

Finding from DeCom, in-service inspection and testing of skirt-pile grouted connections with OPC

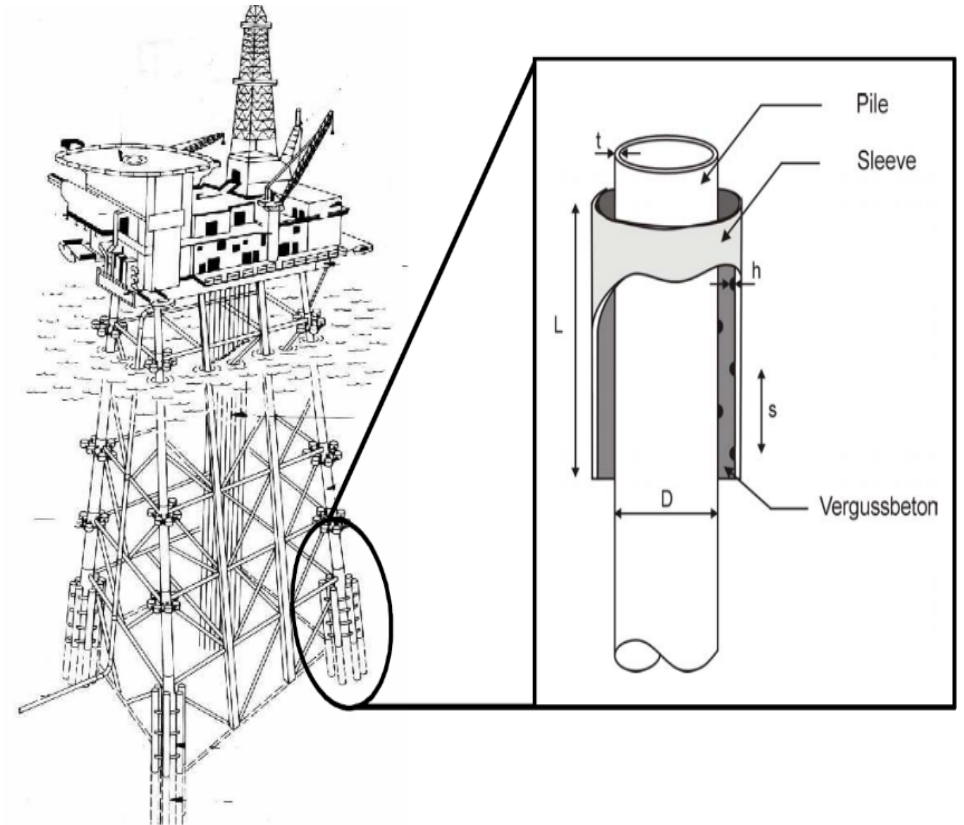
Konstruksjonsdagen 2024

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Background | Skirt-Pile connections

- Originally plain pipe connections, first installed on the Norwegian continental shelf in 1974.
- First standard addressing grouted connections published in 1980 by the department of energy.
- Neat cement grout – Ordinary Portland Cement (OPC) and water + admixtures (sometimes)
 - Not high-strength grout commonly used in the wind industry
- Displacement grouting, filled from the bottom-up delivered by grout hose to the bottom of the connection.
- In displacement grout there is a front of material that can be the lubrication mix used for the grout lines and/ or the first phase of grout that is a mix of grout and water.



Ref. Historic application of grouted connections in skirt-pile foundations (Anders, 2007)

Background | DeCom inspections

- **To date:** Involved in the inspection of 6 jackets during the DeCom process, in recent years.
- **Typical Objective:** Retrieve information on the integrity of the grouted pile-sleeve and pile-leg connections as input to ongoing development of NORSOK rules.
- **Typical SoW:** Perform close visual inspection of the skirt and leg-pile grout condition (post toppling). However, additional insight gained through limited coring.

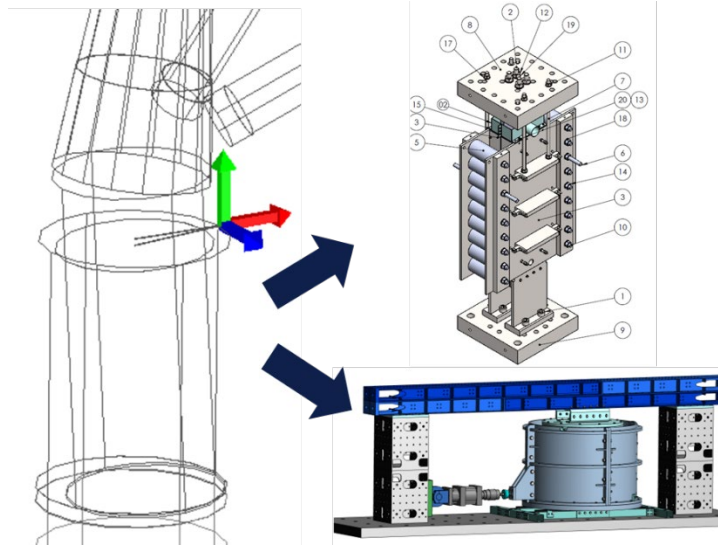
Background | In-service inspection

- Close visual inspection of grout top surface had its limitations.
 - Only top surface accessible.
 - No access to most utilized part of connection.
 - If damage is present on the top surface this would indicate loss of integrity over the full length of the connection.
- Move towards NDT acoustic testing. There are limitations and challenges here too.



Background | Grout testing

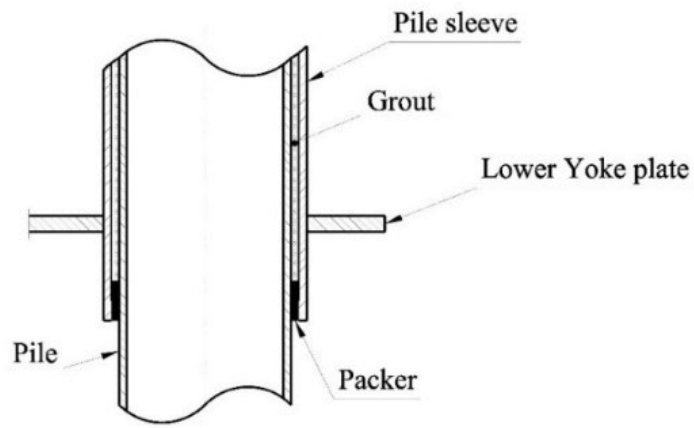
- PQT's
- Mock-up for TQ's and Certification in acc. C502
- Early age cycling structural testing.



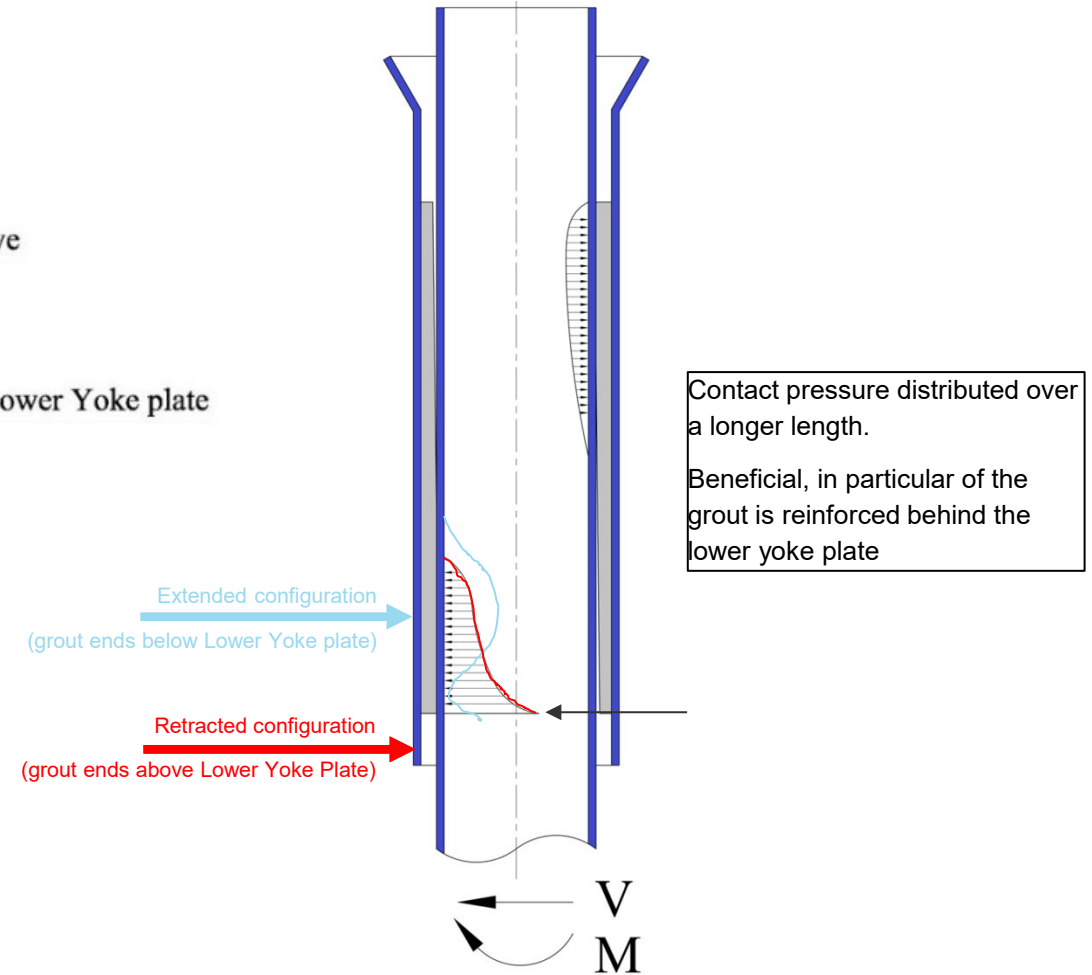
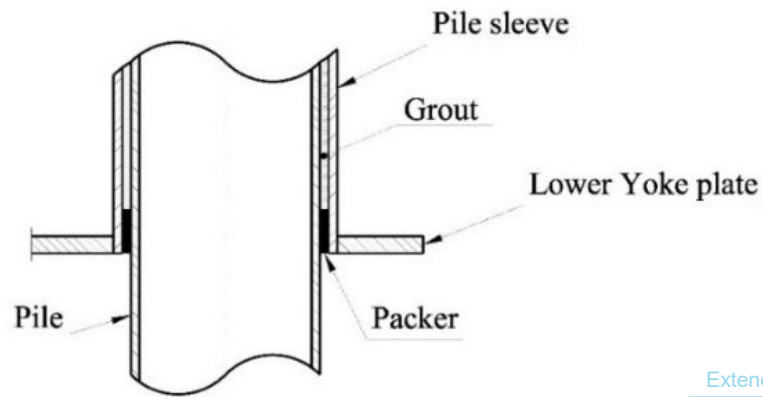
Source of cracking in OPC

Structural cracking | Lower yoke arrangement

Extended configuration

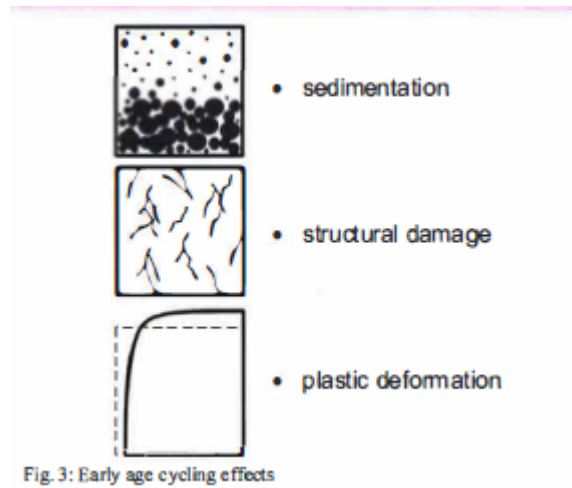


Retracted configuration

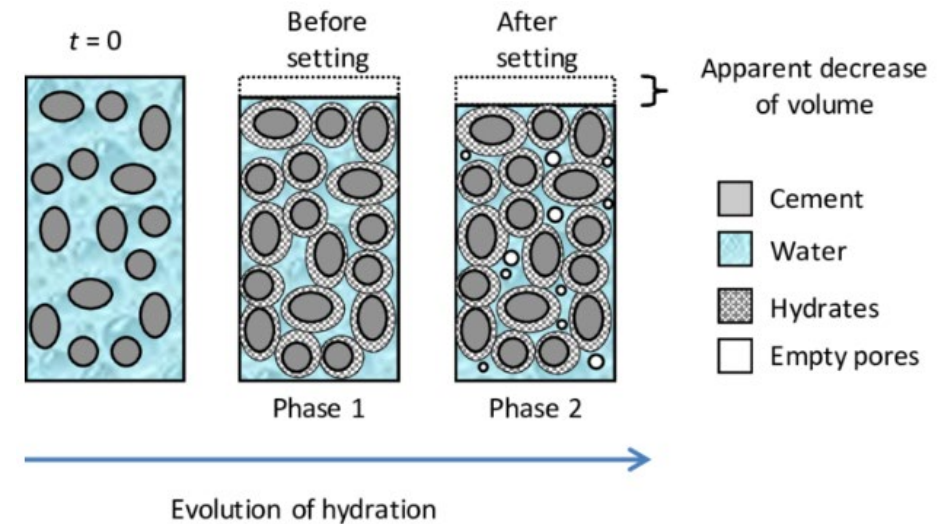


OPC Grout Material Performance (1 of 2)

Early Age Cycling (EAC)



Shrinkage



Ref. Figures above - Thermal Cracking of Massive Concrete Structures (pp.69-114)

OPC Grout Material Performance (2 of 2)

Thermal cracking

Delayed ettringite

Key findings from De-com

DeCom project 1 | Key inspection findings



Figure 9 - Pile B2/S2, window 1



Figure 10 - Pile B2/S2, window 2

DeCom Project 2 | Key inspection findings

G11 - Pile sleeve connection Row A / Row 1



Figure 27 Overview of pile- sleeve connection



Figure 28 Pile Sleeve connection prior to splitting. Some intrusions



Figure 29 Good homogenous cross-section



Figure 30 Layering/hairline cracks in the grout body, seemingly calcified circumferential cracking in the grout volume.

DeCom project 3 | Key inspection findings



Figure 5 - Layering of grout material at approx. 4m elevation from bottom of connection

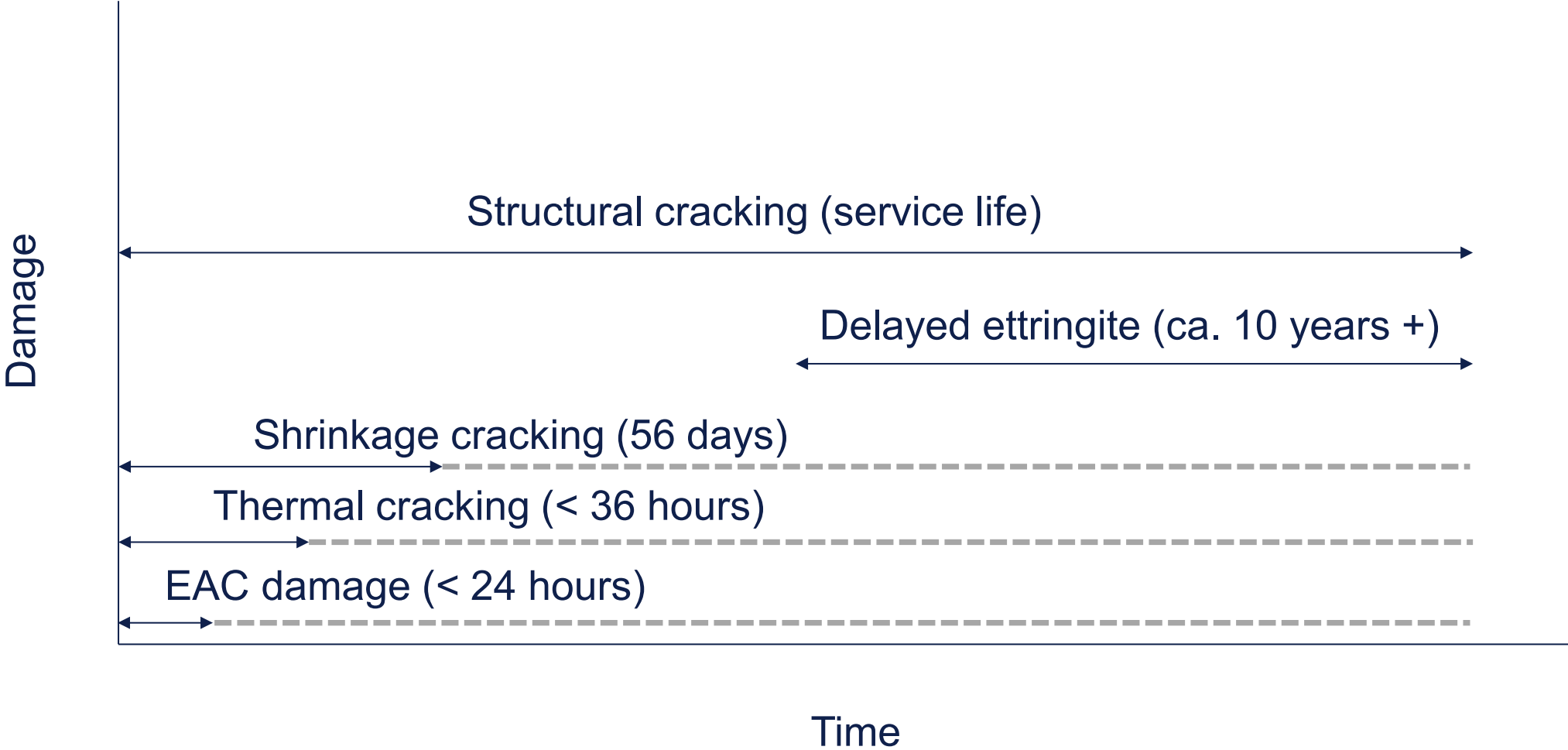


Figure 16 - Delaminated section of grout from core 3 from Elev. 3.91m.

Lab scale testing

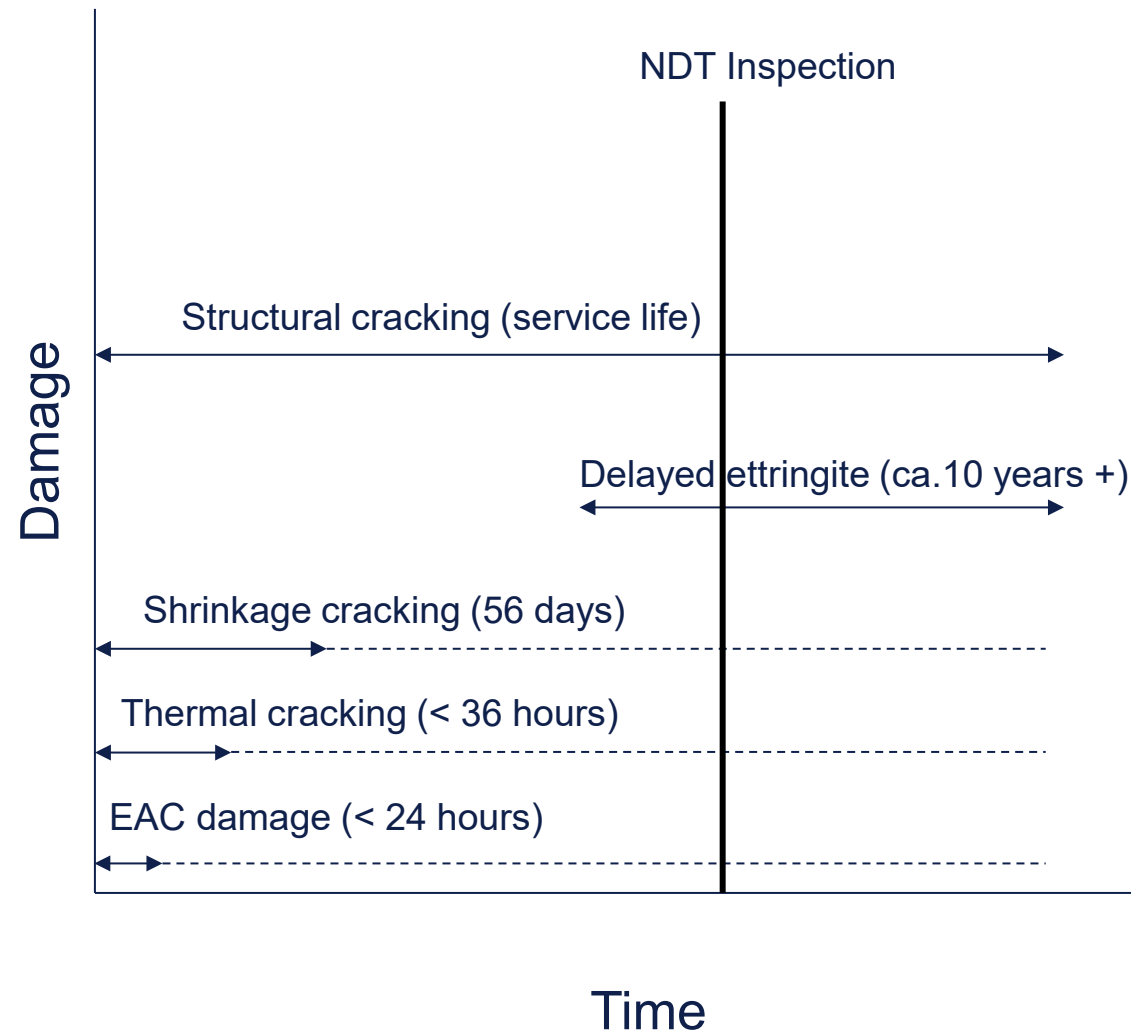


Damage occurrence timeline



Findings from in-service inspection

Inspection results



JIP | Re-analysis and RP for in-service inspection

JIP SoW

Objective(s)

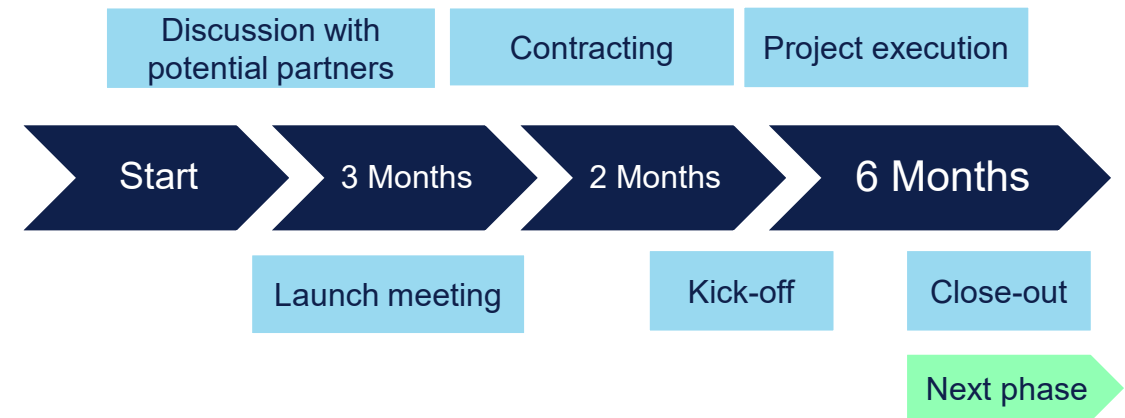
- Standardization of a method for the re-assessment of in-service grouted connections that do not comply with NORSOK N004.
- Set out best practice for inspection planning and considerations for inspection planning

Scope

- Literature review
- Development of Best Practice for Analysis
- Development of Best Practice for in-service inspection
- Development of High level NDT qualification criteria

Deliverables / outcomes

- Background report / threat assessment for NDT tool for grouted connections.
- Draft RP for structural re-assessment of structures not complying with NORSOK 004 (2022)
- Draft RP for inspection methodology of grouted connection.
- High-level qualification criteria for new NDT tools.



Scope

- **Literature review / historic project data** – existing capacity calculation methods, testing undertaken for the development of rules, current inspection methods and limitations.
 - **Best Practice for structural re-assessment of grouted connections**
 - Review of historic project(s) to establish shortcomings regarding re-analysis for grouted connections.
 - Supplementary testing to improve calculation methodologies for connections not covered by existing codes – e.g. geometries not satisfying the boundaries set in NOSOK N004.
 - Establish supplementary calculation rules to address shortcoming in NORSOK.
 - Establish best practice text that can become DNV RP or input for the development of NORSOK N006.
 - **Optional** testing scope – to confirm effect of cracking and re-analysis methodology
 - **Best Practice for in-service inspection of grouted connections**
 - Review of historic project(s) to establish shortcomings regarding inspection methodologies for grouted connections.
 - Define best practice for in-service inspection and interfaces between structural analysis and inspection planning.
 - Establish best practice text that can become DNV RP
- Developed High level qualifying criteria** - Workshop to develop a high-level threat assessment for an NDT inspection tool capable of providing a reliable structural assessment of in-service grouted connection.

Questions?

Thank you.

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