miyamoto. ENGINEERS+ CONSTRUCTION CONSULTANTS

NEW ZEALAND GEOTECHNICAL SOCIETY INC
www.nzgs.org

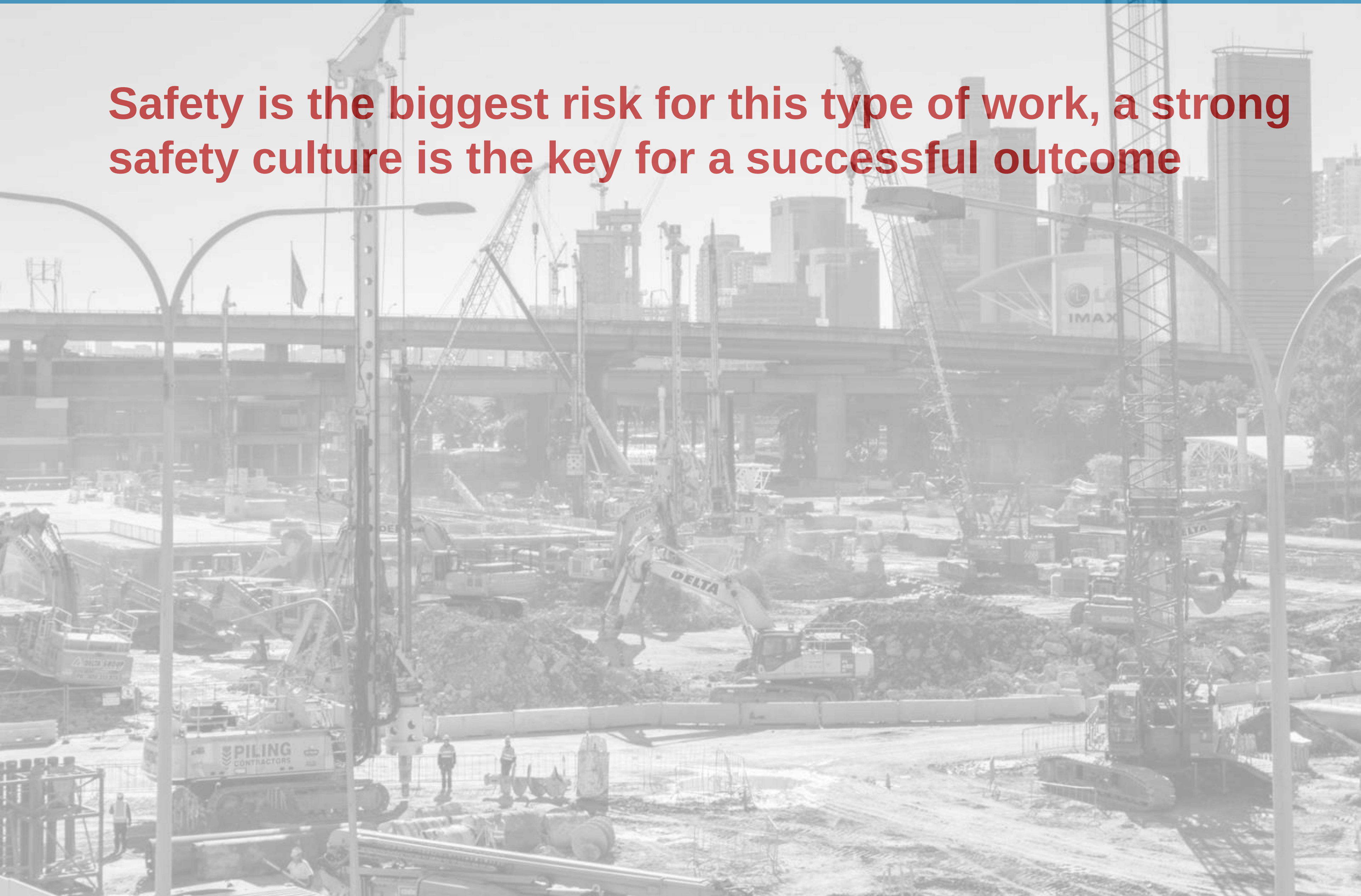
Risk Management
for
Piles & Deep Foundations

by

Martin Larisch

Wednesday 21/11/2018

Safety is the biggest risk for this type of work, a strong safety culture is the key for a successful outcome

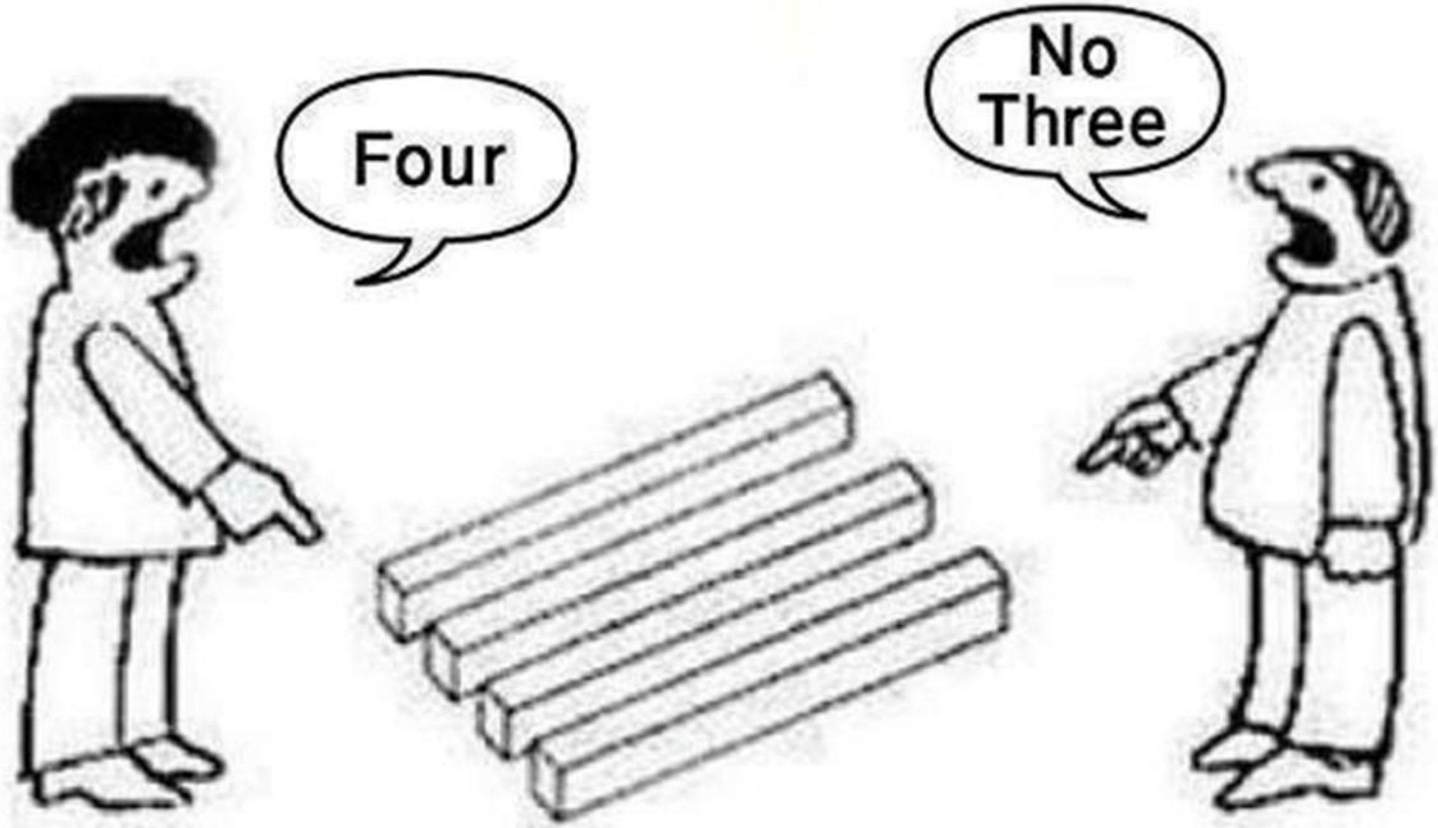


Defects due to inclusions and insufficient tolerances

Defects due to workmanship or insufficient materials

Defects due to workmanship or insufficient materials

It is really confusing!!!



Definition of risk:

‘A situation involving exposure to danger’

‘A probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through pro-active action.’

Main Drivers for successful risk management:

Source: Evans and Peck Report (2/11/2011):

- Resources (numbers, experience, qualification)
- Pre-planning (tender & construction phase)
- Quality of the design
- Clear focus on the owner's business needs
- Co-operative and motivated teams
- Strong commitment by all stakeholders to equitable risk allocation, attention to effective risk assessment, analysis and management

Risk Management

Expectations

Communication

Selected RISKS related to piling & deep foundations:

General:

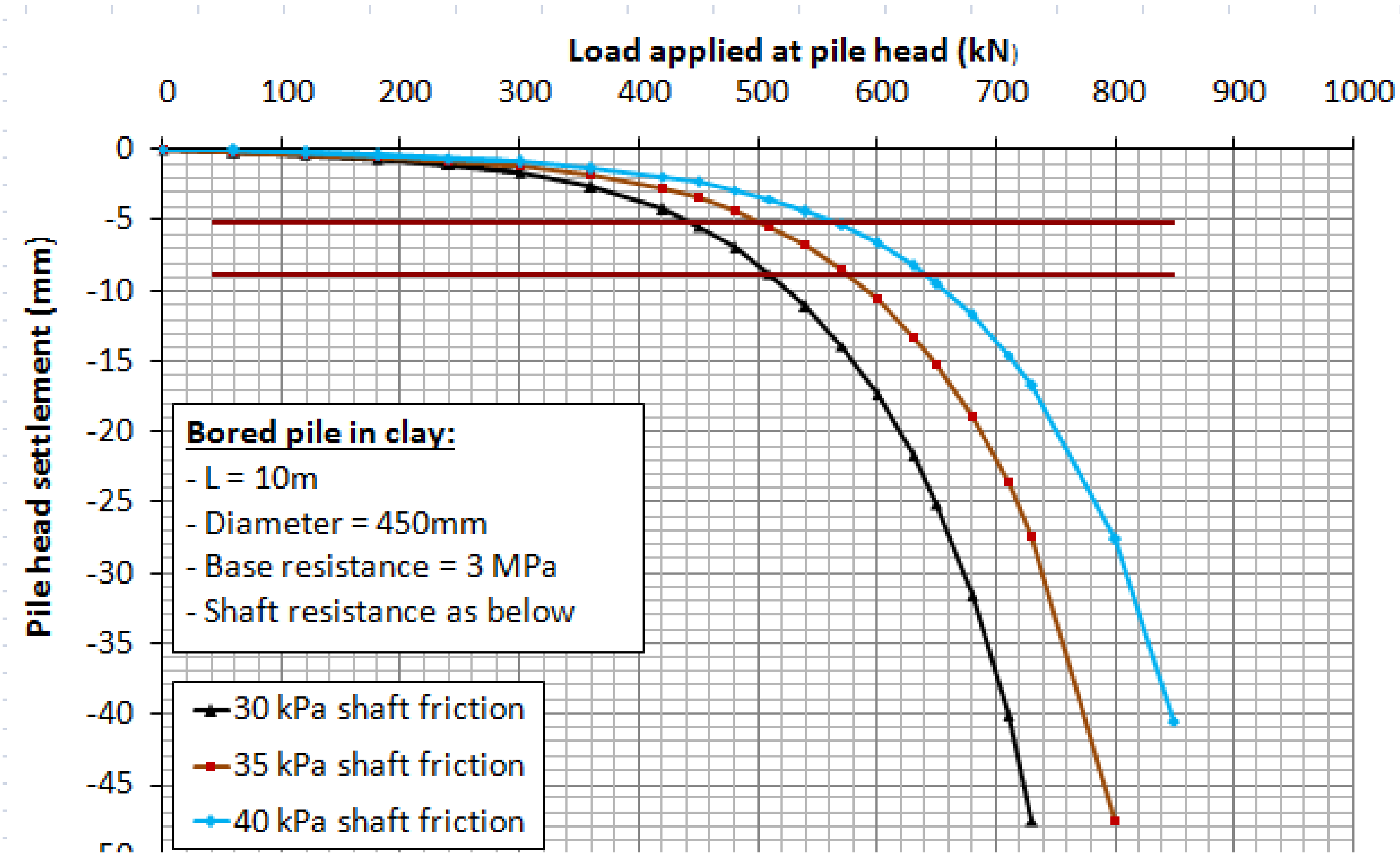
- Safety
- Program
- Budget
- Ground conditions
- Constructability
- Obstructions in the ground
- Design assumptions (performance criteria)
- Necking
- Collapsing ground
- Eccentricity
- Etc..

Design

Construction

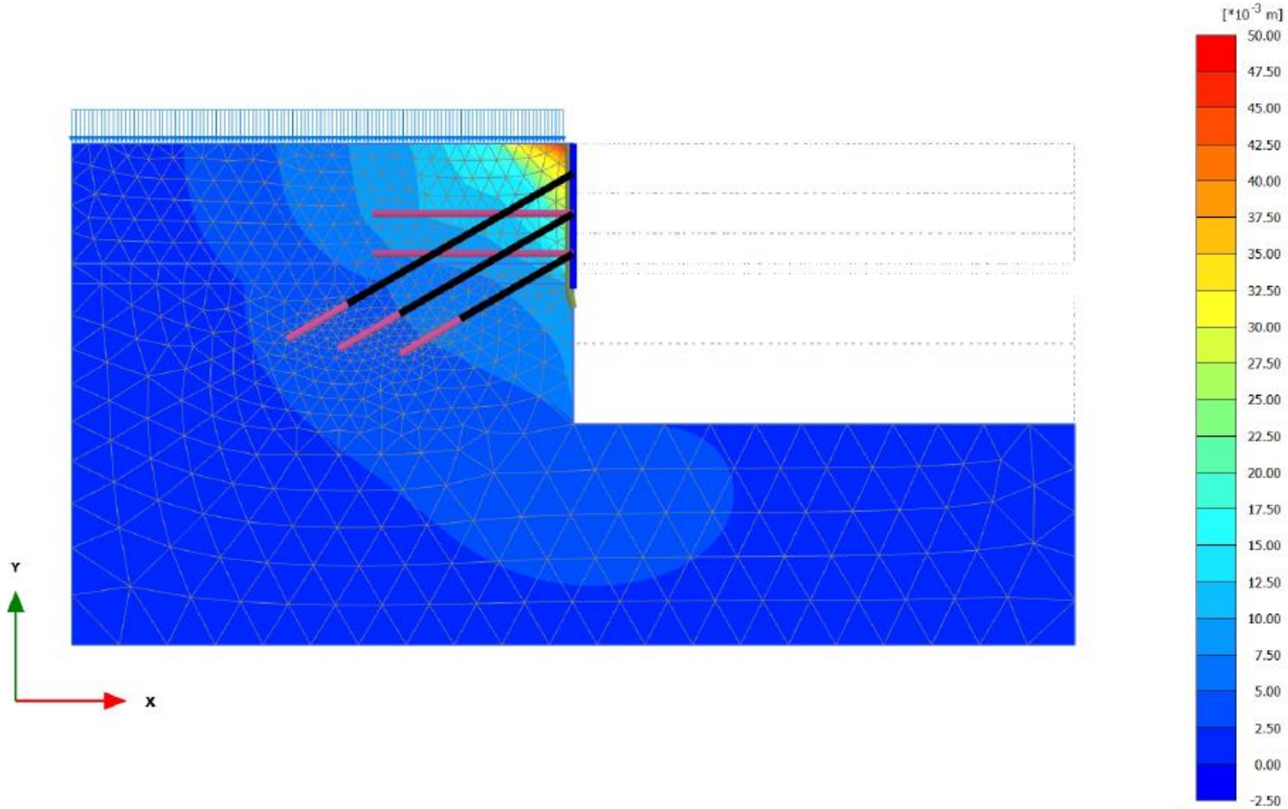
Performance

EXAMPLE – Load Settlement Estimate (Fleming, 1992)



How do design models correlate with site conditions?

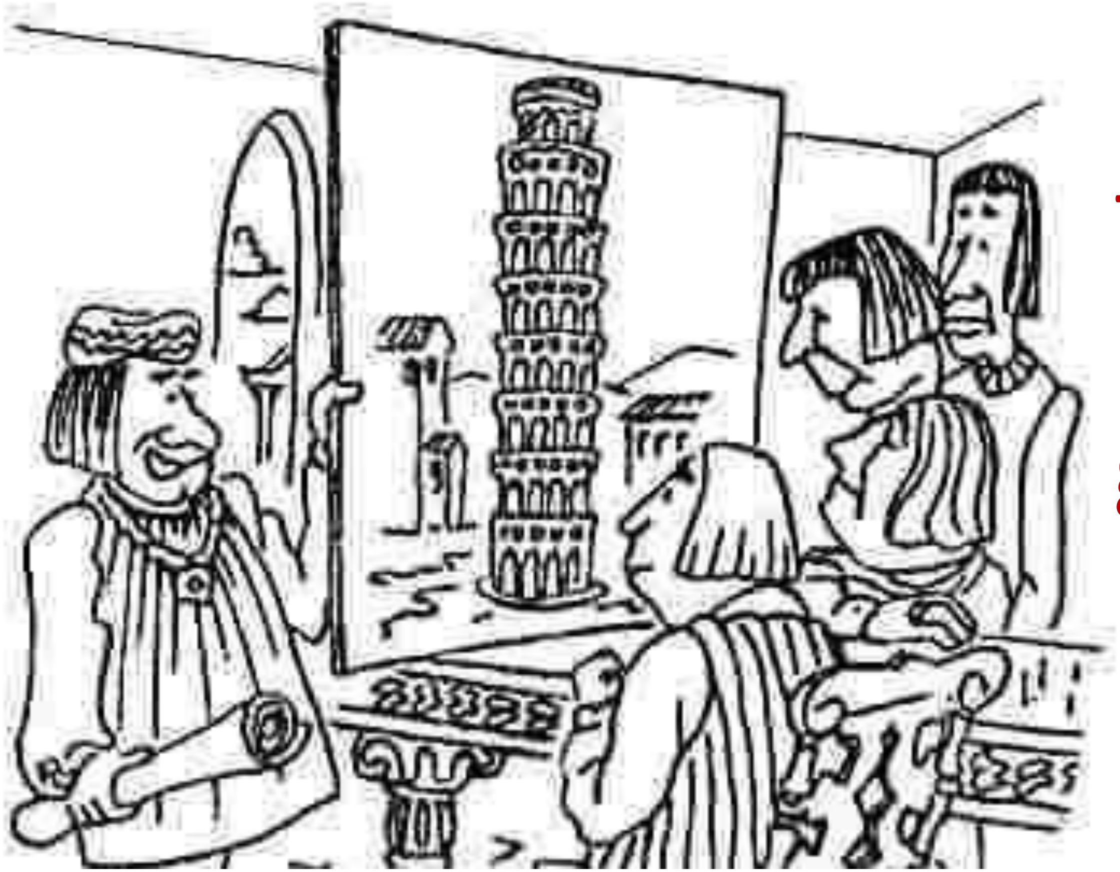
How do we assess / verify our design parameters?



Total displacements u_x

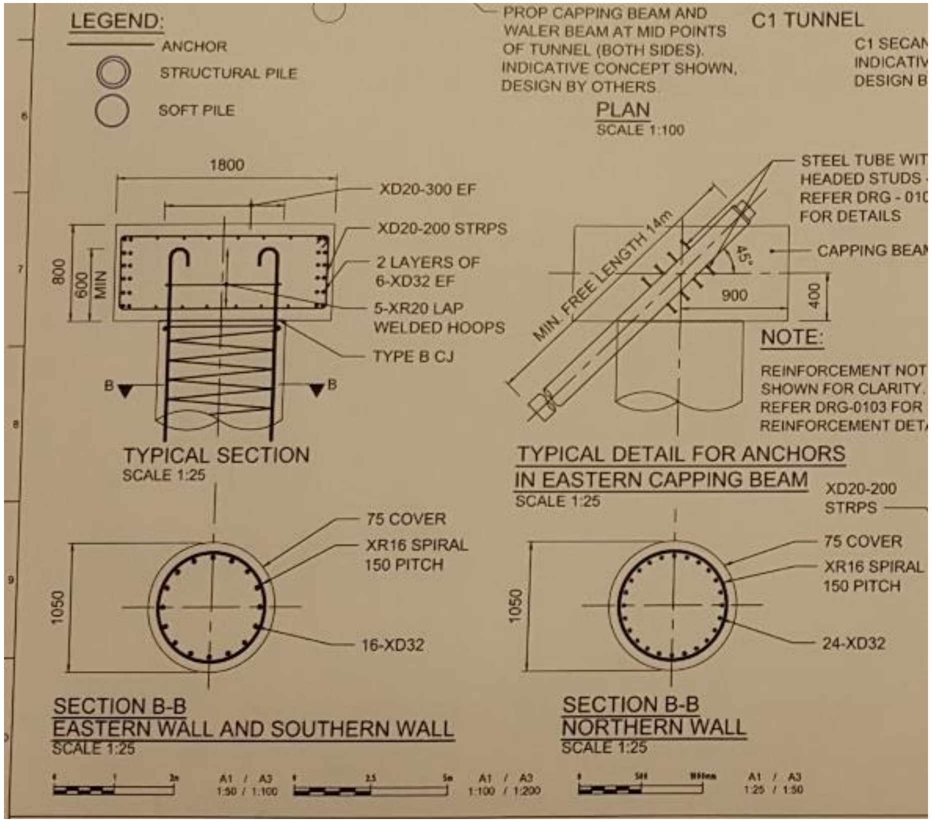
Maximum value = 0.04756 m (Element 336 at Node 7552)

Minimum value = 0.000 m (Element 42 at Node 15628)



"And the best thing is: we reduced the geotechnical investigation by 50%"

Reinforcement detail on the drawing (left) and on site (right)



Construction tolerances must be communicated & understood

Construction tolerances must be communicated & understood

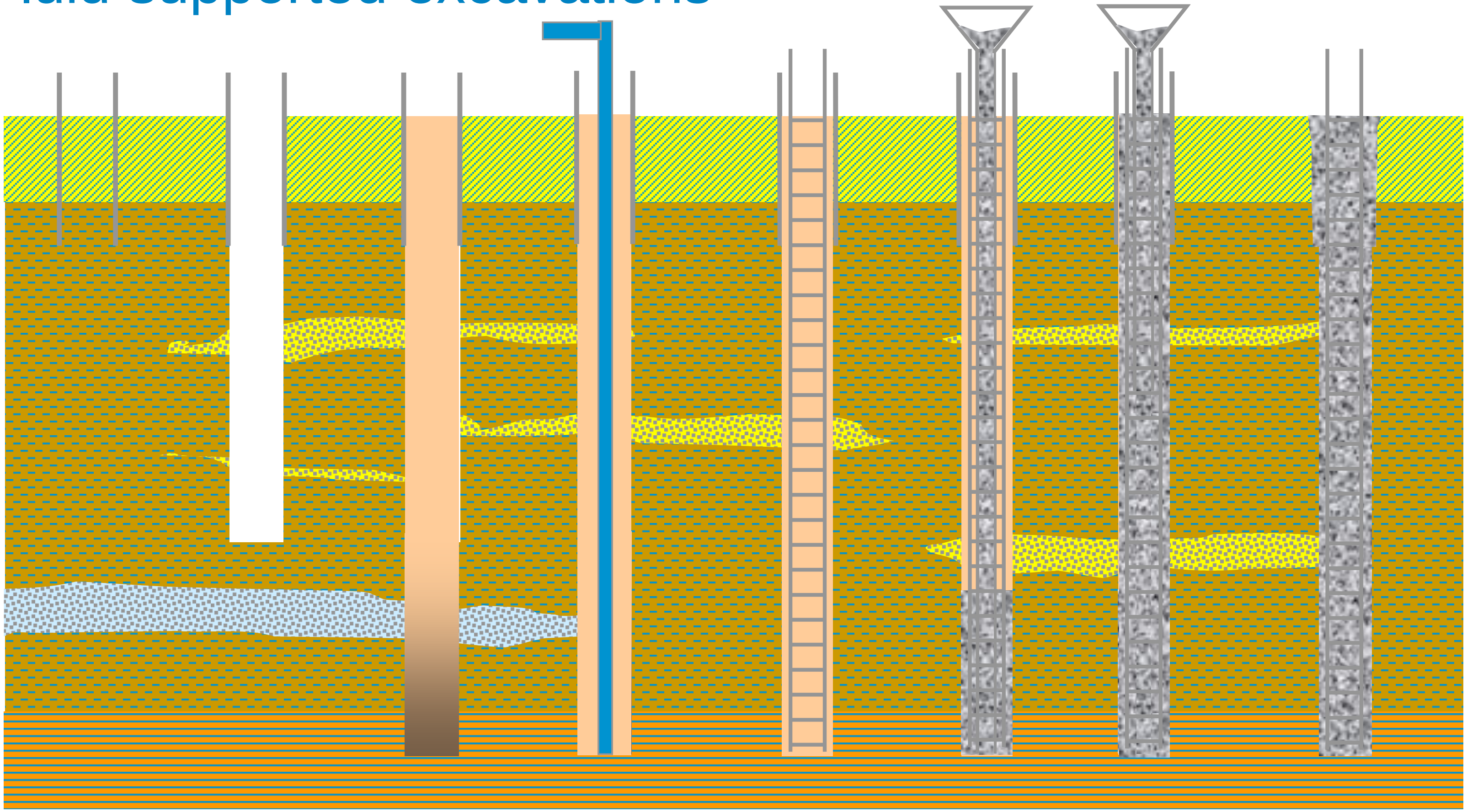
Construction tolerances

- Allow for vertical and horizontal tolerances in your pile design
- Ensure contractors can commit to stricter tolerances
- Ensure water proofing performance and durability requirements are met

Remediation:

- Use of highly workable grout
- Proper planning
- Re-design of foundations
- Design pile caps with 3 piles

Fluid supported excavations



The most common drilling support fluids for deep foundations are:

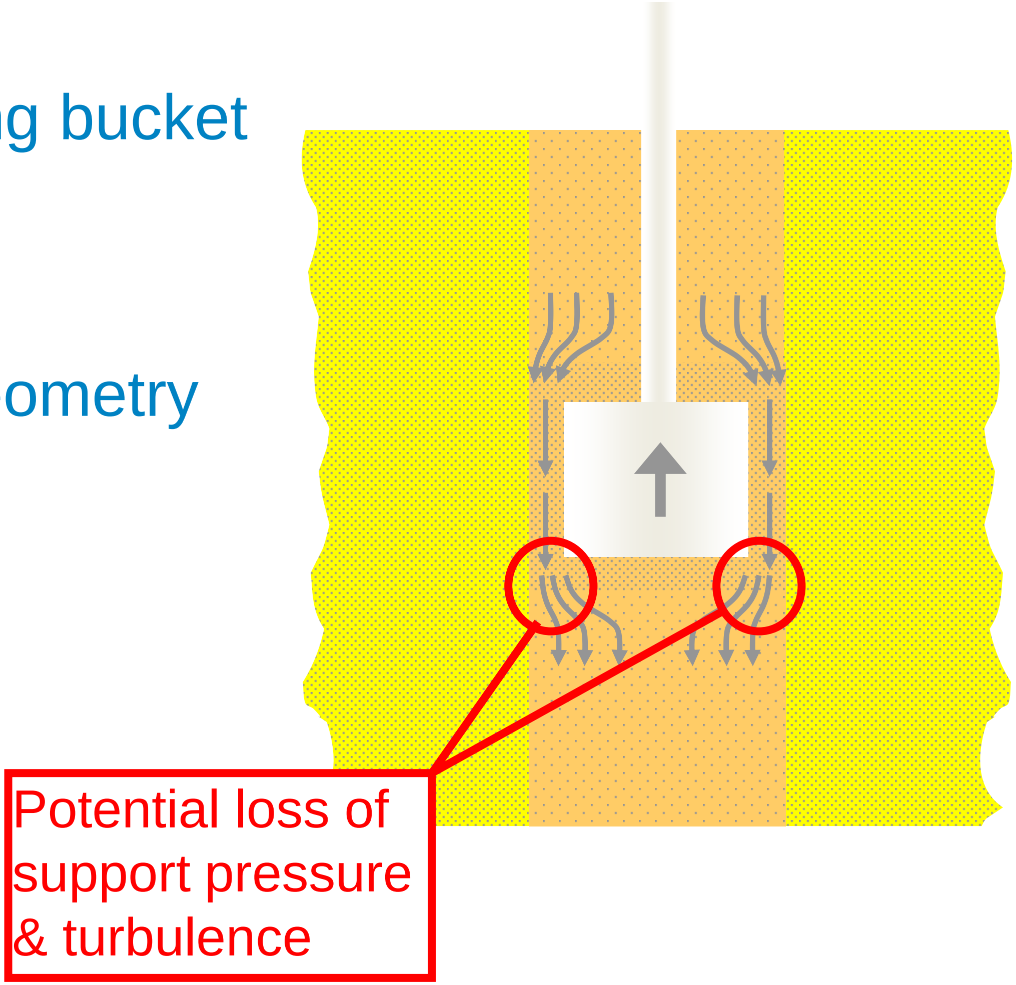
- Water
- **Bentonite** (mineral slurry)

  (keeps solids in suspension – fluid needs to be cleaned and circulated, which is typically time consuming)
- **Polymer**

  (solids settle to the bottom of the excavation where they can be removed by purpose built cleaning tools – no fluid circulation required)

Effect of auger / digging bucket movement:

- The speed of lift
- Bypass area / geometry
- Fluid viscosity



Suitable ground conditions

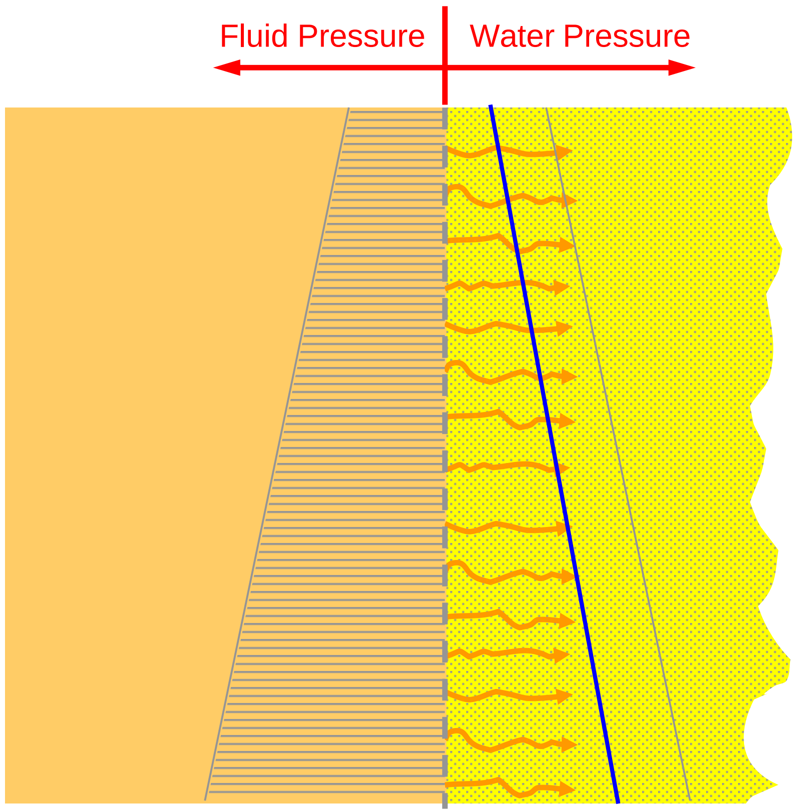
- Loose to very dense sands (bentonite)
- Stiff to hard clays (polymer)
- Layered ground conditions (bentonite or polymer)

Fluid supported piles should be considered carefully for:

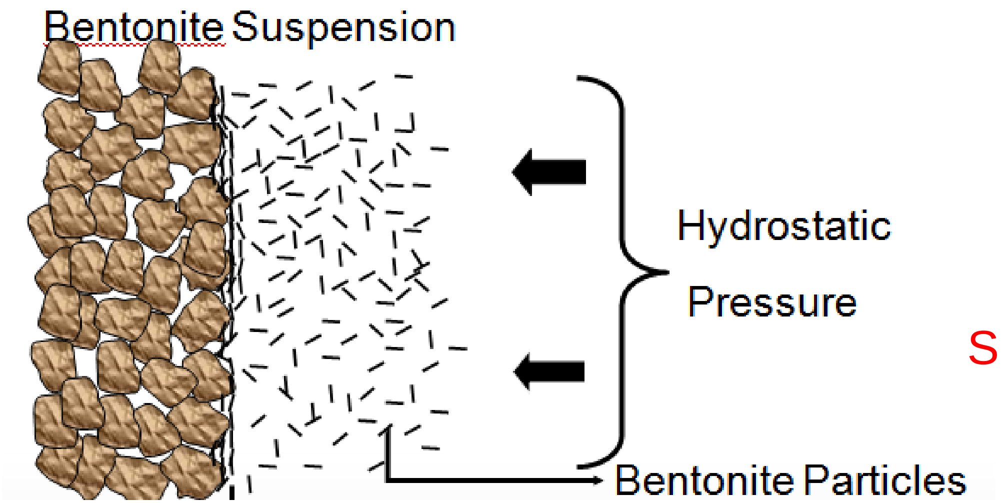
- Gravels and cobbles
- Soft soil conditions
- Soil conditions with obstructions and cavities
- Contaminated groundwater / marine conditions

Maintaining a positive fluid pressure

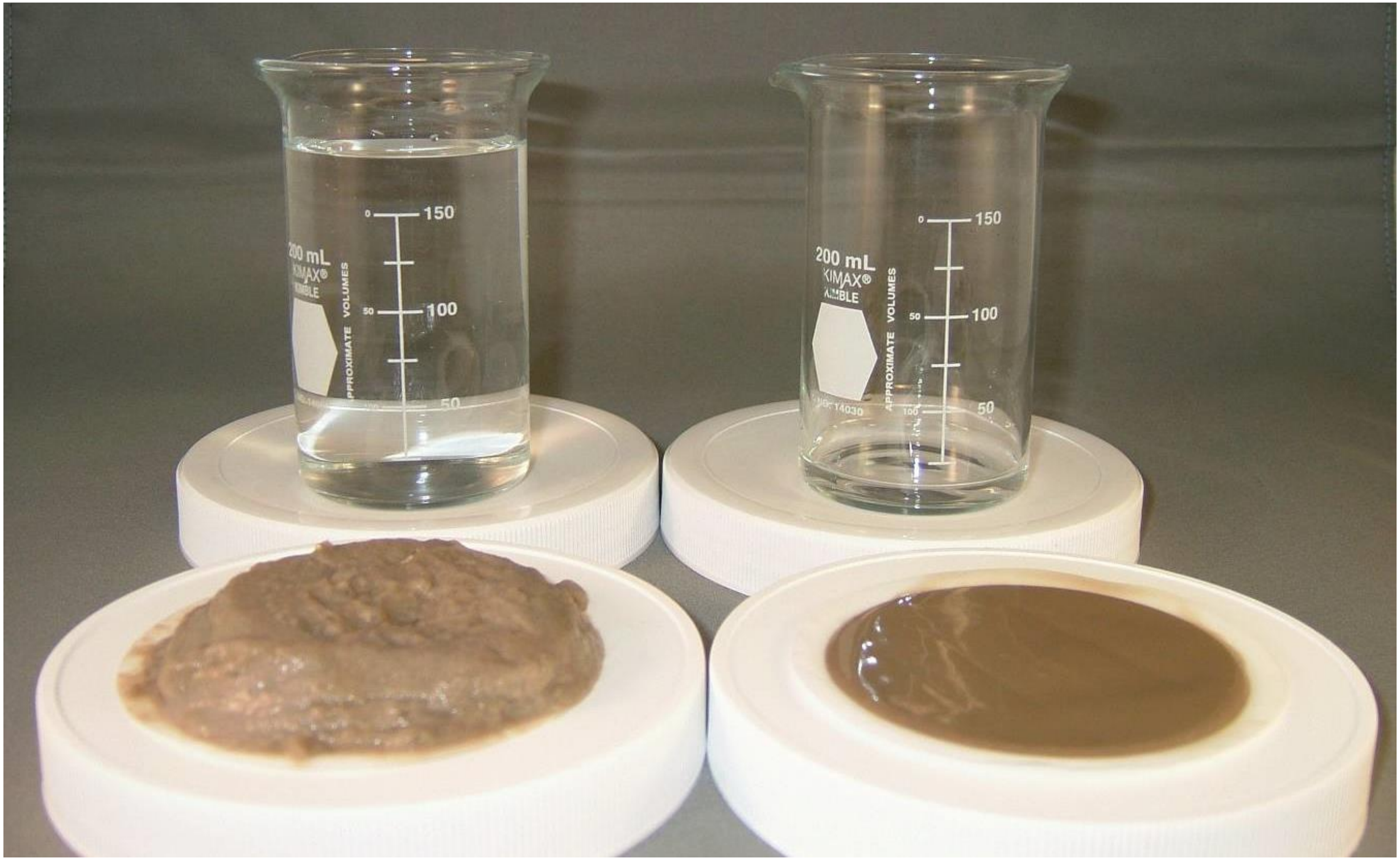
- Minimise fluid loss into soil
- Formation of “Filter cake” or effective “Membrane”
- Bentonite filter cake formed by clogging’ and ‘bridging’



Support fluid pressure <= water pressure
>> INSTABILITY



The filter cake thickness is a function of bentonite quality



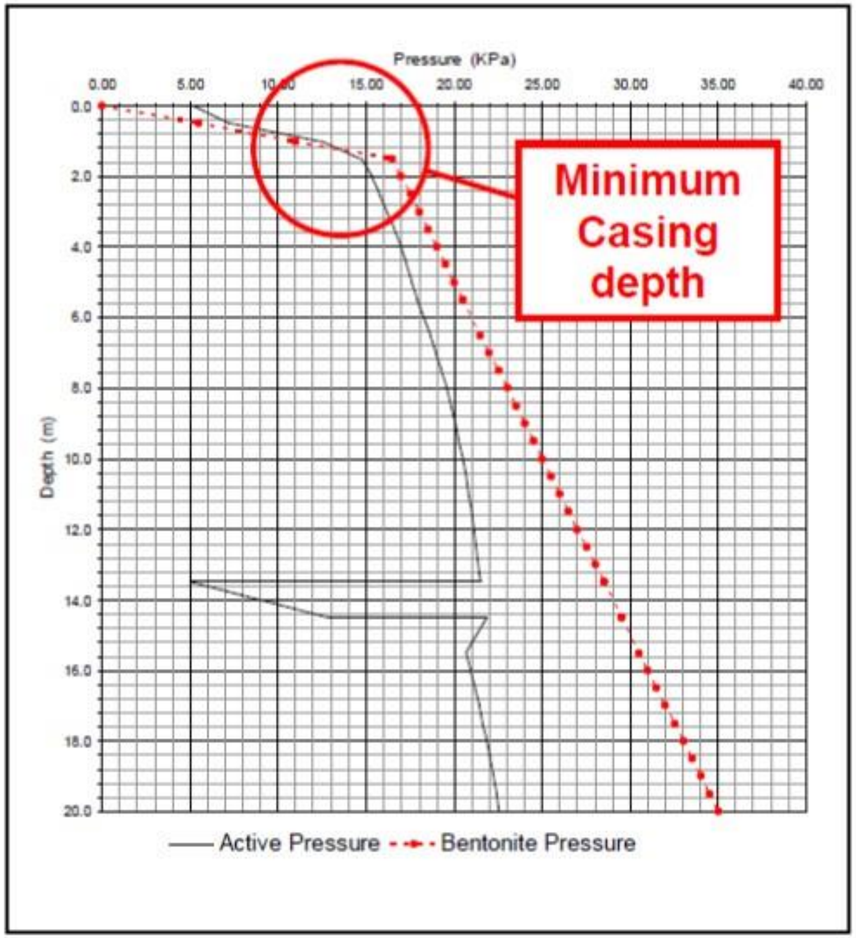
Drilling fluids with different fluid-loss behaviours are shown below (water vs bentonite)

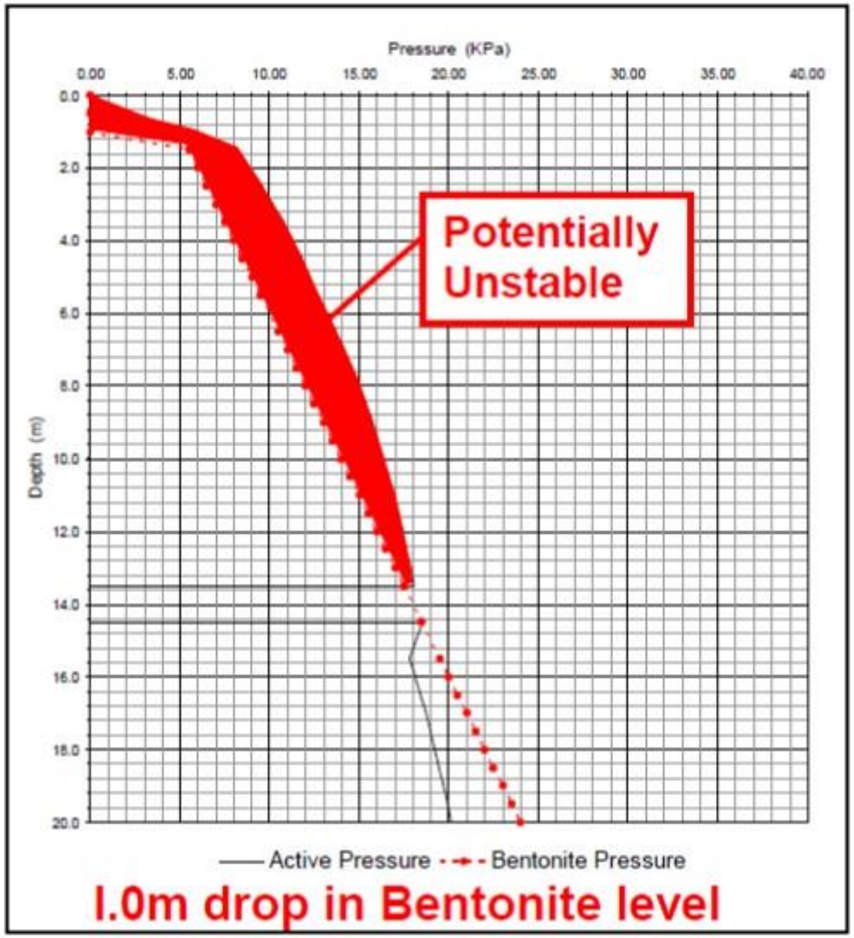
The thin wet layer is where the bentonite platelets and hydrostatic head of the fluid created an impermeable membrane/barrier (the wall cake) which stabilizes granular soils such as sand.

Water

Bentonite

Stability of bored piles and diaphragm walls under fluids





Principle hole ‘cleaning’ mechanism of **polymer fluids**

(Photo courtesy of KB International)

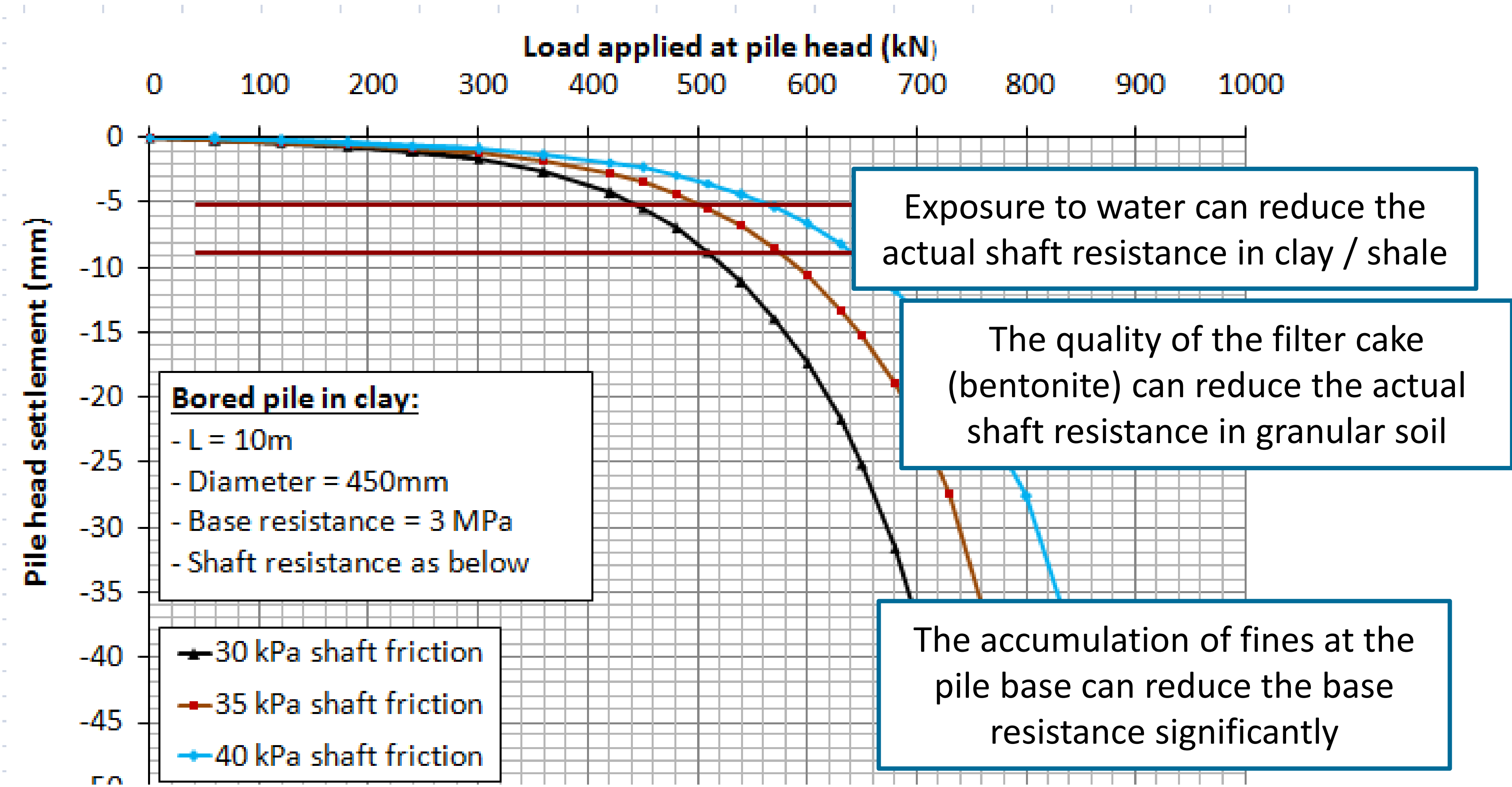
SPERW (2nd Edition 2007) – BENTONITE PROPERTIES

Table C18.1 Typical tests and compliance values for support fluid prepared from bentonite manufactured in the UK

Property to be measured	Test method and apparatus	Compliance values measured at 20°C		
		Freshly mixed	Ready for re-use	Sample from excavation prior concreting
Density	Mud balance	<1.10 g/ml	<1.25 g/ml	<1.15 g/ml
Fluid loss (30 minute test)	Low-temperature test fluid loss	<30 ml	<50 ml	n/a
Filter cake thickness	Low-temperature test fluid loss	<3 mm	<6 mm	n/a
Viscosity	Marsh cone	30–50 seconds	30–60 seconds	30–50 seconds
Shear strength (10 min gel strength)	Fann viscometer	4–40 N/m^2	4–40 N/m^2	4–40 N/m^2
Sand content	Sand screen set	n/a	n/a	<4%*
pH	Electrical pH meter to BS 3445; range pH 7 to 14	7–10.5	7–11	n/a

* 2% prior to concreting if working loads are to be partly resisted by end bearing

EXAMPLE – Load Settlement Estimate (Fleming, 1992)



- Fluids will lose their properties after a certain period of time, check the properties frequently if you want to leave excavations open for an extended period of time
- Ensure base cleanliness, especially for polymer fluids
- Be aware of potential reduction of shaft friction in clays when using water or bentonite
- Consider shear thickening and shear thinning behaviour of different fluids during mixing and pumping
- Ensure sufficient concrete workability for wet pours, resistance against bleeding (risk of fluid dilution) and potential chemical reactions with concrete admixtures or ground water
- **ALWAYS KEEP THE FLUID LEVEL >2m ABOVE GWL**

Drilling fluids

- Clean pile base thoroughly
- Use polymer for cohesive soils (avoid clay swelling)
- Use bentonite in granular soils (avoid fluid losses)
- Monitor the fluid properties several times per day
- Ensure polymer won’t react with concrete admixtures

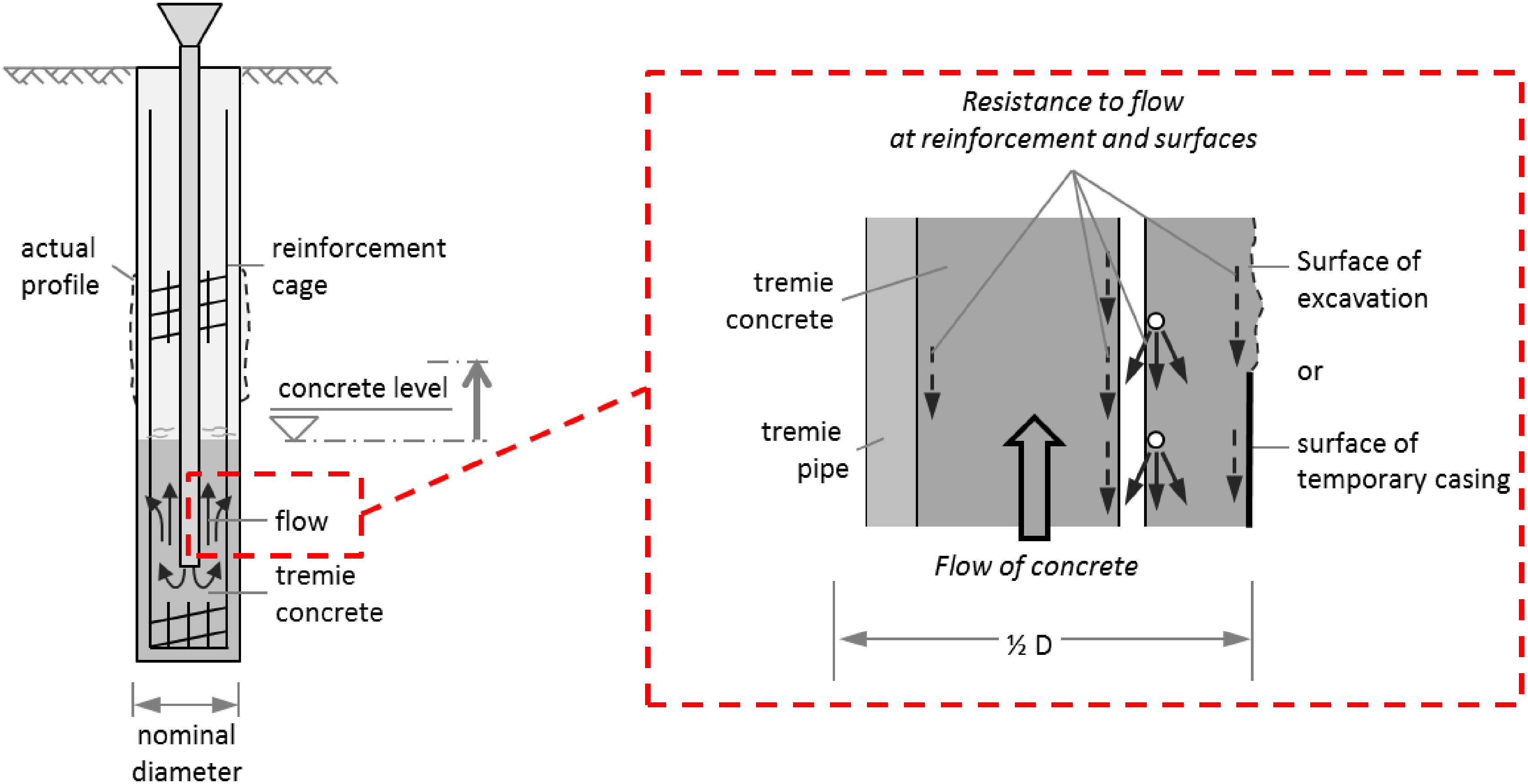
Remediation:

- Use of workable concrete
- Pile replacements ($$)
- Re-design of foundations

Concrete is playing an important part in piling…

Define & understand concrete performance criteria

(e.g. keep tremie pipe embedded into fresh concrete by >3m)



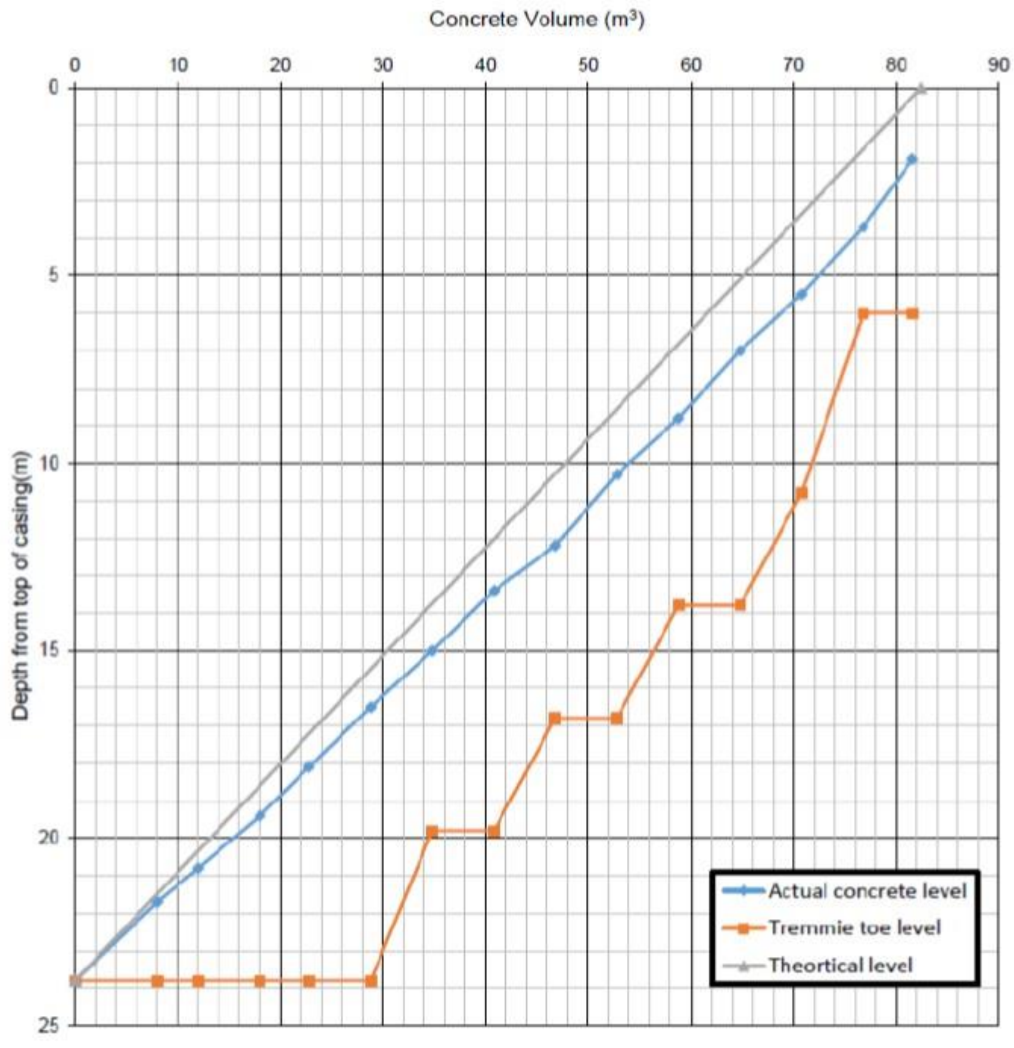
Dry pour (<75mm of water at the base) vs wet pour…

(Photos courtesy of Active Minerals Australia)

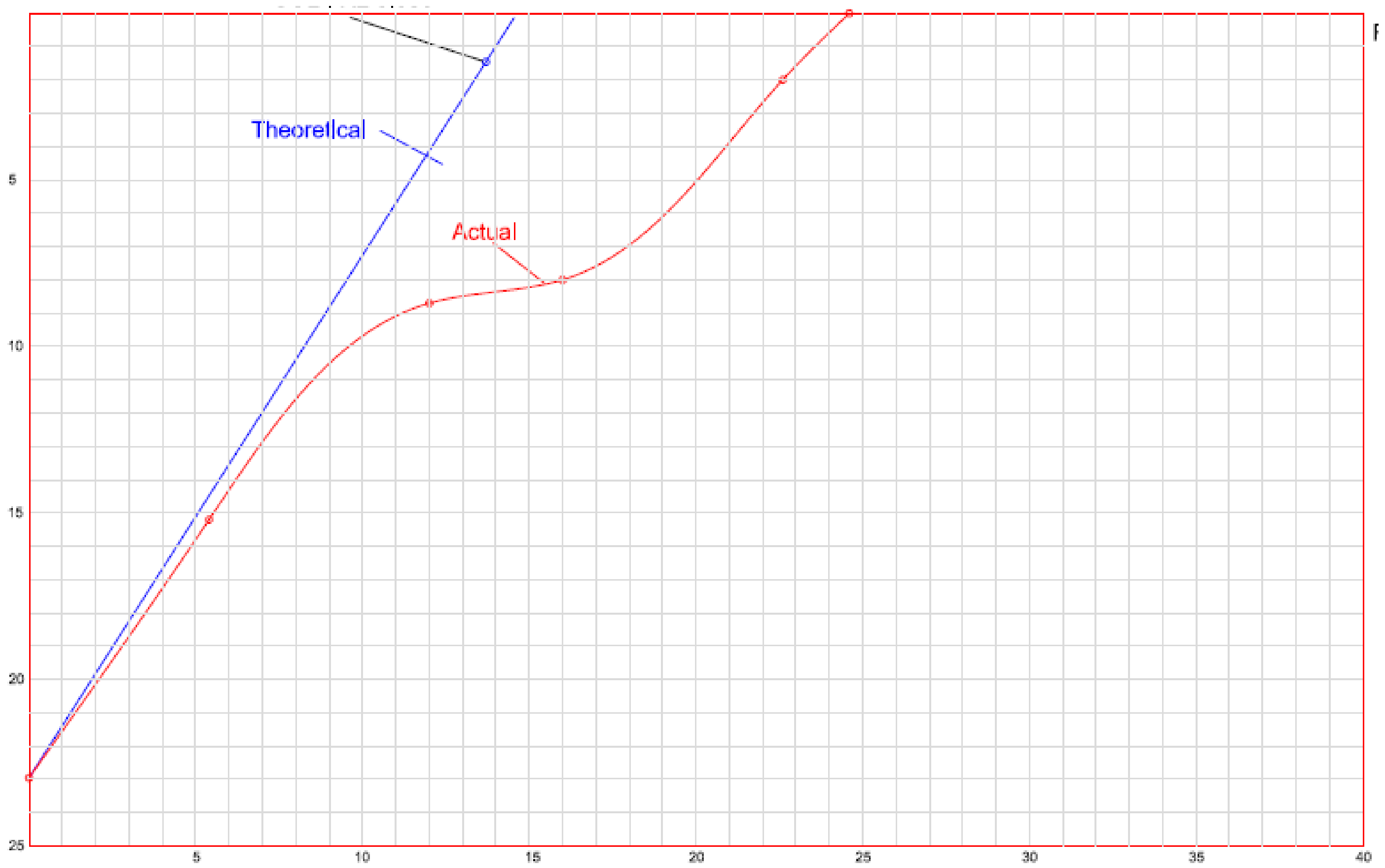
Slump under fluid

DRY (230mm/370mm) | WATER (200mm/290mm) | POLYMER (200mm/290mm)

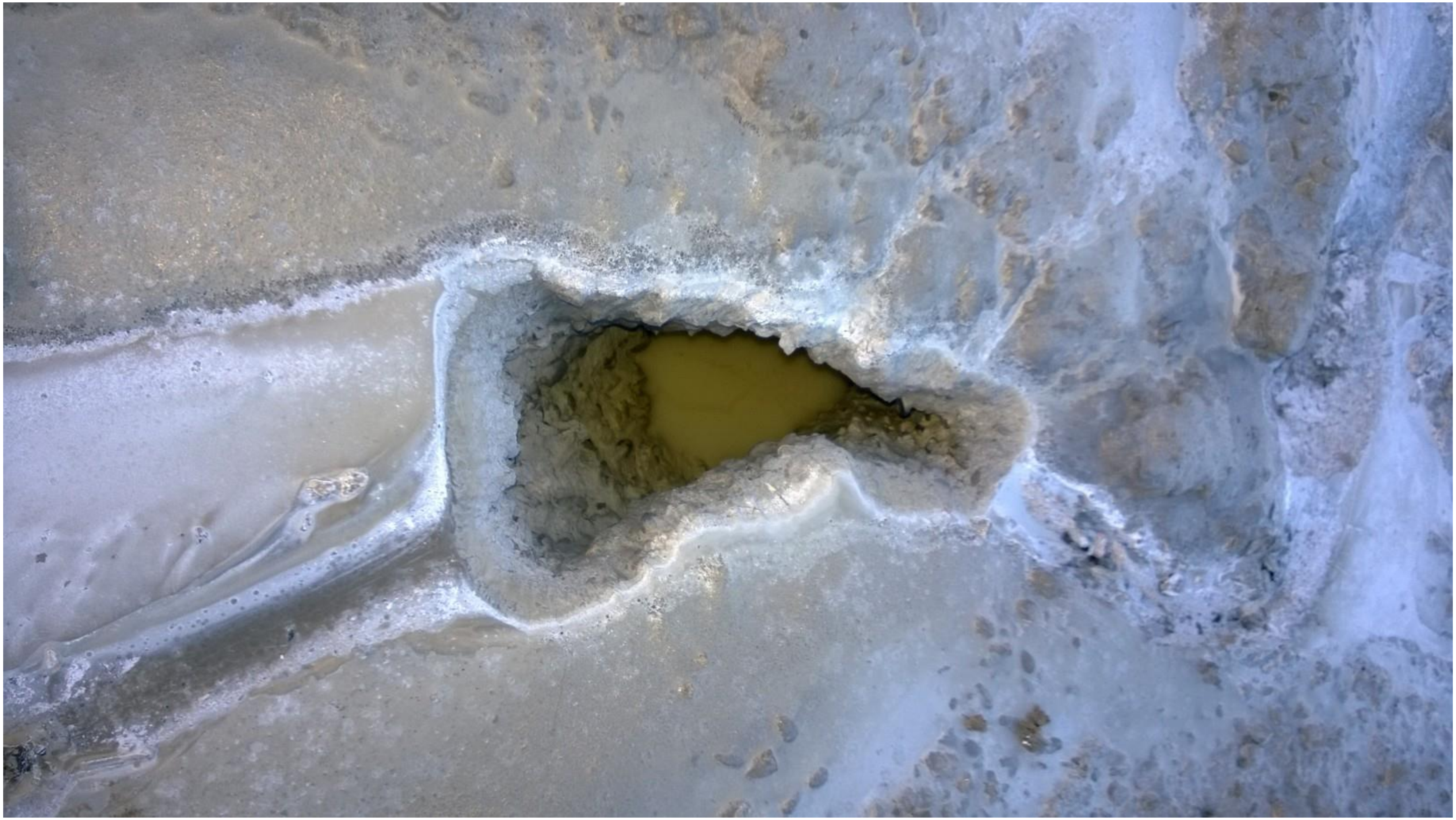
Concrete displacement records



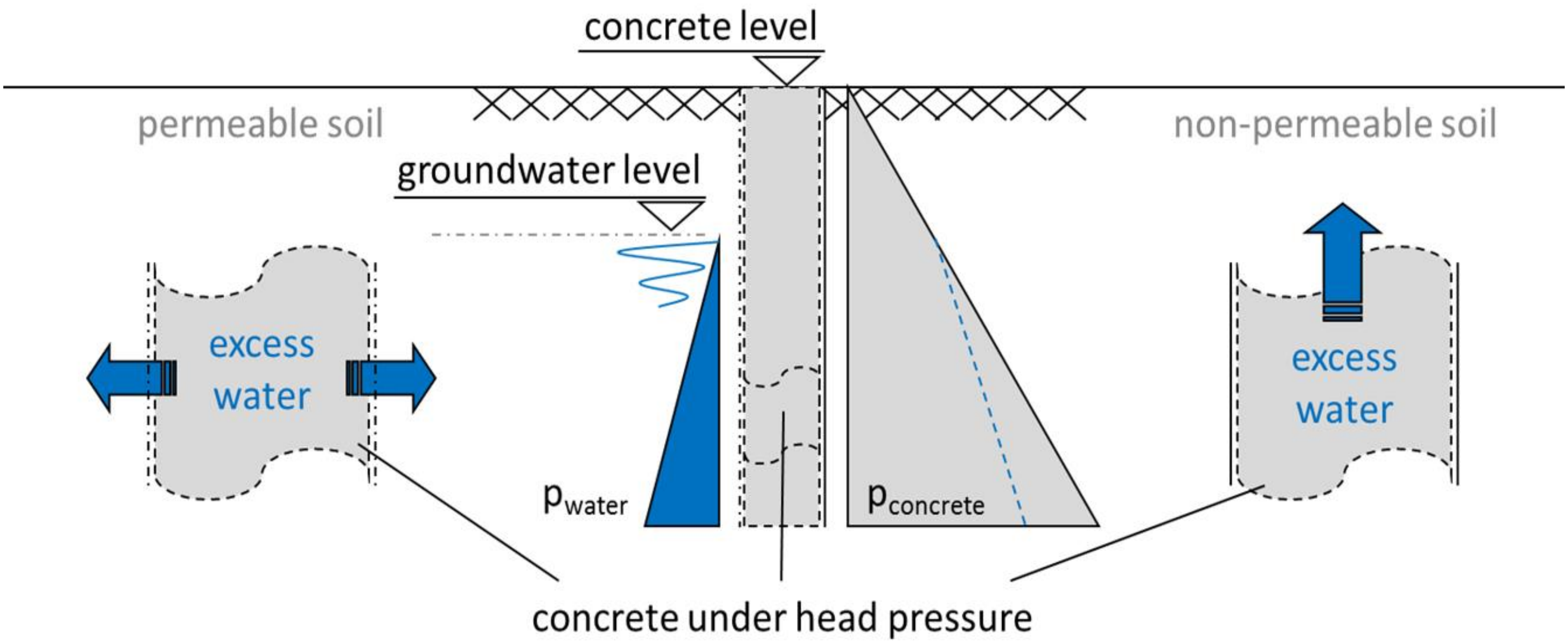
Concrete displacement curves – what happened?



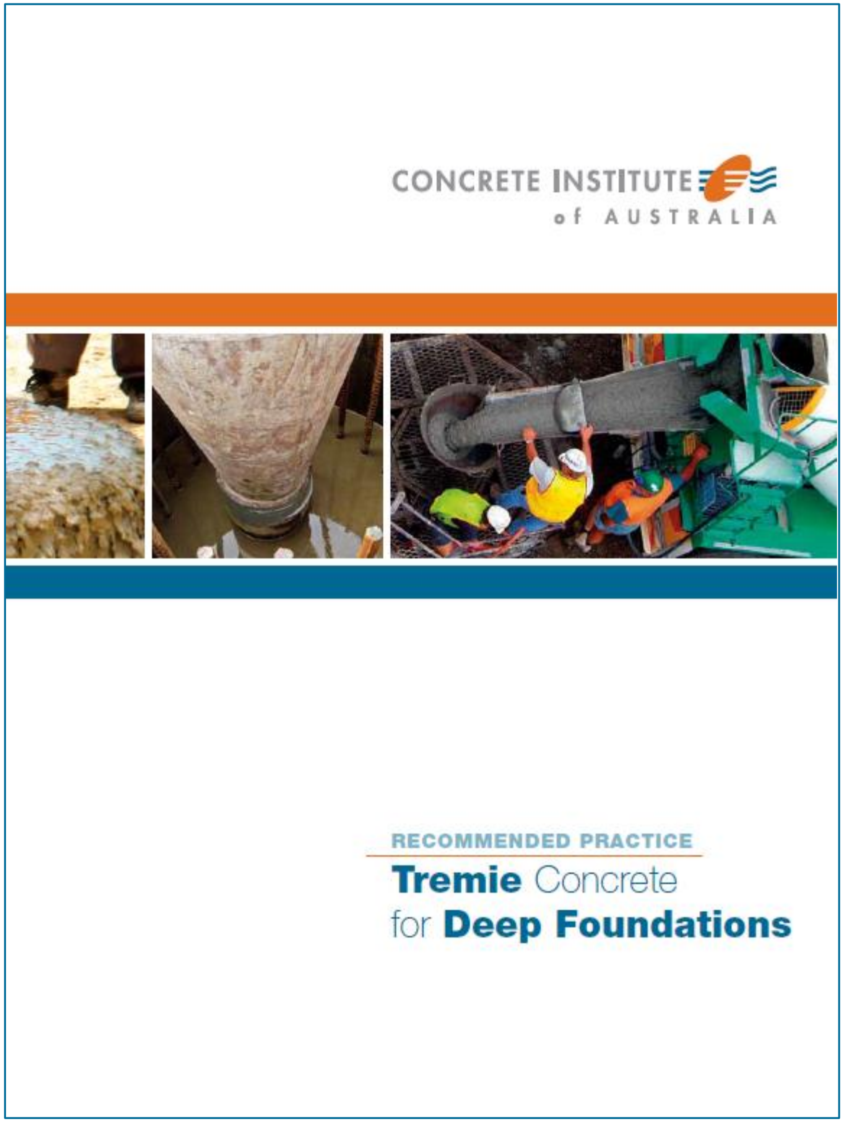
Concrete bleeding under pressure

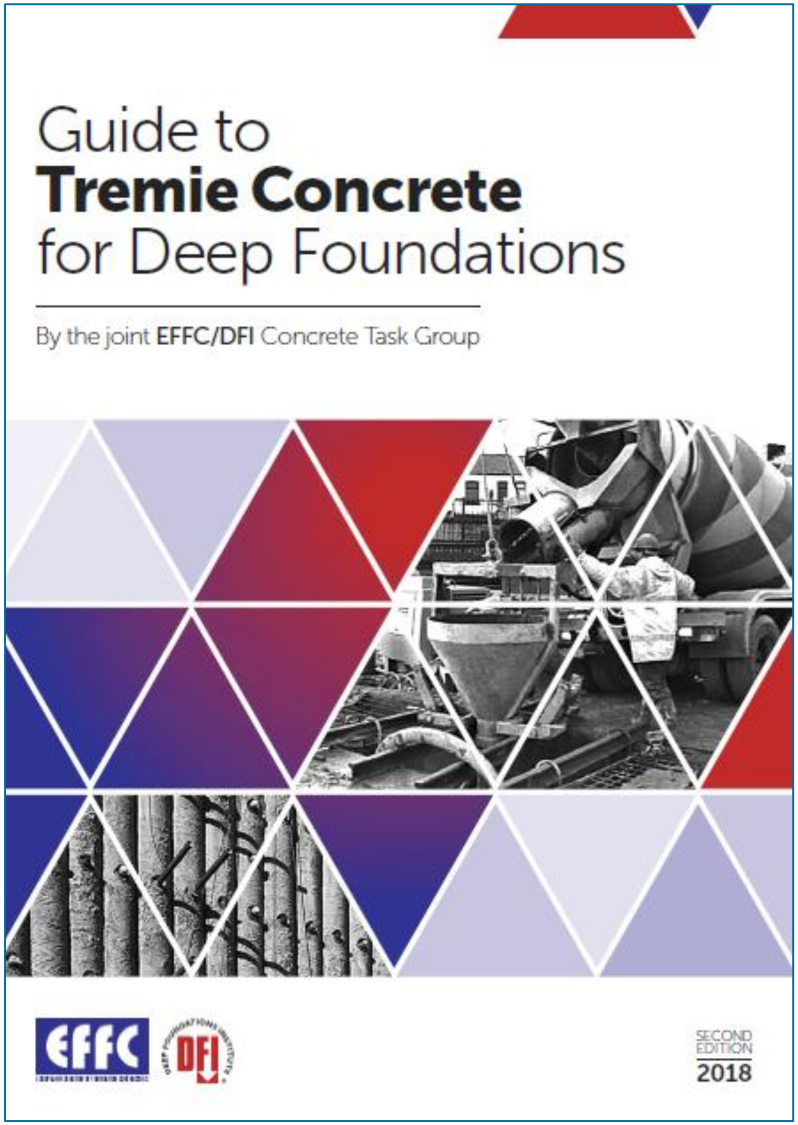


Concrete bleeding under pressure



Test Method and properties assessed	Suggested value for structural element of length l and for optional pouring conditions		
	Dry	Wet, flow distance	
	-	< 1.2 m	≥ 1.2 m
Slump h (mm)	≥ 140*	≥ 180	≥ 220
Slump flow D_{final} (mm) T_{final} (sec)	- -	400 - 600 ≤ 5	450 - 650 ≤ 3
L-Box Travel distance from bars (mm) Filling Ratio T_{end} (sec) L-Box Passability (mm)	> 200 - - ≤ 40	(full) ≥ 0.2 ≤ 12 ≤ 40	(full) ≥ 0.4 ≤ 8 ≤ 20
Bauer filtration Filtration loss (l/m³) Filter cake thickness (mm)	≤ 30 ≤ 150	≤ 30 @ l ≤ 15 m / ≤ 15 @ l > 15 m ≤ 150 @ l ≤ 15 m / ≤ 100 @ l > 15 m	


CONCRETE INSTITUTE
of AUSTRALIA
RECOMMENDED PRACTICE
Tremie Concrete
for Deep Foundations


Guide to
Tremie Concrete
for Deep Foundations
By the joint EFFC/DFI Concrete Task Group
EFFC
DFI
SECOND EDITION
2018

Concrete bleeding under pressure

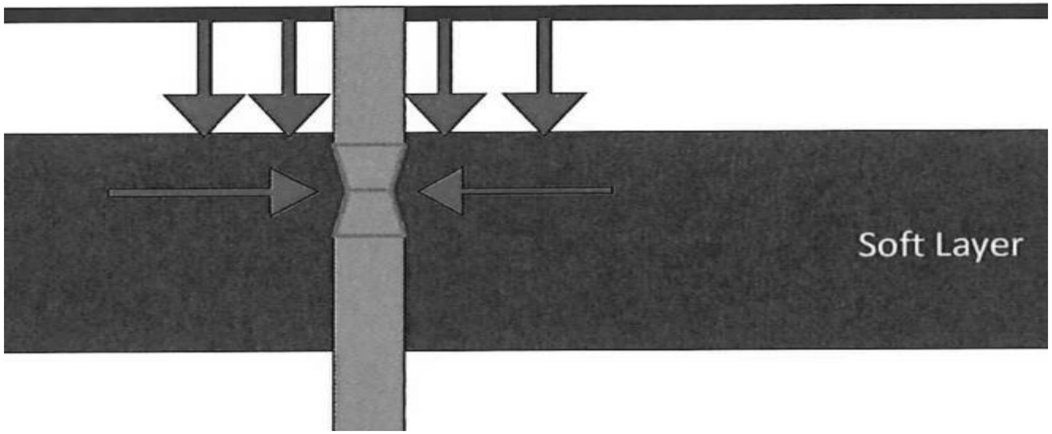
- Reduce water content to about 180l/m3 and then further adjust during trials
- Ensure at least 500kg/m3 of fines (< 0.6mm) in your mix
- Carry out lab and field trials

Remediation:

- Shotcrete
- Cathodic protection ($$)
- Re-design of piles
- Pile replacements ($$)
- Removal of defect sections

Piles can be subject to necking if the following occurs:

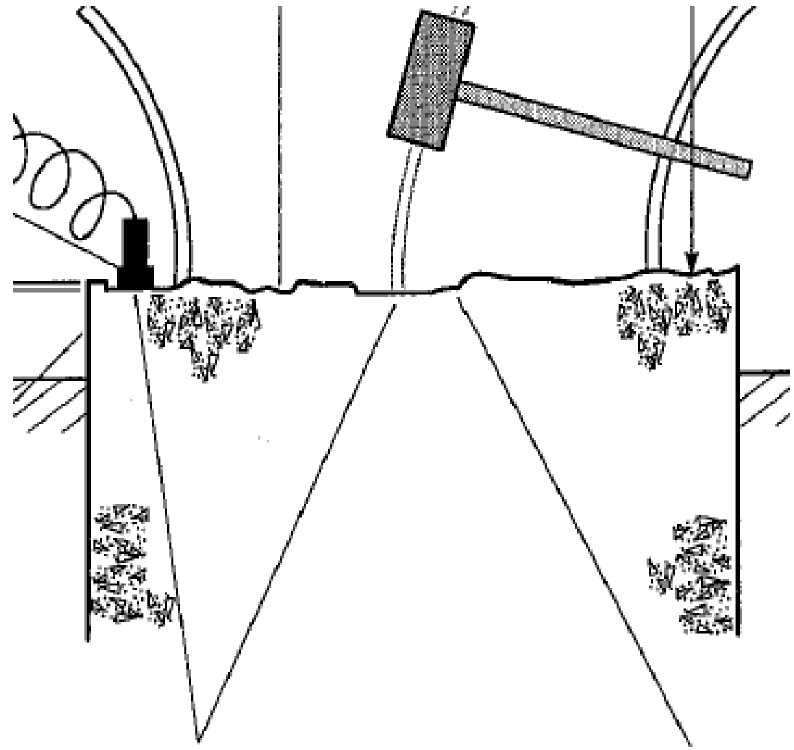
- Very soft layers are below a layer of fill
- The pressure of the fill causes the soft layer to move laterally into the pile excavation if concrete pressure is insufficient
- Low cut off levels can be the reason for insufficient pressure
- Necking can also be caused by piling rigs (ground pressure)



Pile integrity testing

Detect pile damages during installation, NOT afterwards when the structure is built

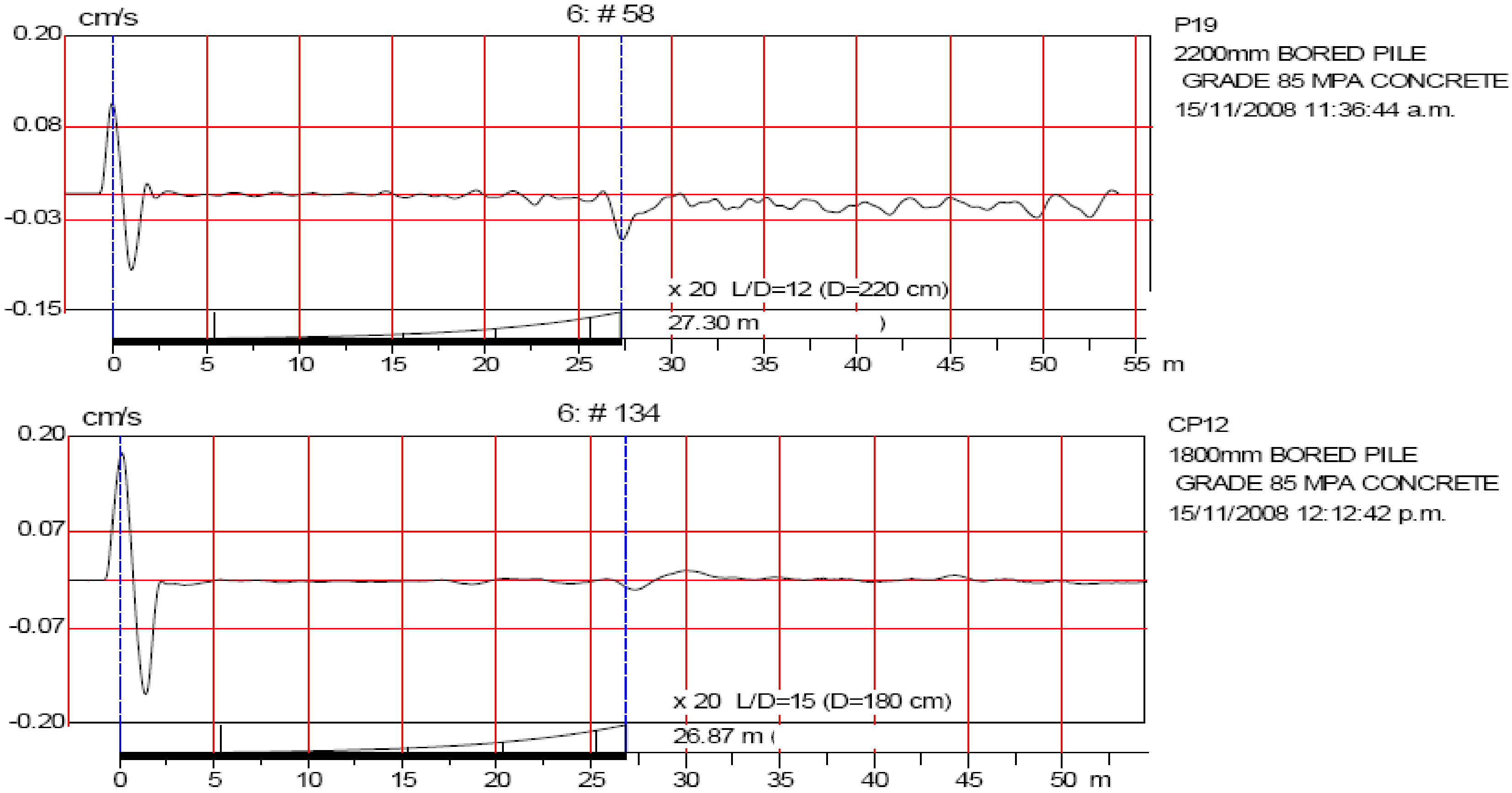
Low strain integrity tests (PIT)



Low strain integrity tests (PIT)

- PIT tests (identifies defect and inhomogeneous areas)
- Non destructive test method involving hammer impact at the pile top and measurement of resulting pile top motion
- Low strain compression wave travels down the pile shaft
- Wave will be reflected when change of impedance occurs (at pile toe, inhomogeneous areas, cracks, necking or bulging)
- Suitable for small diameter piles (typically up to 900mm) and 20-25m depth

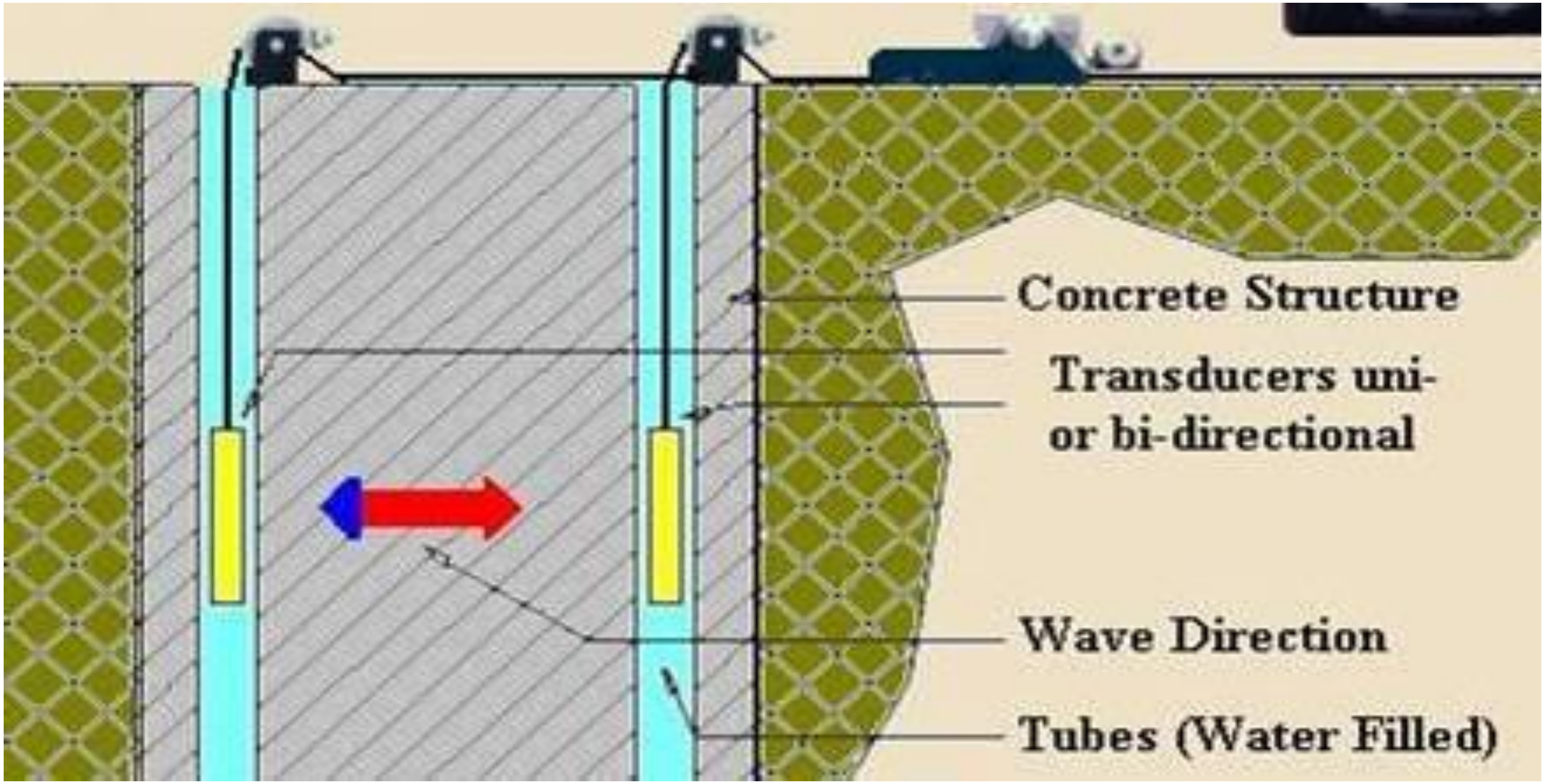
Low strain integrity tests (PIT)



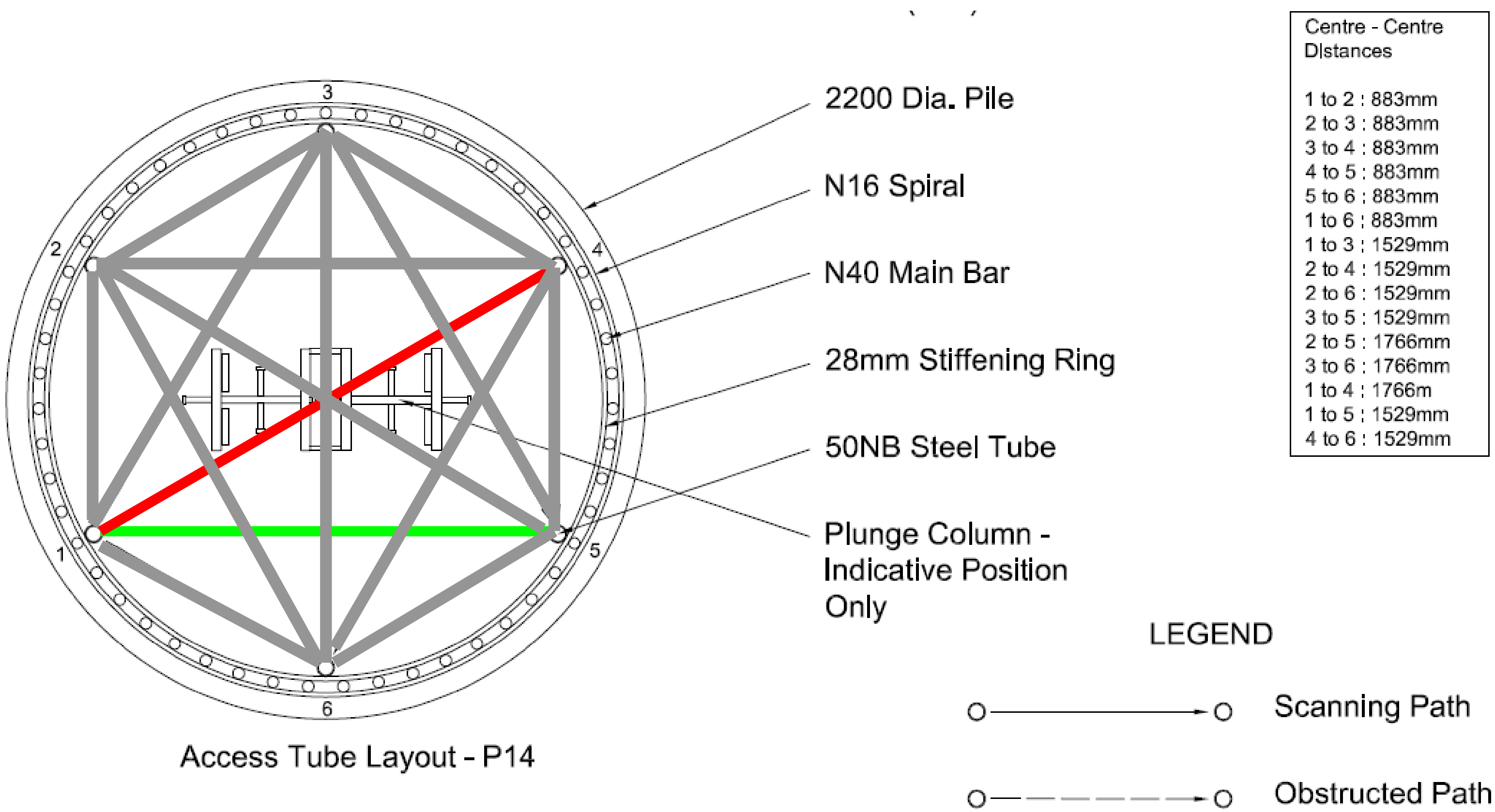
CHL/CSL – Cross hole sonic logging

- Cross Hole sonic Logging (CHL) is a non destructive test method which transfers ultrasonic pulses through concrete from one probe to another
- Time between pulse generation and signal reception and strength of the received signal is measured
- Signal gives a relative measure of concrete quality between transmitter and receiver
- CHL inspects the structural integrity of a pile and the location of potential defects
- Changes in arrival time and/or energy level of the sonic pulses emitted by the probes is considered indicative of possible defects
- CHL won’t provide any information about the concrete cover of the pile

CHL – Cross hole sonic logging

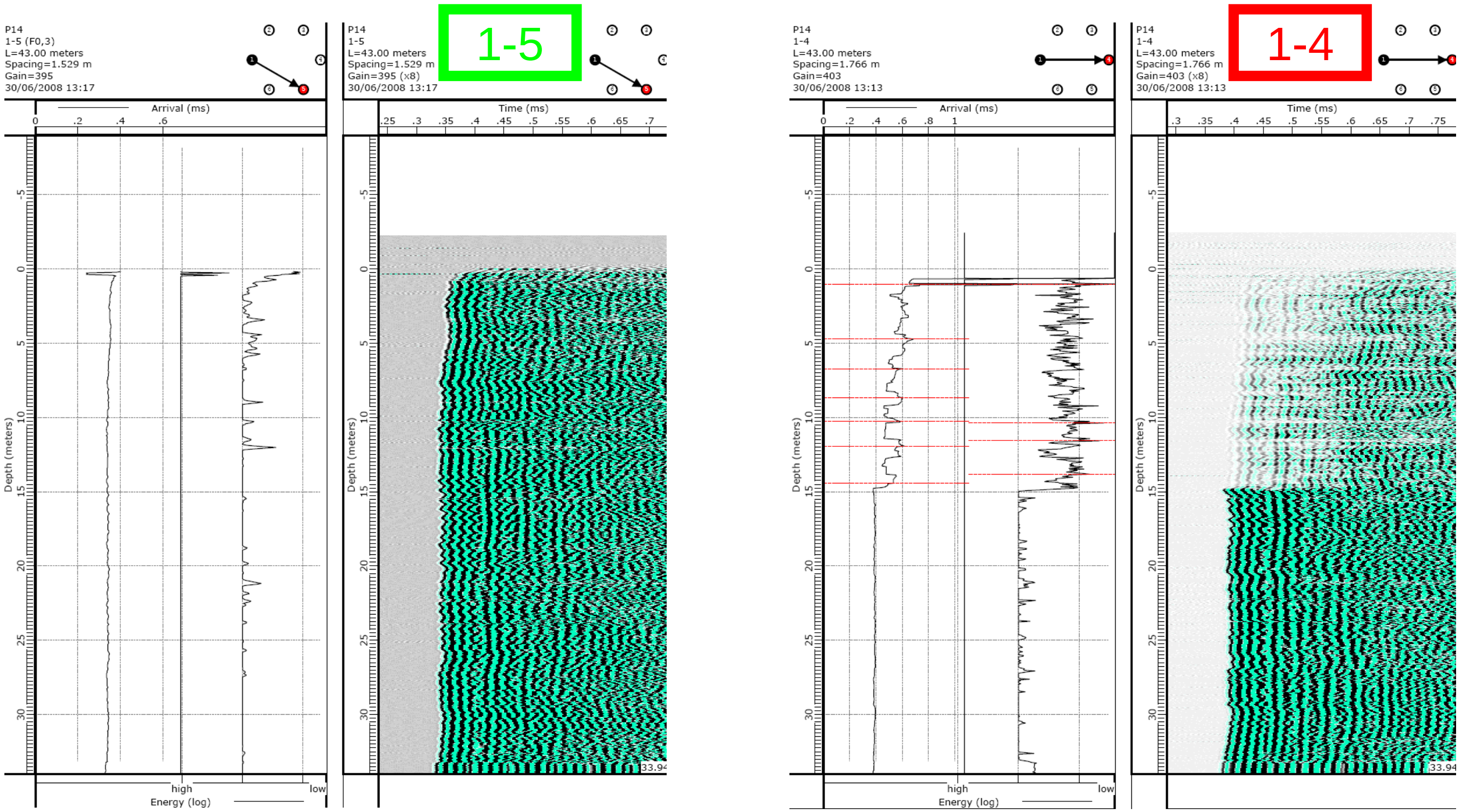


CHL – Cross hole sonic logging



Access Tube Layout - P14

CHL – Cross hole sonic logging

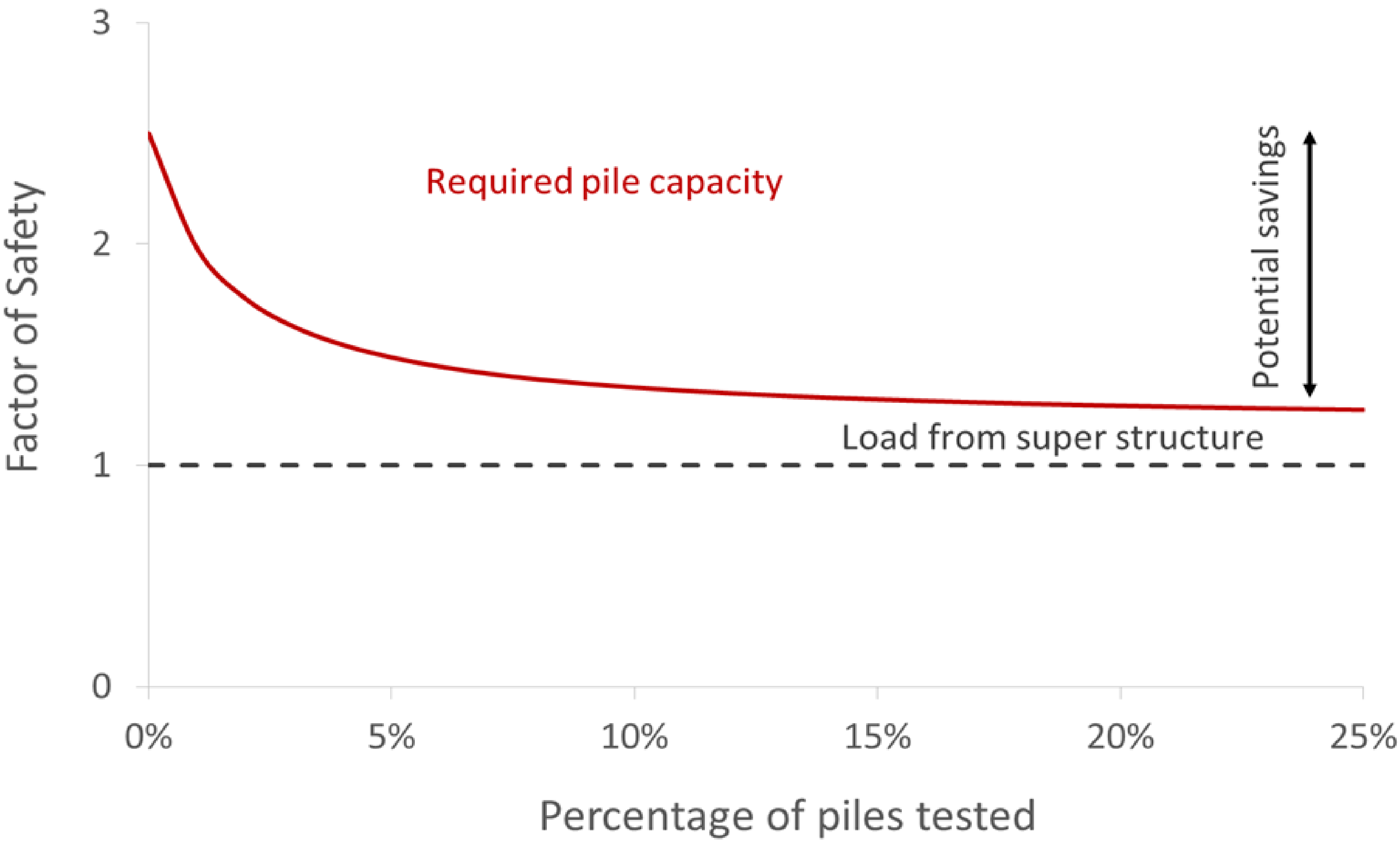


Dynamic pile testing

Detect pile damages during installation, NOT afterwards when the structure is built

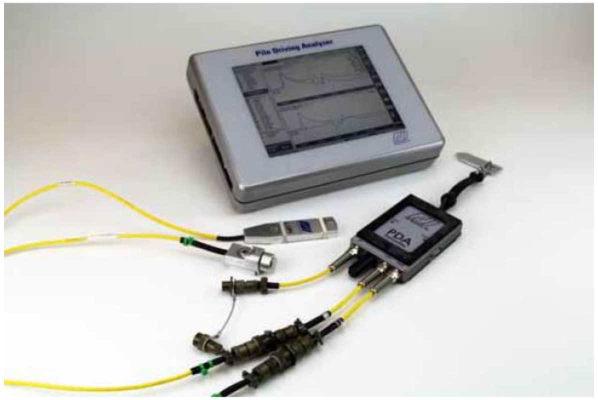
Why would we do it?

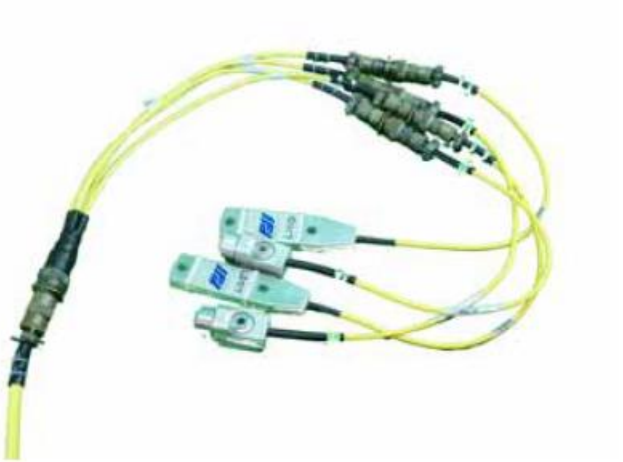
- Required by specification or national code;
- Determine pile capacity based on test results rather than text book formulae (get REAL results);
- Monitor and ensure pile integrity;
- Improve quality of driving criteria for untested piles;
- Reduce geotechnical factor of safety;
- Carry out remote testing for safety & cost savings
- VALUE ENGINEERING
  - No sacrificial test piles required (time & cost savings)
  - Building of pile load test data base (for future designs)
  - Utilizing real data to calibrate design models



3
2
1
0
Factor of Safety
Required pile capacity
Potential savings
Load from super structure
0%
5%
10%
15%
20%
25%
Percentage of piles tested

Dynamic Pile Load Testing (PDA)





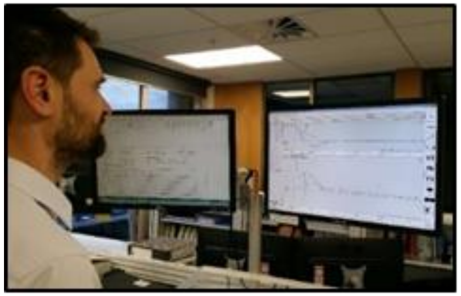
REMOTE Dynamic Pile Load Testing
lower cost & effort

Testing Engineer provides instant feedback

Site Engineer attaches gauges

Testing Engineer OFF SITE

Site Engineer ON SITE



Testing Engineer logs in

Site Engineer connects test computer

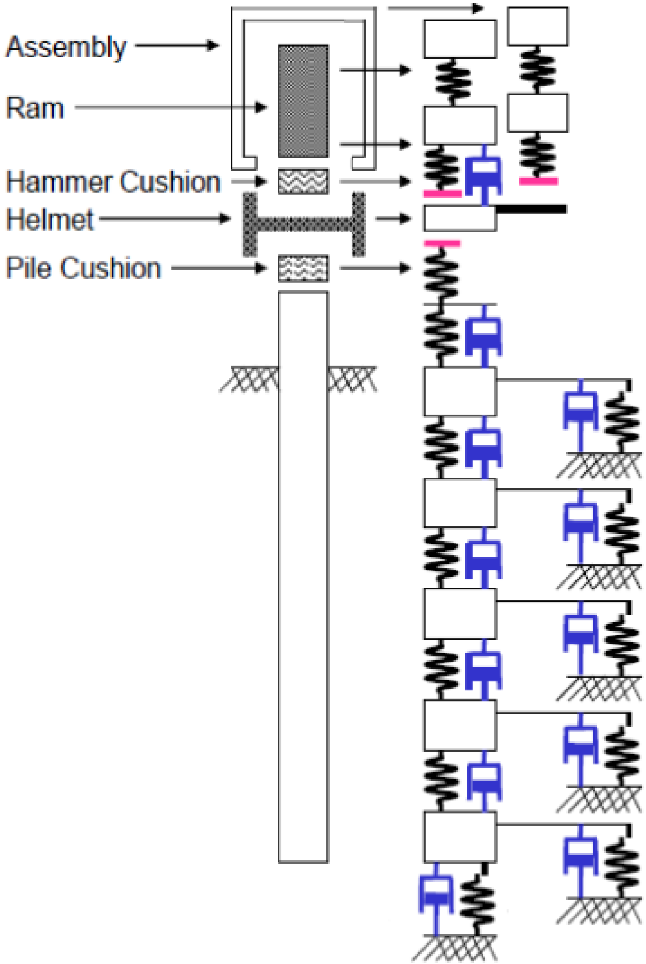
What can we do with dynamic pile testing?

- Monitor driving stresses;
- Measure hammer efficiency;
- **Infer** geotechnical strength of pile (for driven piles and bored piles up to 1,200mm and about 20m depth);
- Ensure piles are not damaged

The global piling industry is still heavily relying on pile driving formulae from the 1930's, rather than testing piles on site.

Driveability Analysis:

- Model pile driving
- Hammer Size
- Estimate risk of damage
- Estimate risk of refusal
- Estimate pile lengths
- Driving criteria
  - Premature Refusal
  - Hammer too small
  - Over-stressing of piles
  - Insufficient capacity



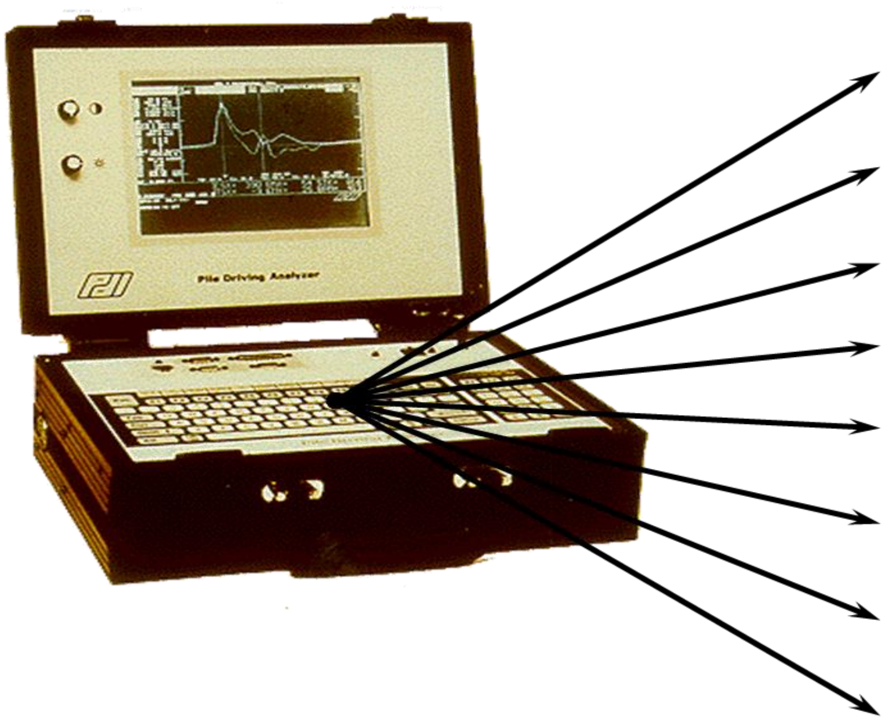
Drivability analysis (model and predict performance)

BOREHOLE	MODEL	ESTIMATED REFUSAL LEVEL AT 2.5 MM DRIVING SET [m RL]		
		5.6T DROPHAMMER	13.5T DROPHAMMER	JUNTTAN HHK-9S
BH1	LB	-26.8*	-26.8*	-26.8*
	UB	-26.8*	-26.8*	-26.8*
BH2	LB	-25.5	-26.8*	-25.4
	UB	-23.7	-24.6	-23.6

Drivability analysis (model and predict performance)

BOREHOLE	MODEL	MAXIMUM AVERAGE DRIVING STRESSES IN PILE [MPa]		
		5.6T DROPHAMMER	13.5T DROPHAMMER	JUNTTAN HHK-9S
BH1	LB	311	378	254
	UB	315	380	257
BH2	LB	289	370	253
	UB	289	370	253

Effective use of dynamic testing (PDA) can provide:



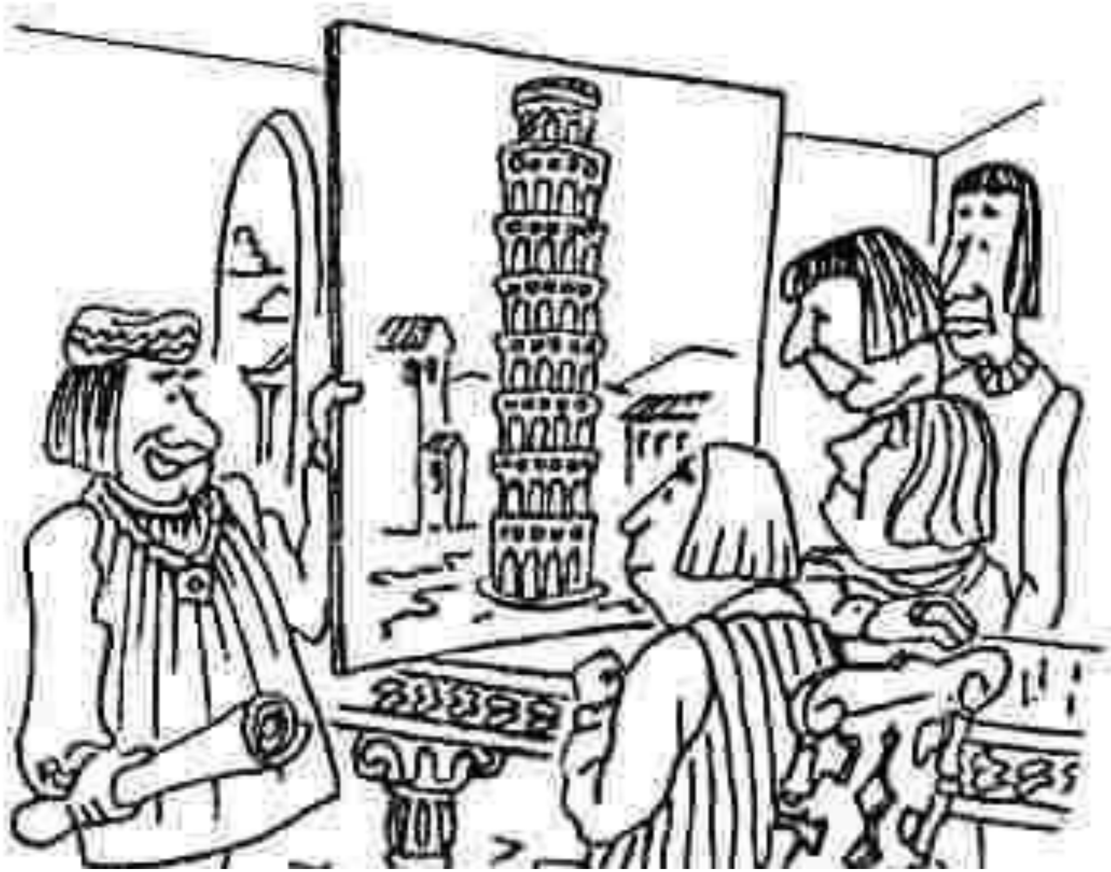
- capacity
- resistance distributi
- design feedback
- time effects
- hammer performan
- stress control
- pile integrity
- group interaction

“In spite of their obvious deficiencies and unreliability, pile driving formulas still enjoy great popularity among practicing engineers, because the use of these formulas reduces the design of pile foundations to a very simple procedure. The price one pays for this artificial simplification is very high.”

- Karl Terzaghi (1942)

Summary:

- Effective risk management involves clear and effective communication amongst all parties involved in a project, right from the start;
- Geotechnical risk is always significant;
- The better the information, the better the quality of the answer;
- Engineering can help you save money;
- Installation effects and environmental boundary conditions should be considered in the design phase;
- Designs should accommodate safety and ease of construction;
- Construction verification provides valuable feedback



"And the best thing is: we reduced the geotechnical investigation by 50%"