Retaining structures: anchor test data & wall corrosion

Luca Flessati

Mark van Koningsveld

Ken Gavin

TU Delft

New challenges in Civil Engineering

New design

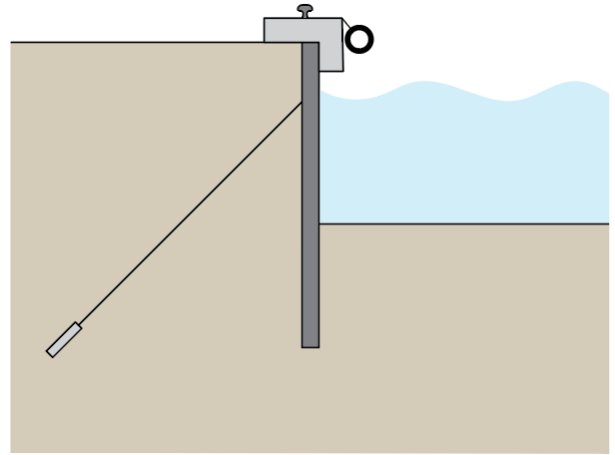
- sustainable
- resilient
- economic

Existing structures

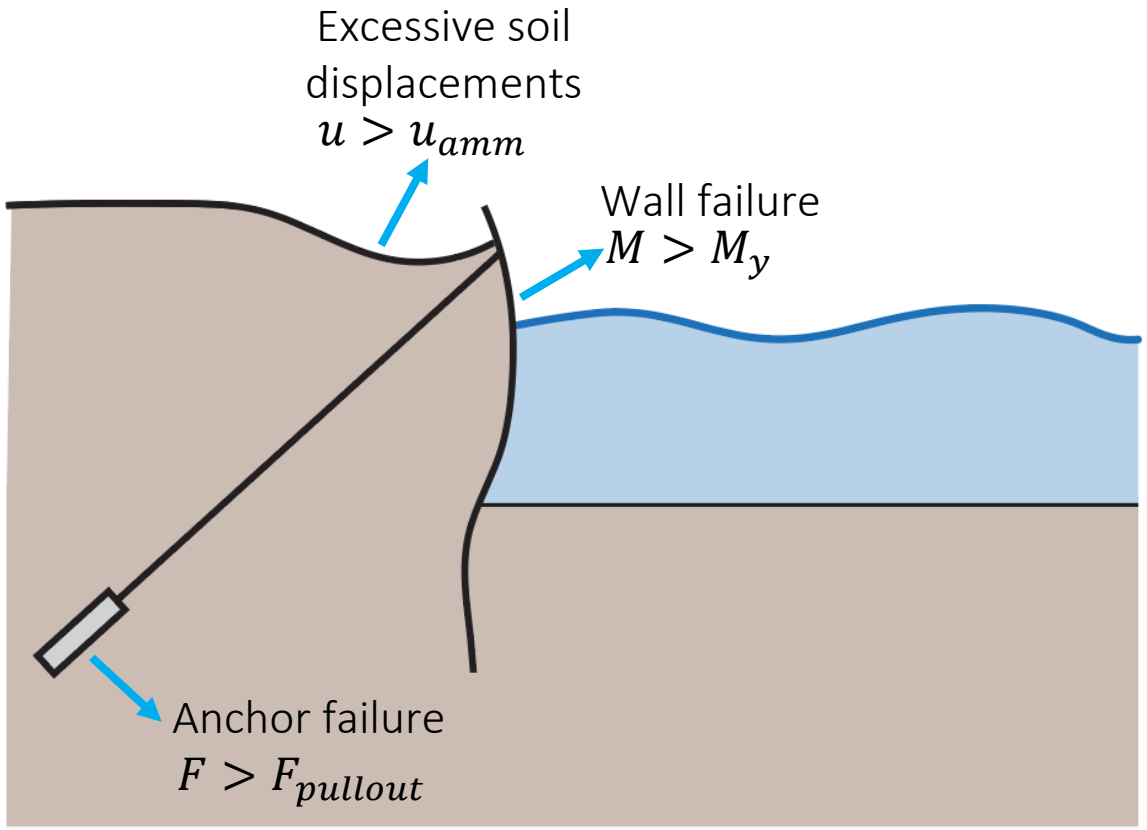
- current state
- residual life
- retrofitting

Research ⟷ Field data

Grondkerende constructies



Quay walls: loss of functionality



The quay wall loses functionality when the first of the three "fails"

↓

Increasing the safety of only one of the three not necessarily implies an increase in global safety

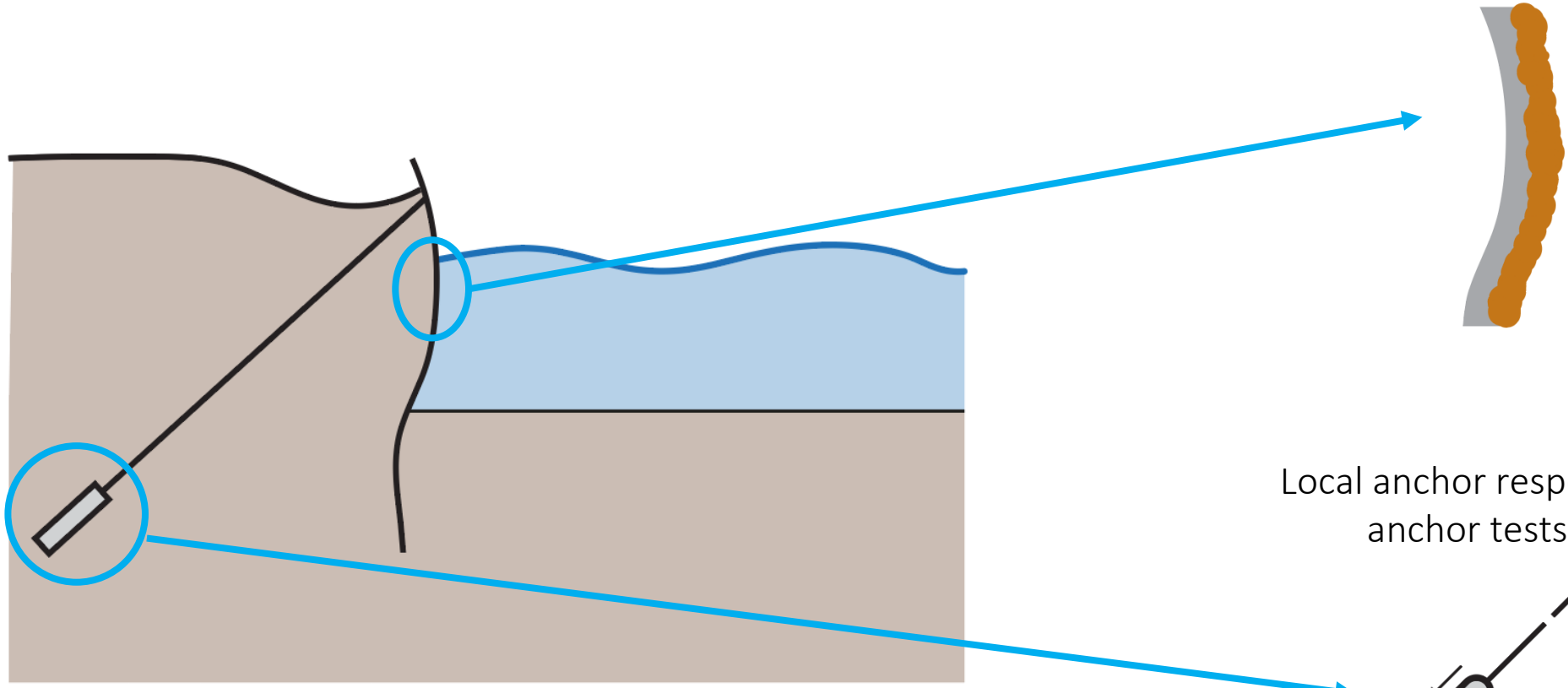
↓

Engineering question:
Which is the "weakest link"?

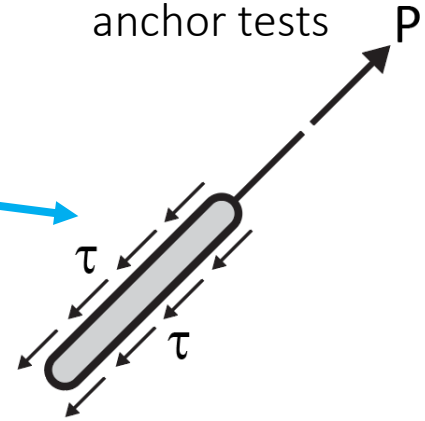
Other possible local failure could be considered!

Quay walls: loss of functionality

Wall response:
Corrosion measurements



Local anchor response:
anchor tests



Anchors

Design

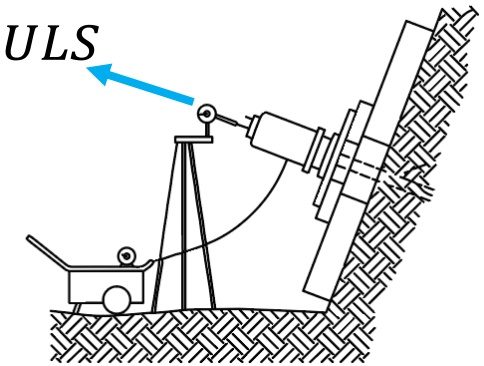
Simplified calculation method:

$$R_{a,d} = \alpha_t L_a O \, q_{c:gem}$$

- α_t: 1.5%
- L_a: Length in sand layer
- O: Grout body circumference
- $q_{c:gem}$: From CPTs

Tests

$$P_p = R_{ULS}$$



$$R_{a,d} \overset{?}{=} R_{ULS}$$

Anchor design

Some remarks

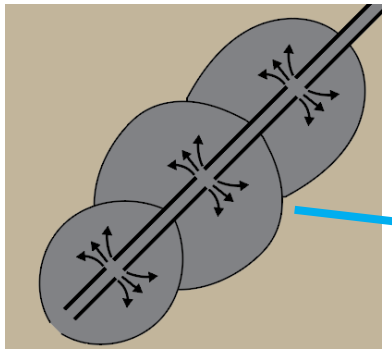
Design

Simplified calculation method:

$$R_{a,d} = \alpha_t L_a O\, q_{c:gem}$$

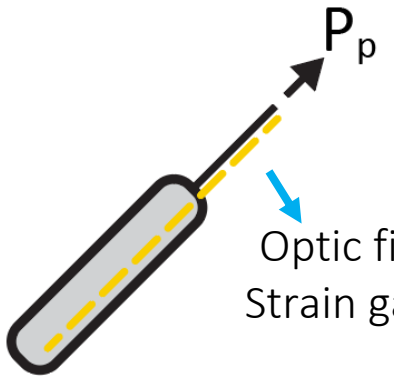
- α_t: 1.5%
- L_a: Length in sand layer
- O: Grout body circumference
- $q_{c:gem}$: From CPTs

Grouting



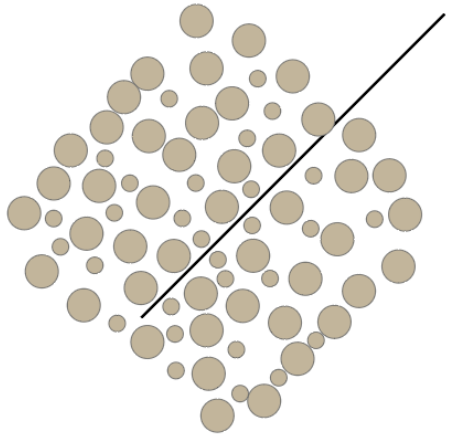
O?

Inj. pressure?
Inj. flow rate?
Grout mix-design?
Soil permeability?
Effective stress?

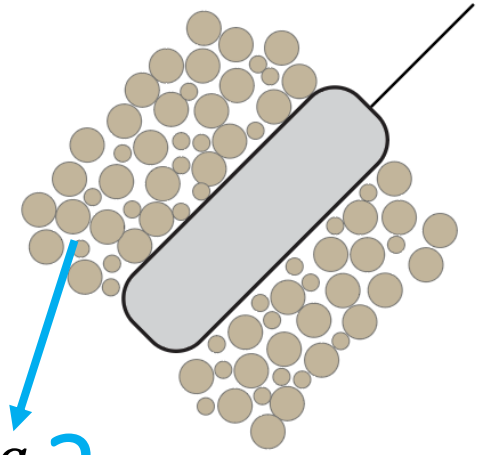


Optic fibre Strain gages → Distribution of axial force in anchor → α_t

Before grout



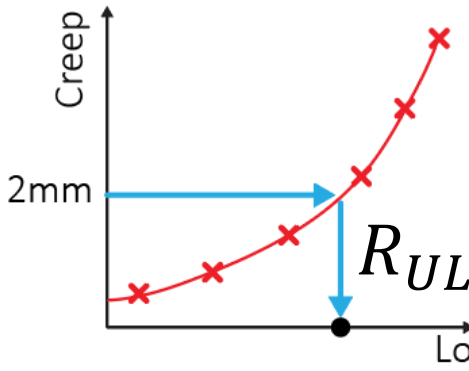
After grout



q_c?

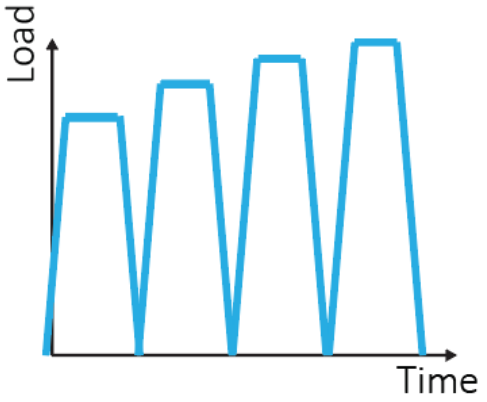
Anchor tests

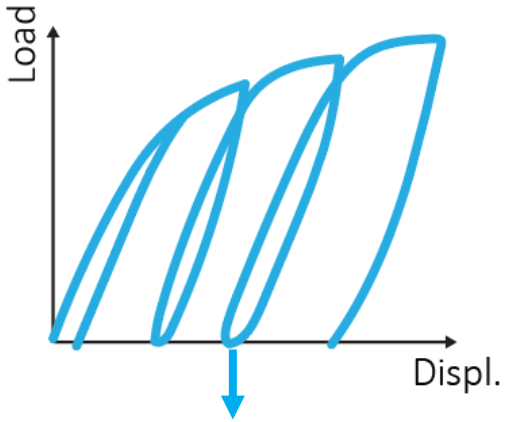
Some remarks



R_{ULS}?

Failure tests

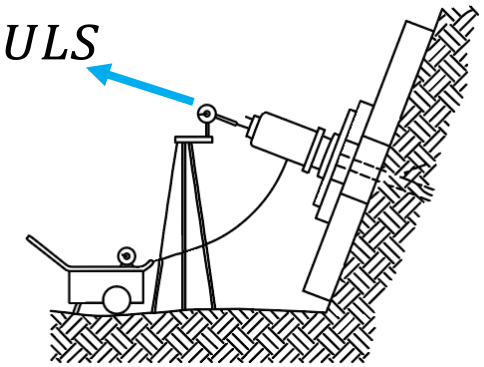




Plastic strains during unloading → Cyclic vs monotonic tests

Tests

$P_p = R_{ULS}$



Anchors

Research goals

Anchor test data

Understand the response

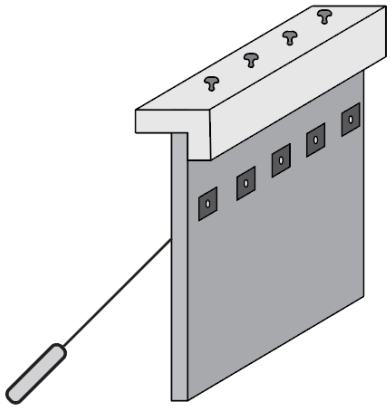
Verify design method

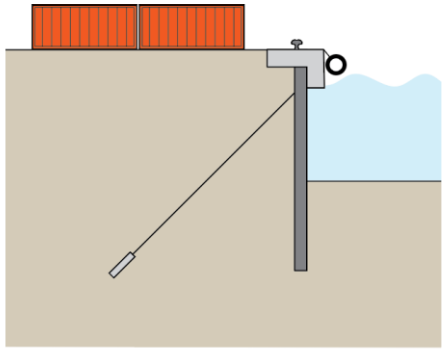
Verify test interpretation

More reliable estimation of anchor failure load (larger)

Less anchors (with the same safety)

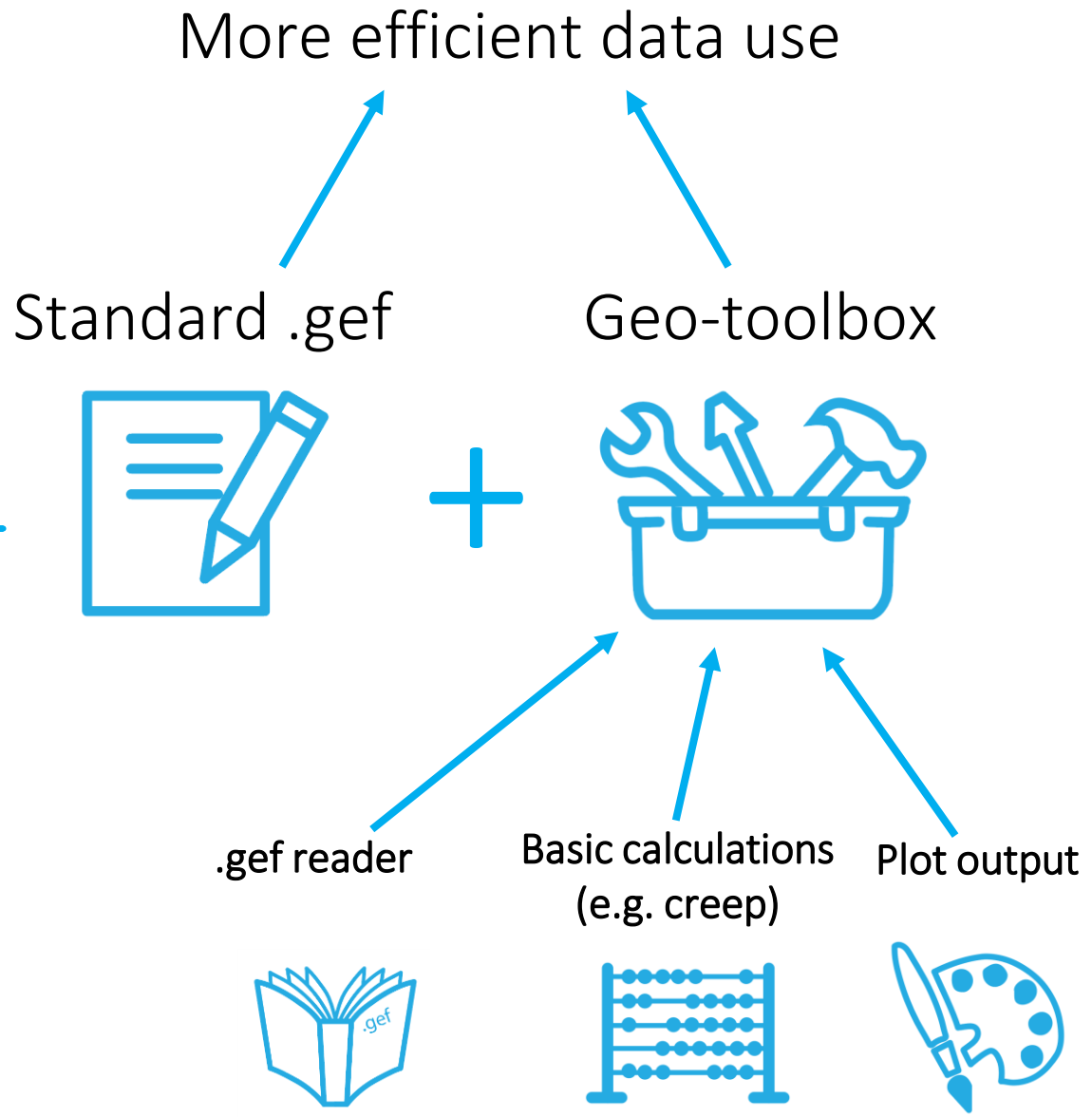
Larger perturbations can be applied





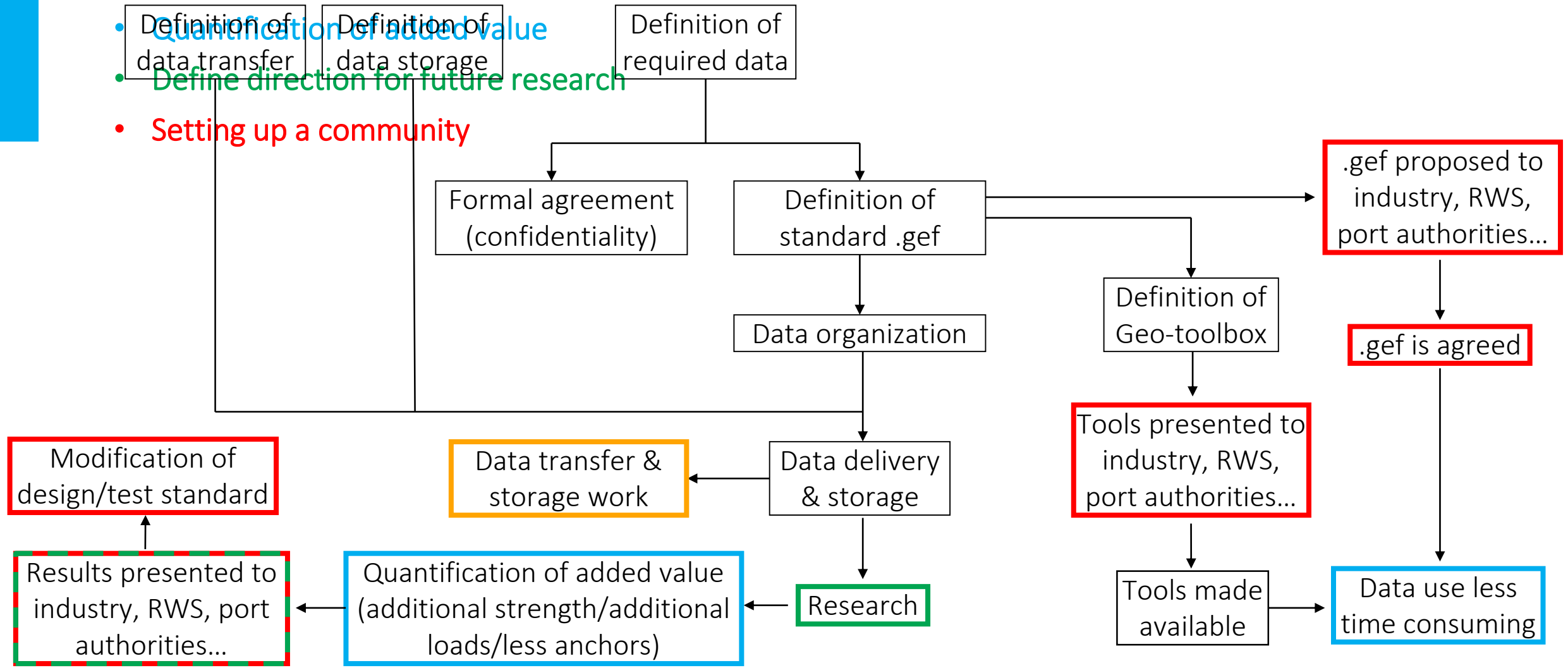
Required data

- Test data (time, force, displacements)
- Anchor position
- Anchor geometry (Free length, grout length…)
- Anchor type (including cable & type of steel)
- Anchor pre-stress
- Soil properties
- Grouting data (pressure, flowrate, volume)
- Grout properties (mix design, strength)

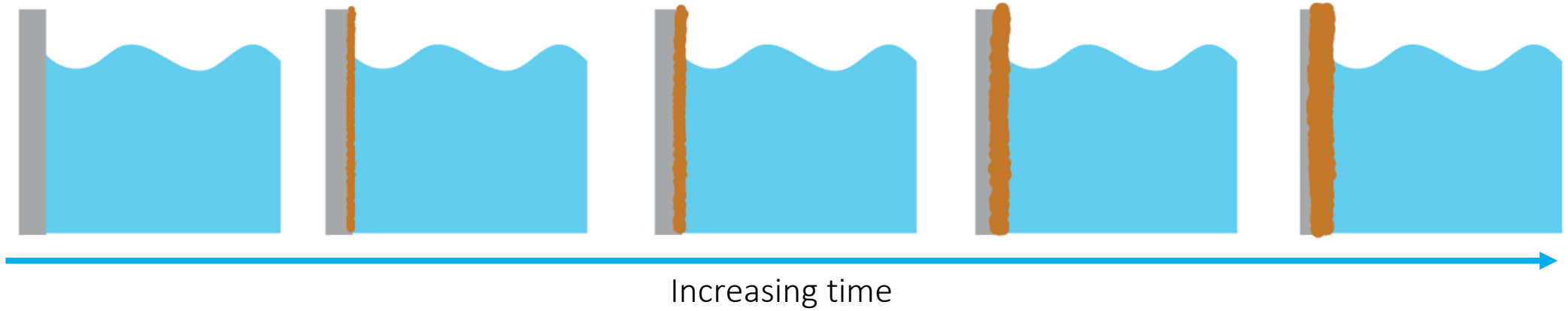


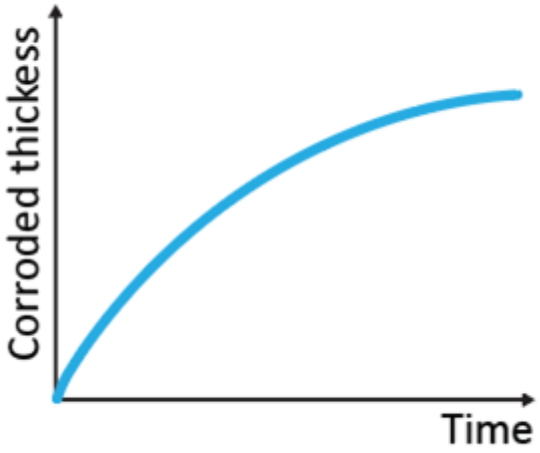
Expected goals and how to reach them

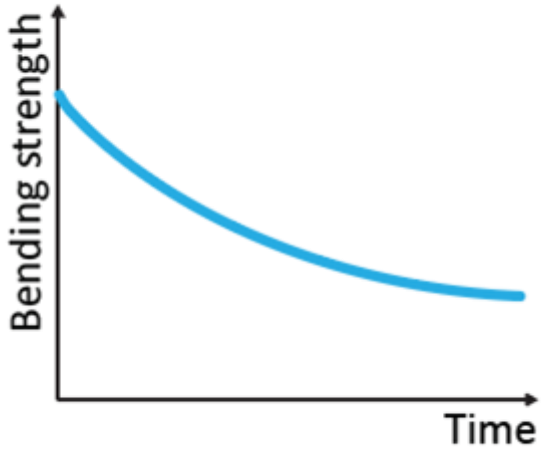
- Successfully transferring/storing data
- Quantification of added value
- Define direction for future research
- Setting up a community

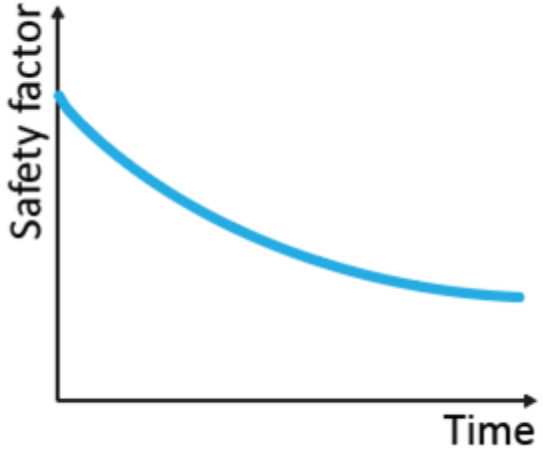


Wall corrosion







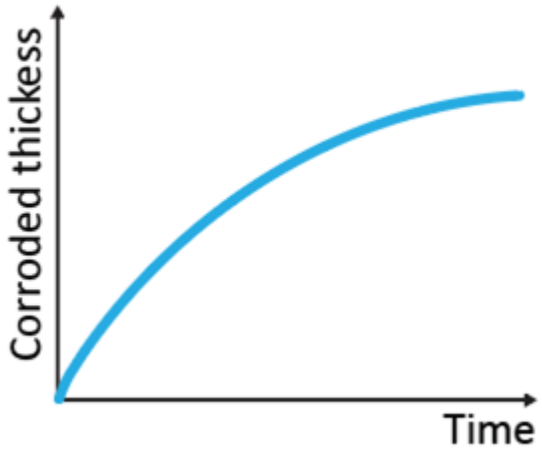


Quay wall management requires:

- Corrosion curves
- Simple Fs calculation

Wall corrosion

Corrosion curves



Direct determination of corrosion curves from data → Site specific

Correlating corrosion curves with environmental conditions (temperature, salinity, other chemicals) → Possible extension to other sites

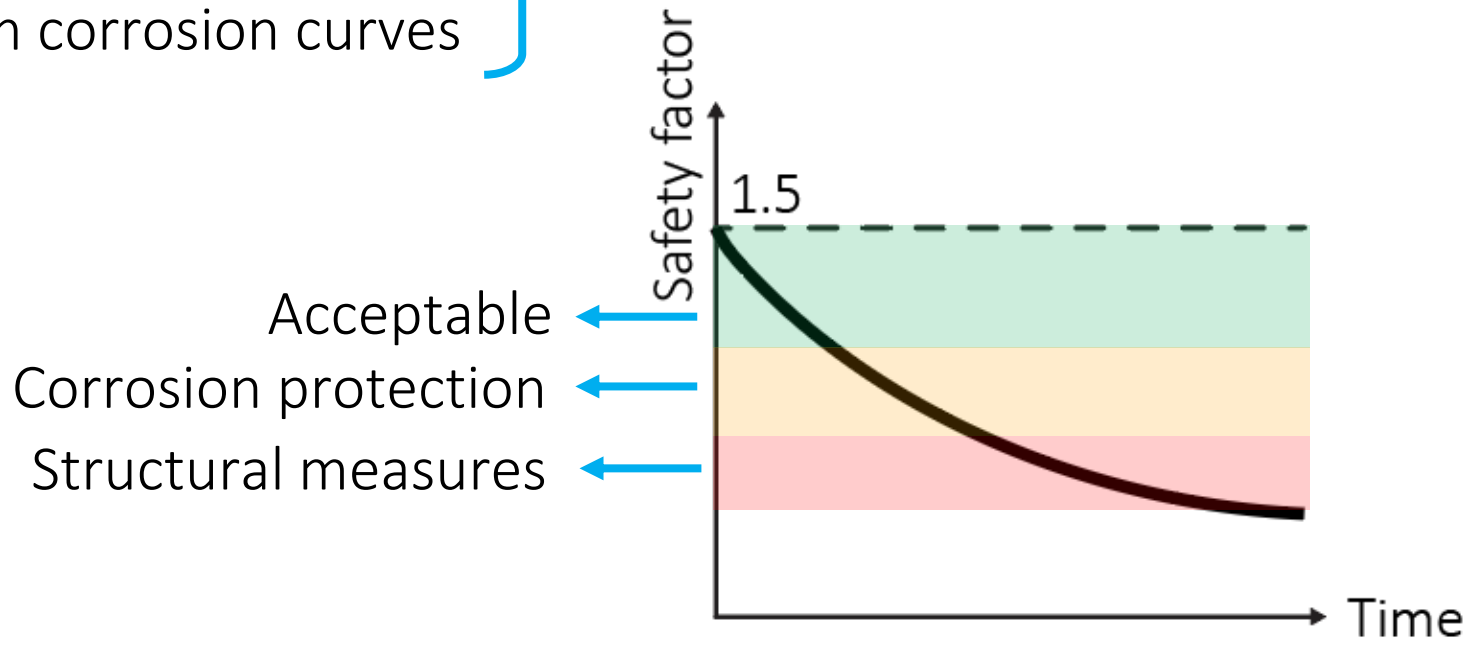
Wall corrosion

Safety factor calculation for quay walls management

Assumptions:

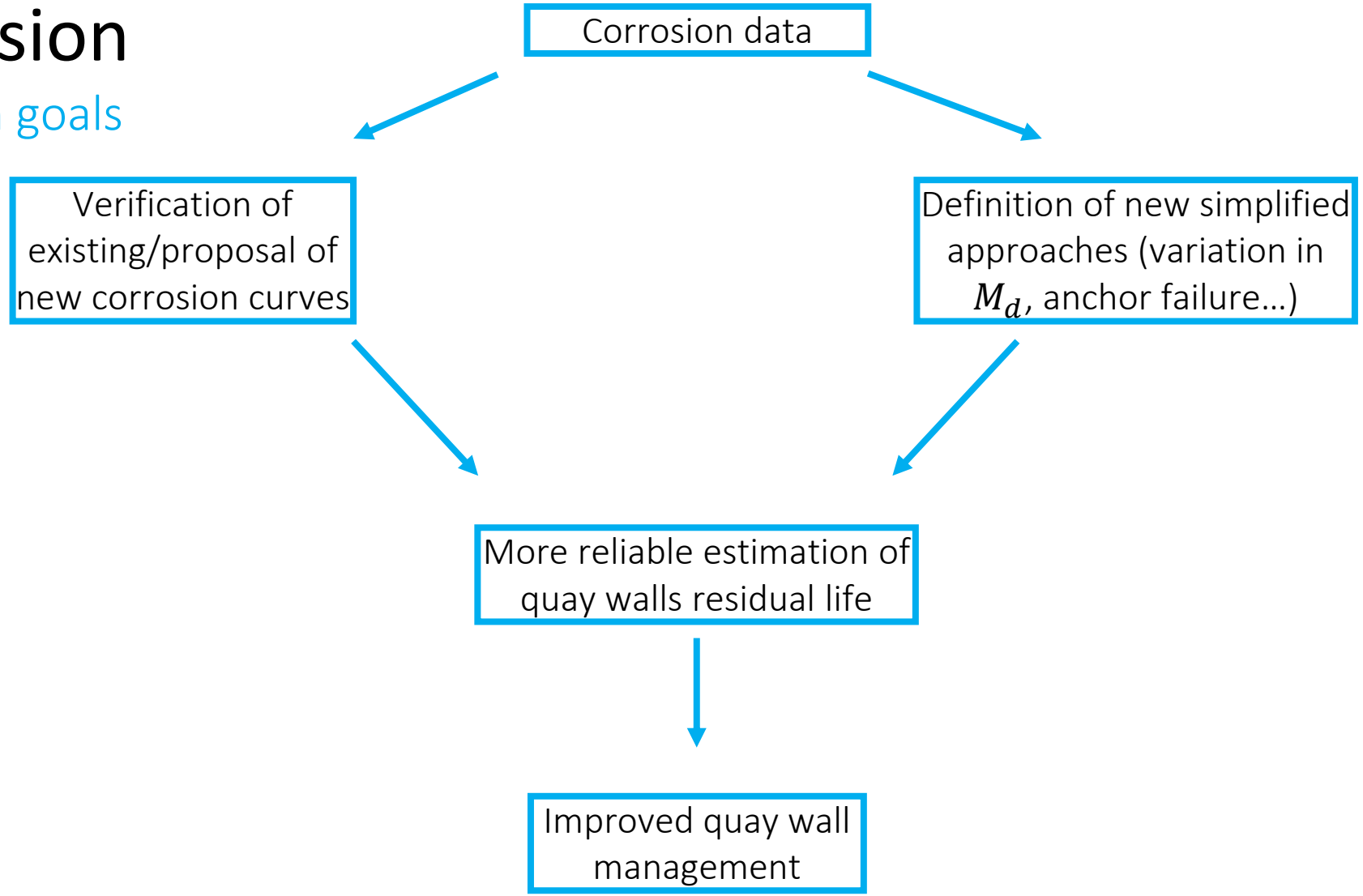
- Failure only on the wall side
- $M_d = \frac{M_{y0}}{1.5}$ constant with time
- $M_y(t)$ calculated from corrosion curves

$$F_s = \frac{M_y(t)}{M_d} = 1.5\frac{M_y(t)}{M_{y0}}$$



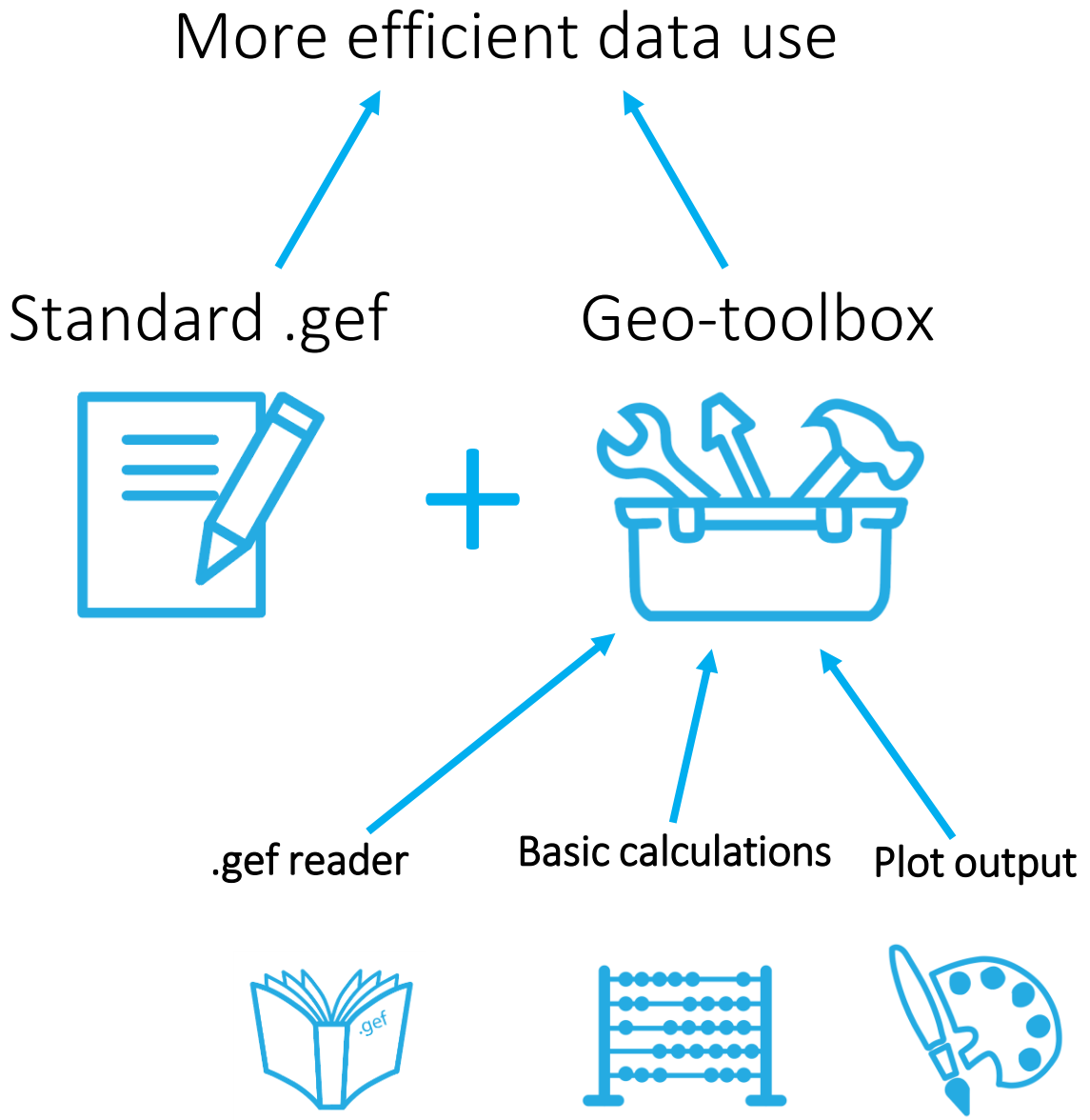
Corrosion

Research goals



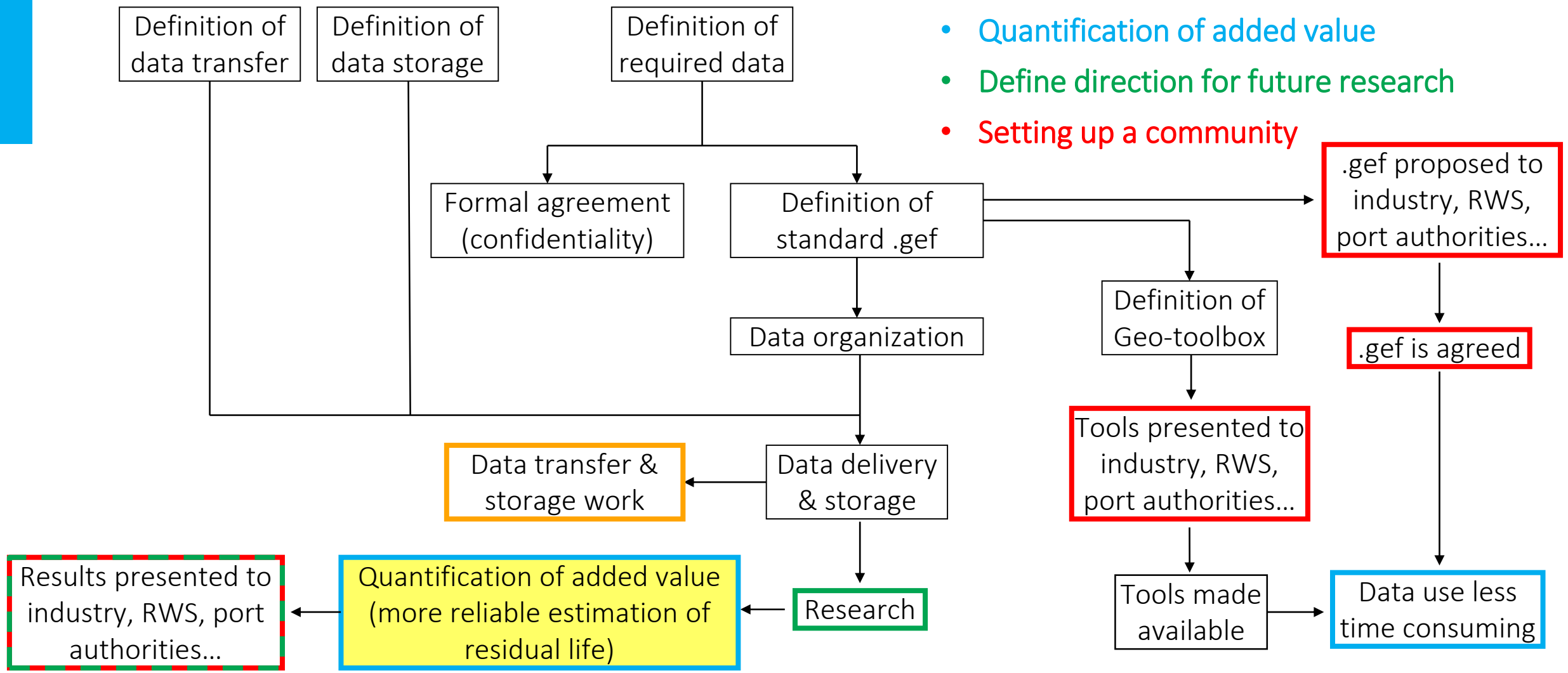
Required data

- Corrosion measures
- Date of construction
- Type of wall and geometry
- Type of steel
- Corrosion protection
- Water temperature
- Water chemical (salinity, oxygen, nitrates)
- Water level (tides)
- Water velocity/current

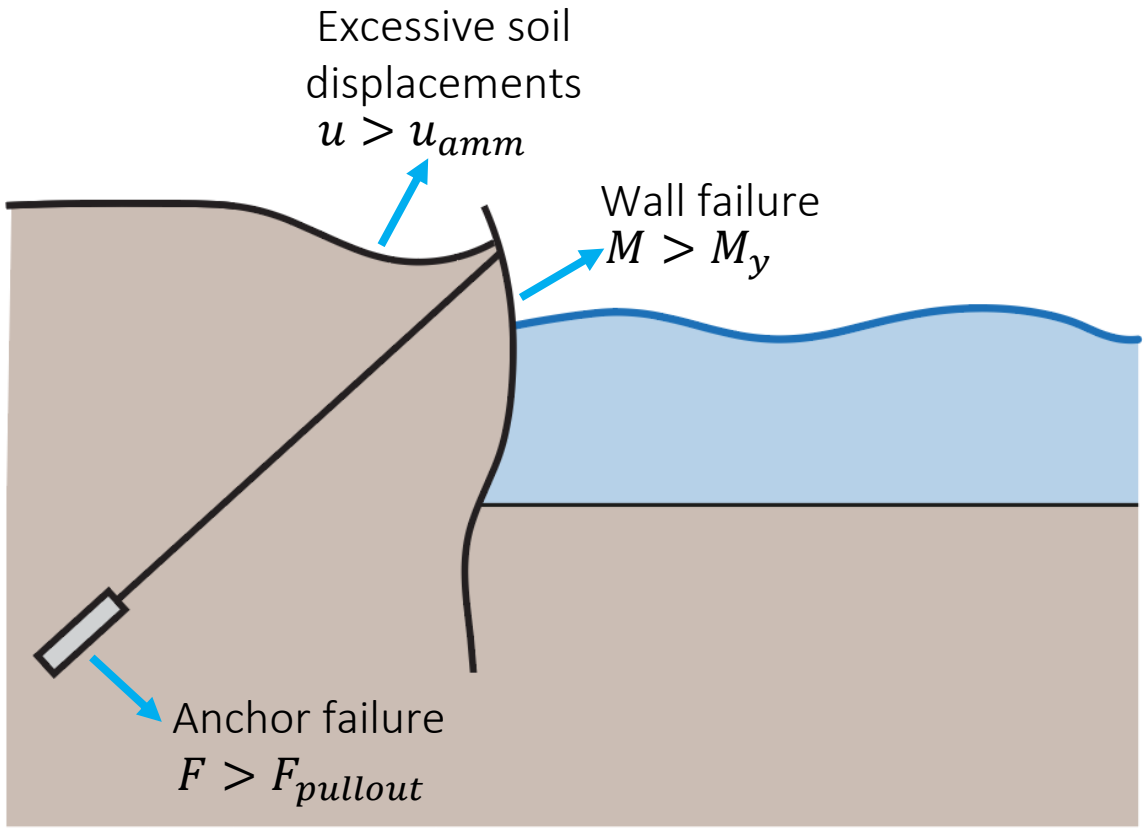


Expected goals and how to reach them

- Successfully transferring/storing data
- Quantification of added value
- Define direction for future research
- Setting up a community



Quay walls: loss of functionality



The quay wall loses functionality when the first of the three "fails"

↓

Increasing the safety of only one of the three not necessarily implies an increase in global safety

↓

Engineering question:
Which is the "weakest link"?

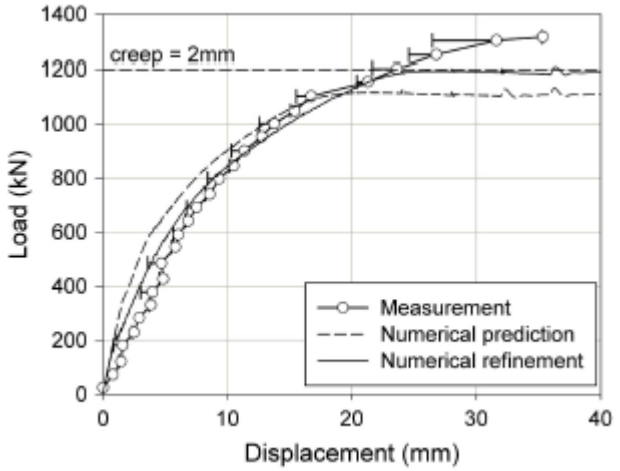
Other possible local failure could be considered!

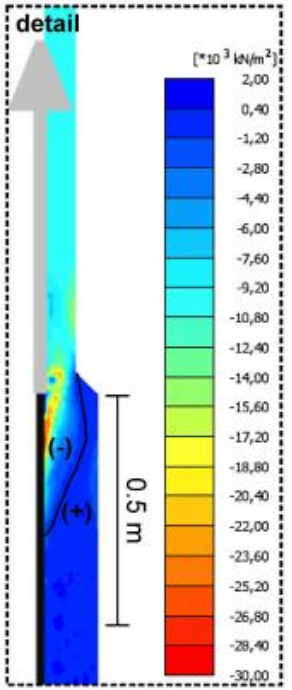
Bedankt voor jullie aandacht

#betterTUgether

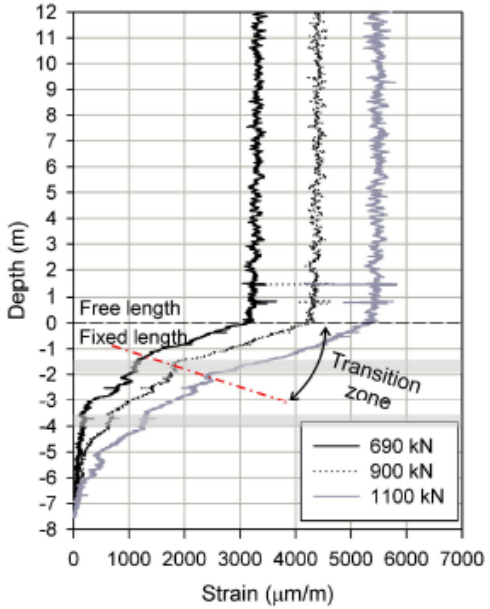
TU Delft

Load – displacements: test vs FE



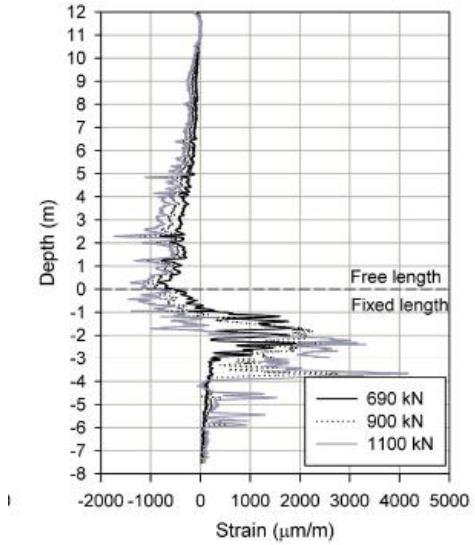


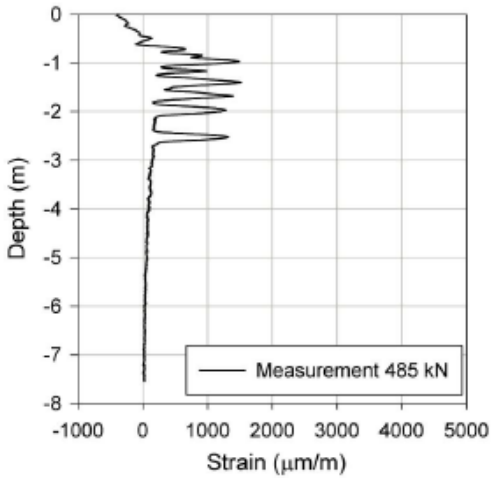
Test
Strains along the cable

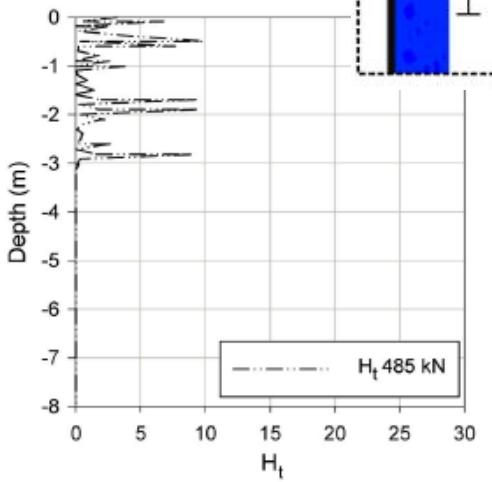


Grout Strains: test vs FE

Test
Strains along the grout







Fabris et al. (2021). ASCE