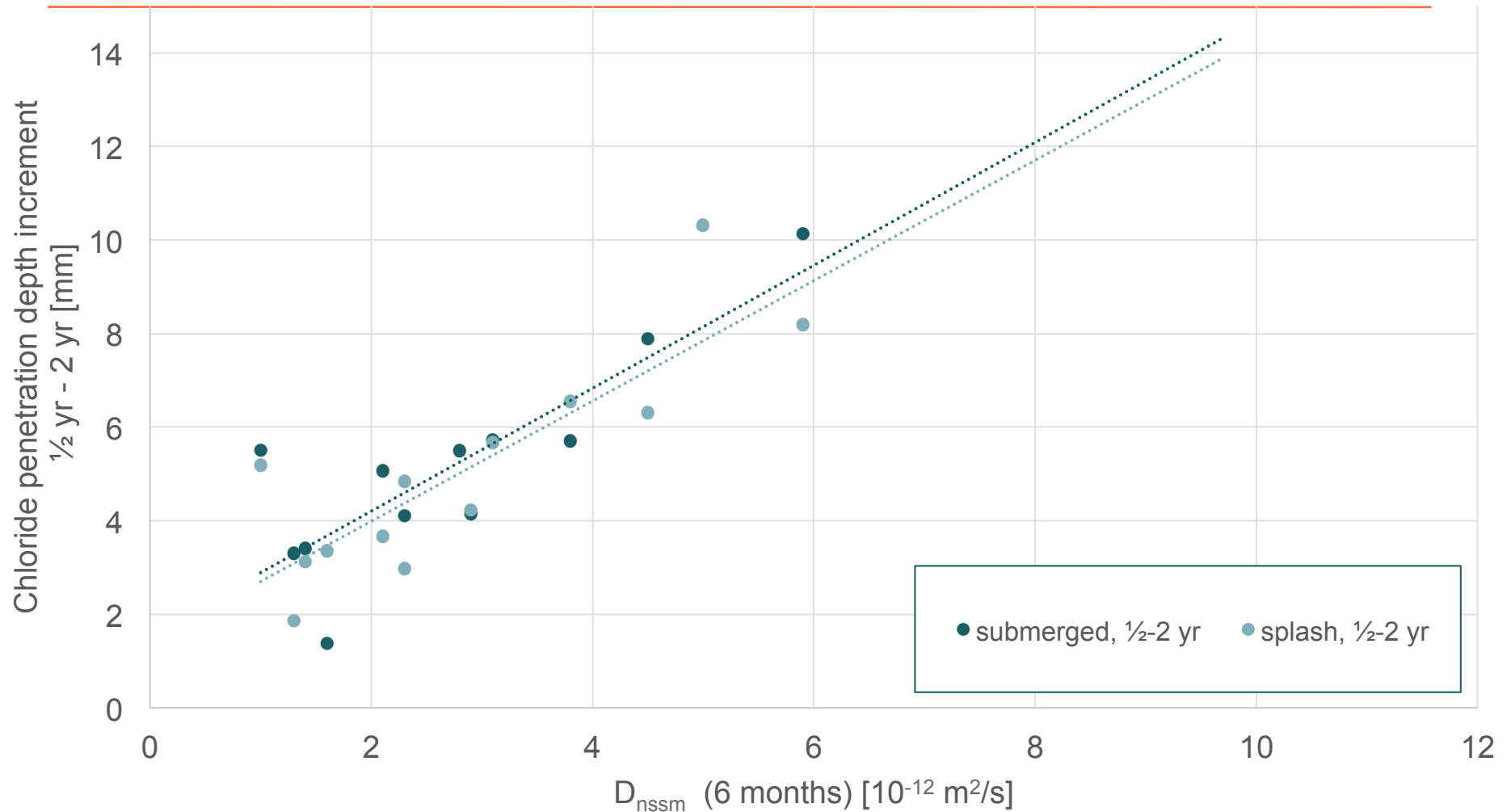
# Results: Chloride migration tests on small blocks



# Correlation: $D_{app}$ vs. $D_{nssm}$

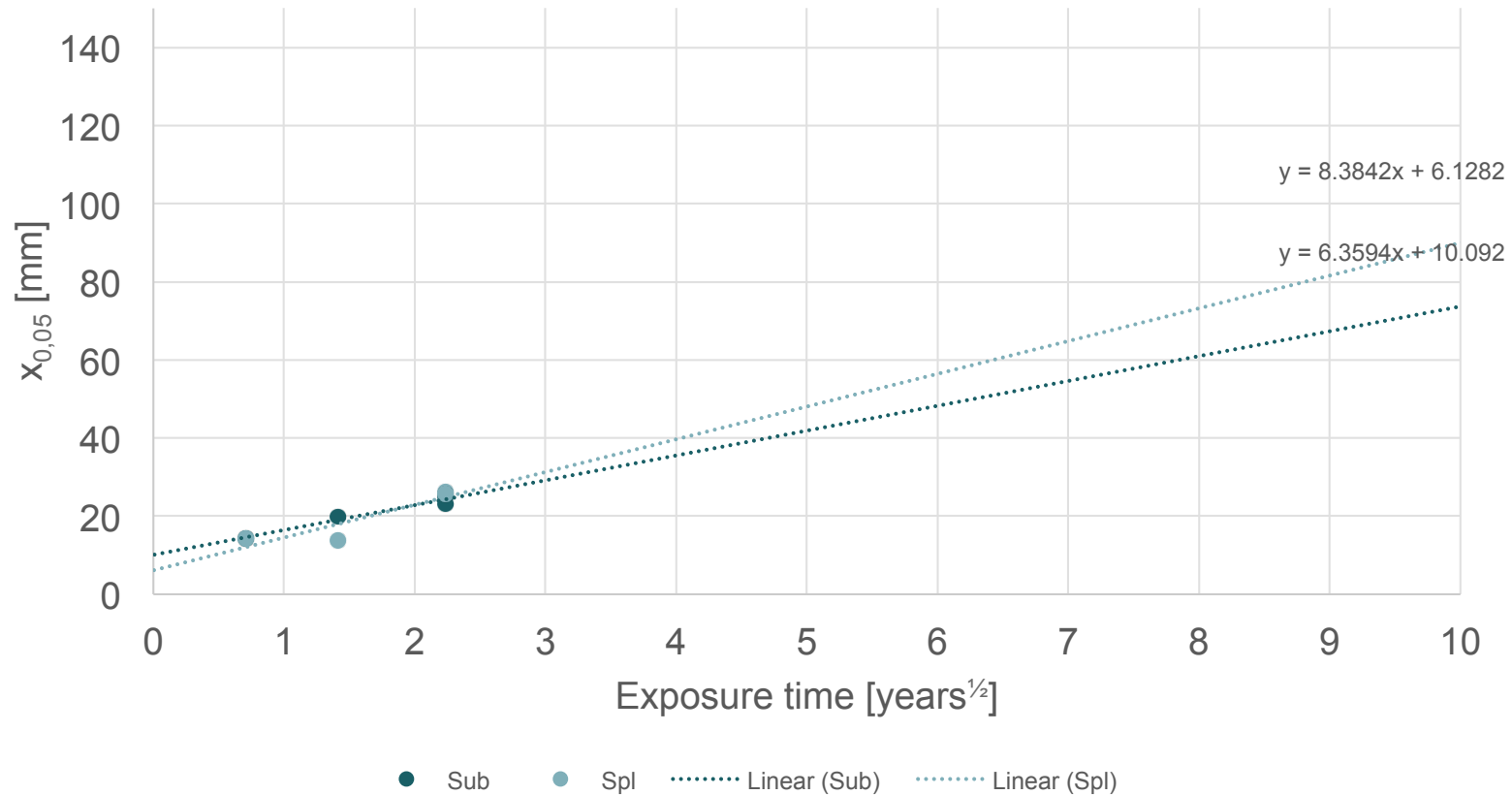


# Correlation: $D_{nssm}$ vs. Penetration depth increment



# $X_{0.05}$ v. Sqrt (time) based on 0.5, 2 and 5 year data

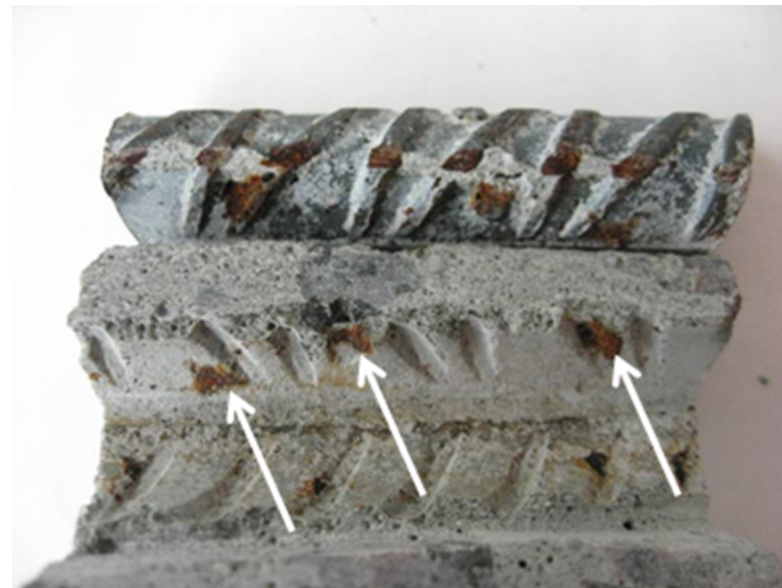
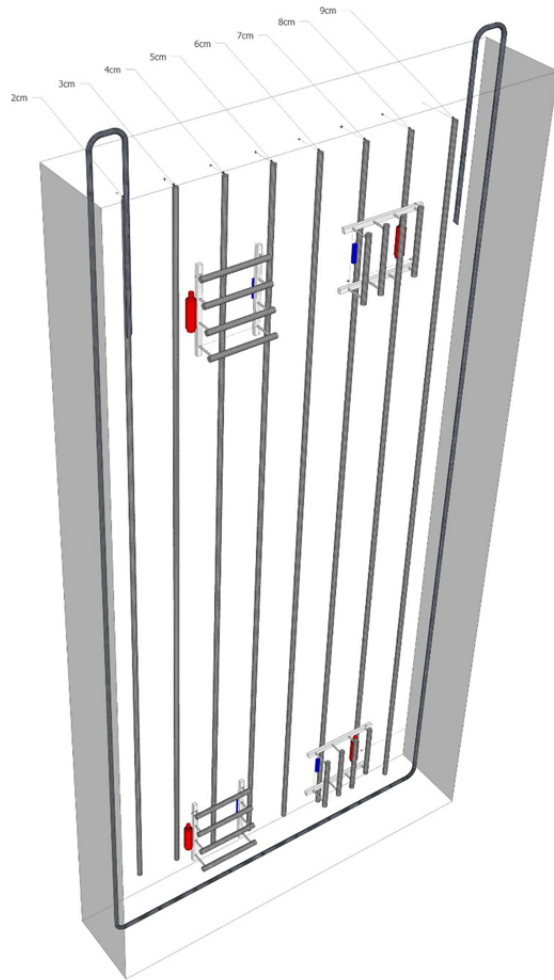
Figure F -  $x_{0,05}$  vs. Sqrt(time)





# Instrumented blocks

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# Conclusions

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- Concrete types made from Portland cement and fly ash are permeable in the early age
- During the first half year these concrete types will develop low permeability
- After the first half year the chloride ingress appear to follow the square root formula
- The use of chloride migration coefficients ( $D_{nssm}$ ) as input parameters to service life modelling should be performed with caution.
- $D_{nssm}$  shall be measured not earlier than 4-8 months when blended binders and fly ash are used.

# Functional requirements for concrete?

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- Calculation methods for functional requirements must be commonly agreed and scientifically accepted if to be used in a contract
- Such methods could not be identified for chloride initiated reinforcement corrosion
- Lack of scientific knowledge and common understanding of chloride threshold values and ageing factor for chloride ingress
- Requirements to binder combinations, cover and water/binder-ratios have therefore been specified

# Calculation of minimum concrete cover

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- Data from up to 20 year old Scandinavian exposure sites have been used
- The Clinc-comp model developed and improved by Tang, Nilsson and Frederiksen have synthesised the data
- Conservative threshold values have been chosen



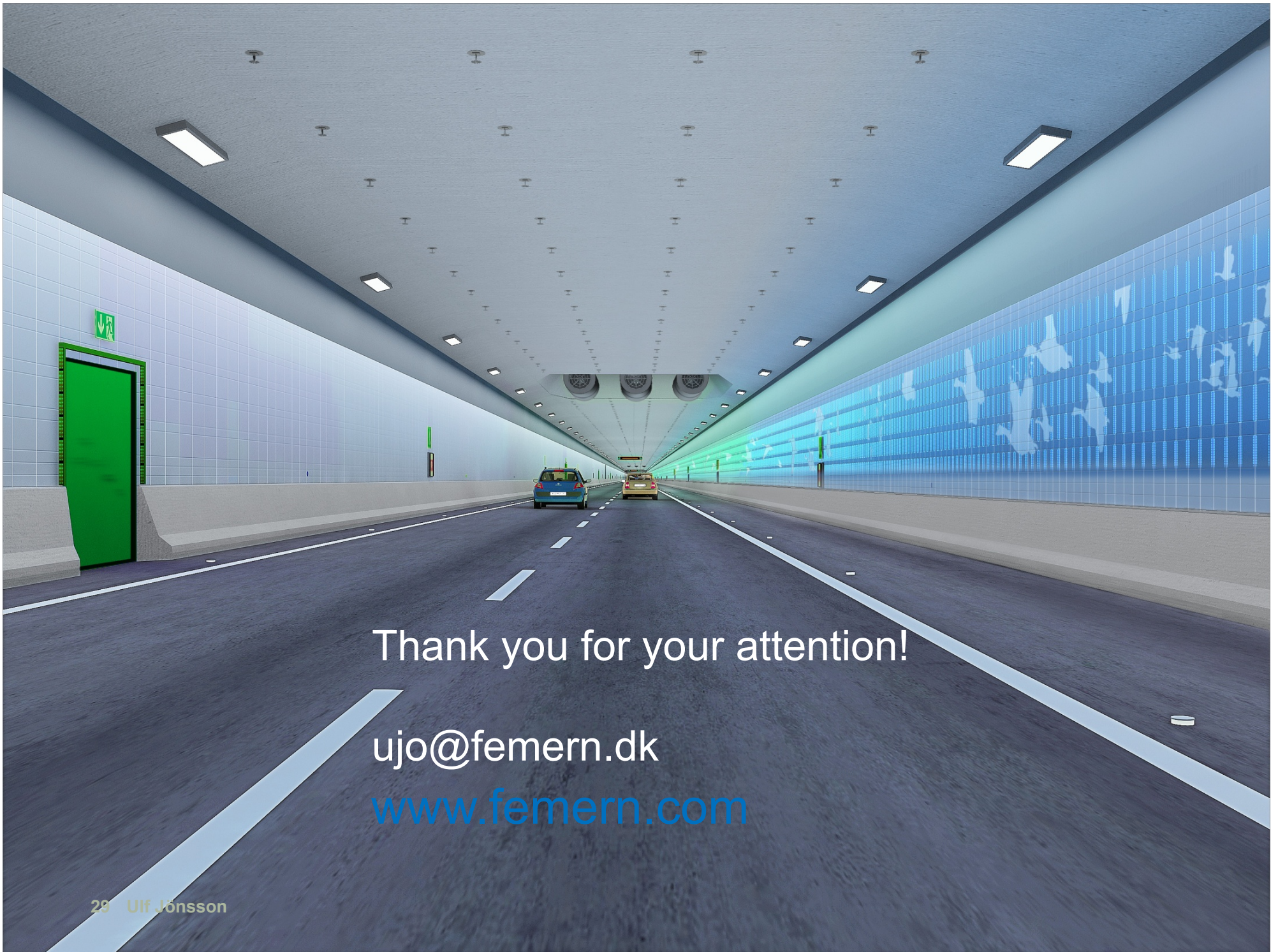
# Calculation of minimum concrete cover

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- The model has been used to define a matrix of minimum concrete covers and maximum water cement ratios for different allowed binder combinations.
- Results from core drillings in south Scandinavian marine structures and recent new data on threshold values have confirmed the project choices, when tested in the model.

[www.concreteexpertcentre.dk](http://www.concreteexpertcentre.dk)

## Fehmarn Belt Concrete Investigations



Thank you for your attention!

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