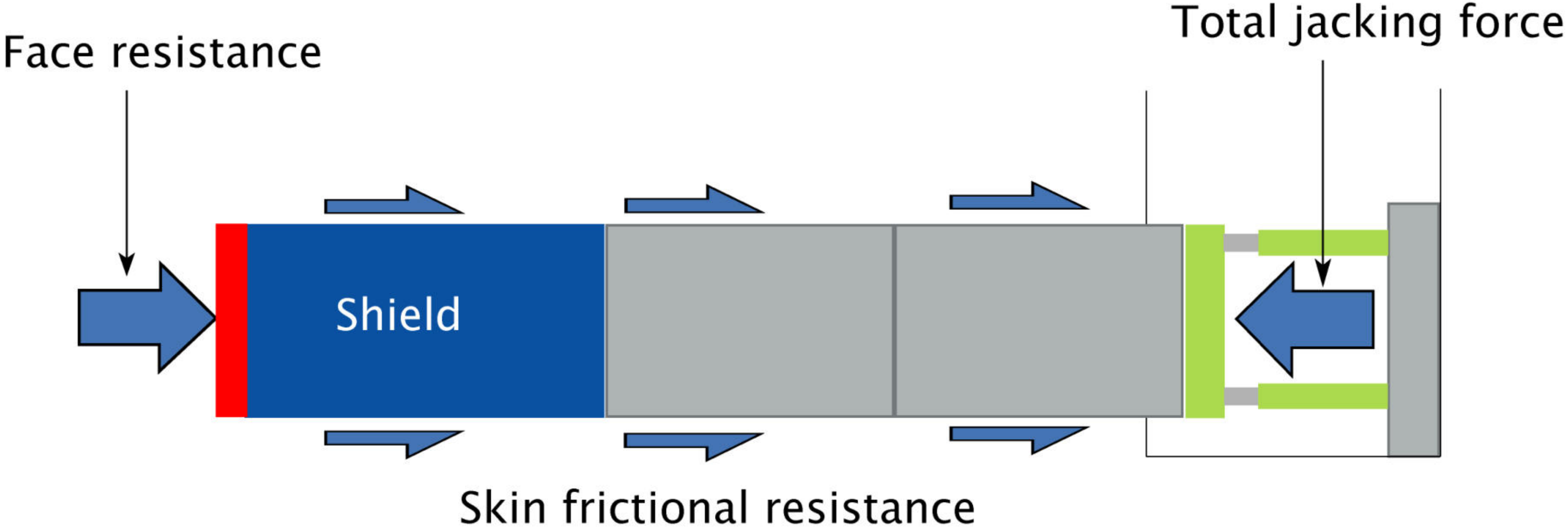
Interface friction in microtunnelling and pipe jacking - the role of lubricants in reducing jacking forces

Dr Ciaran Reilly

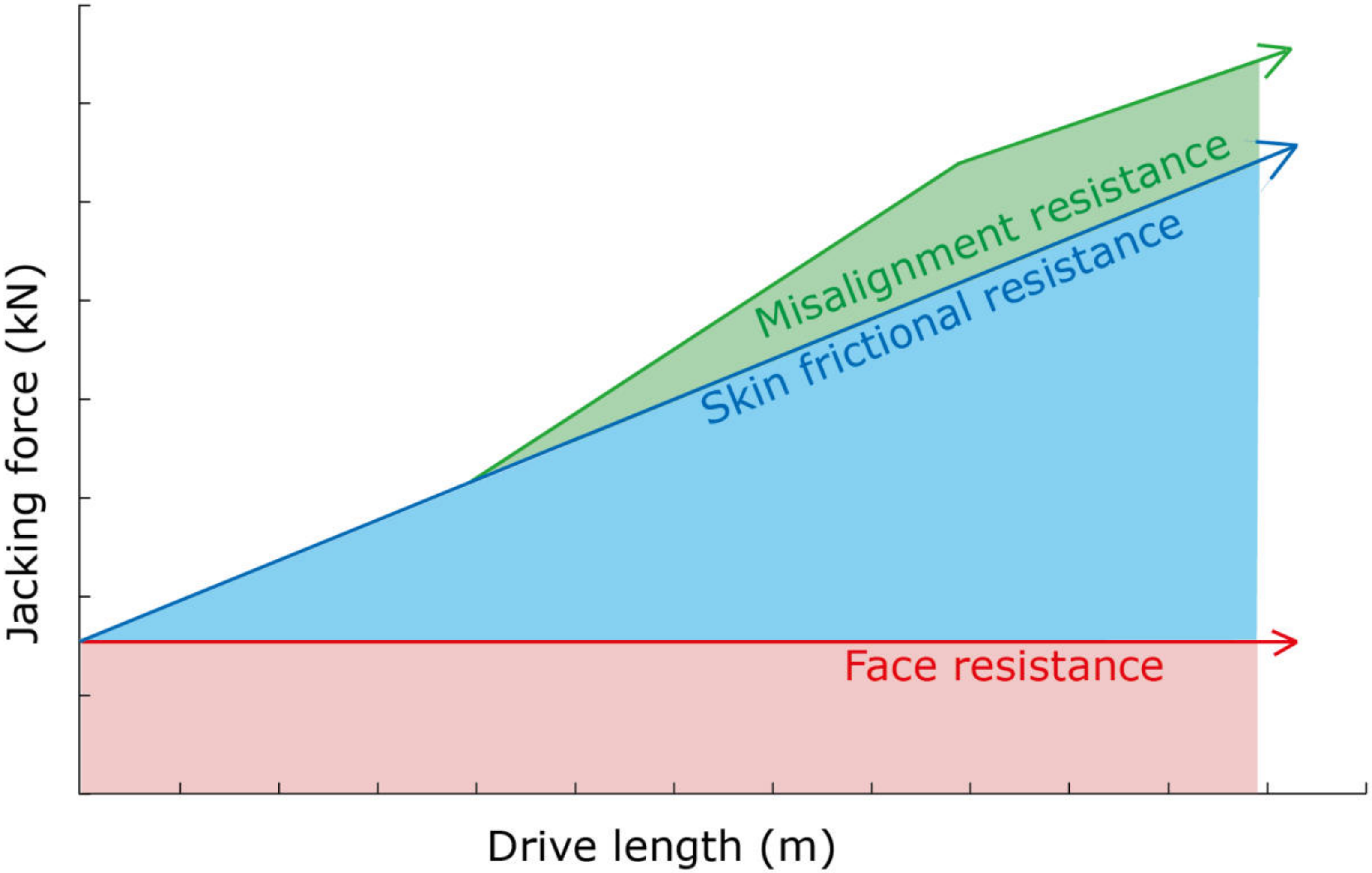
Ciaran Reilly & Associates

12 March 2026, No-Dig Roadshow, Dublin

Jacking force



Jacking force



Lubrication

Slurry injected through injection ports every 2 or 3 pipes

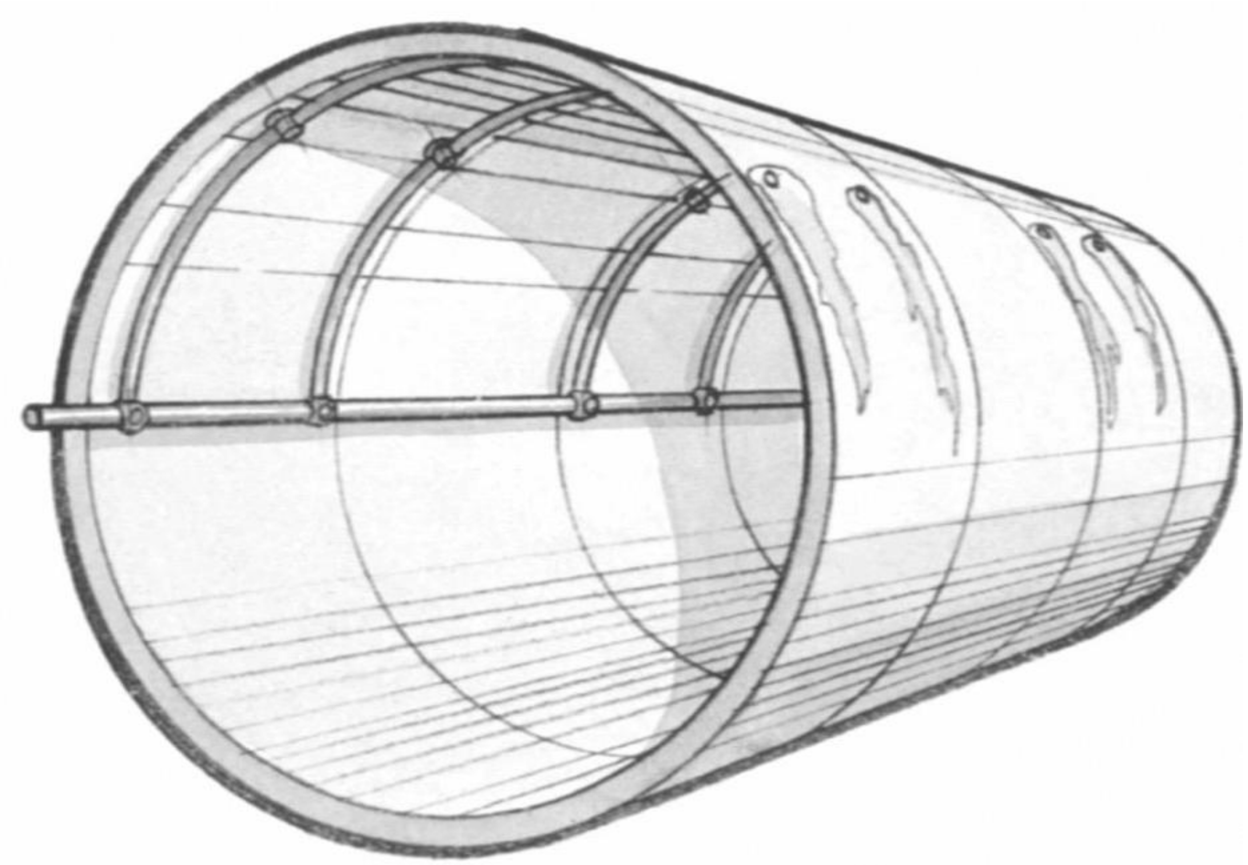
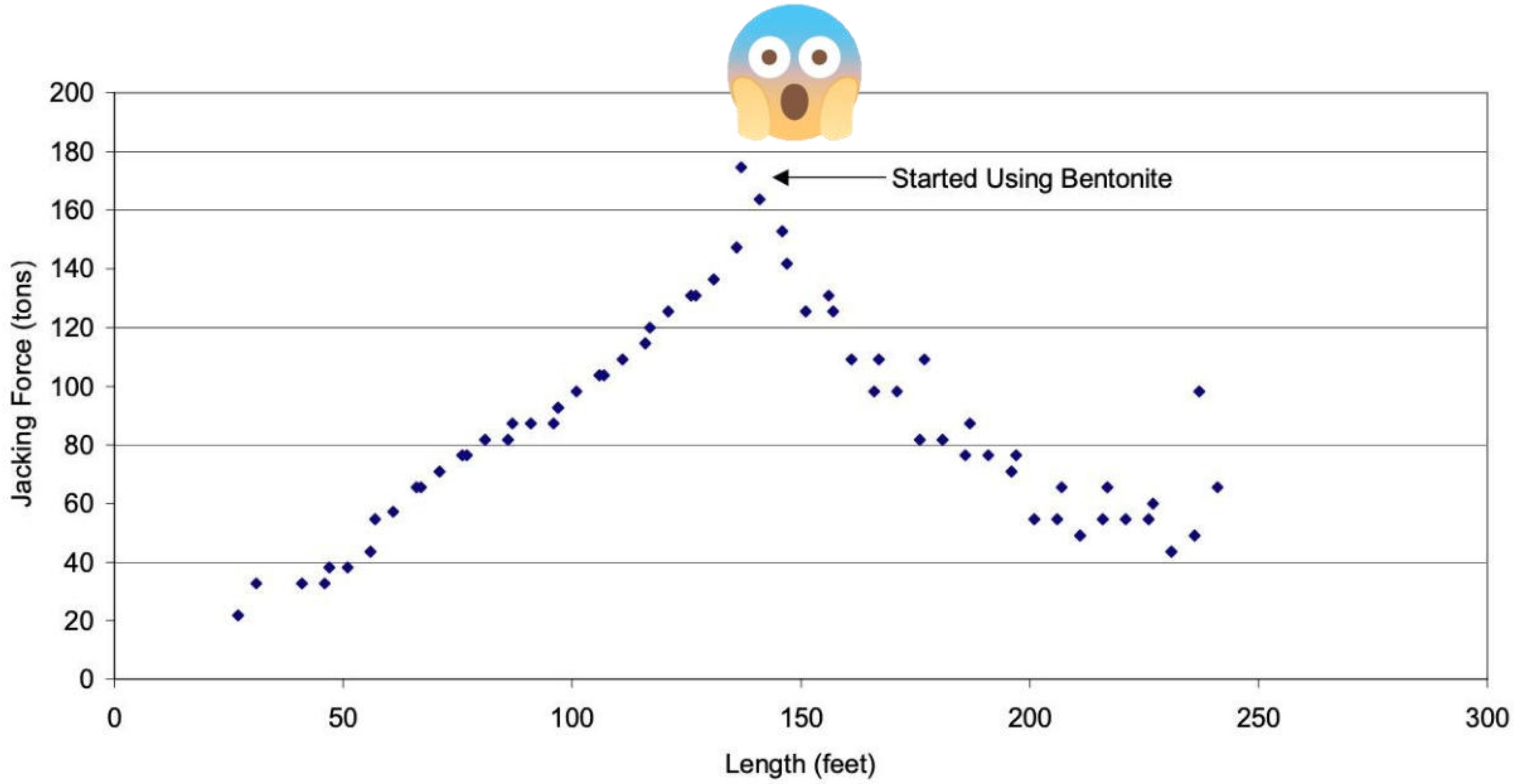


Image: Pipe Jacking Association

Lubrication

Table 6.1. Summary of Lubricated Segments and Interface Friction Coefficients.

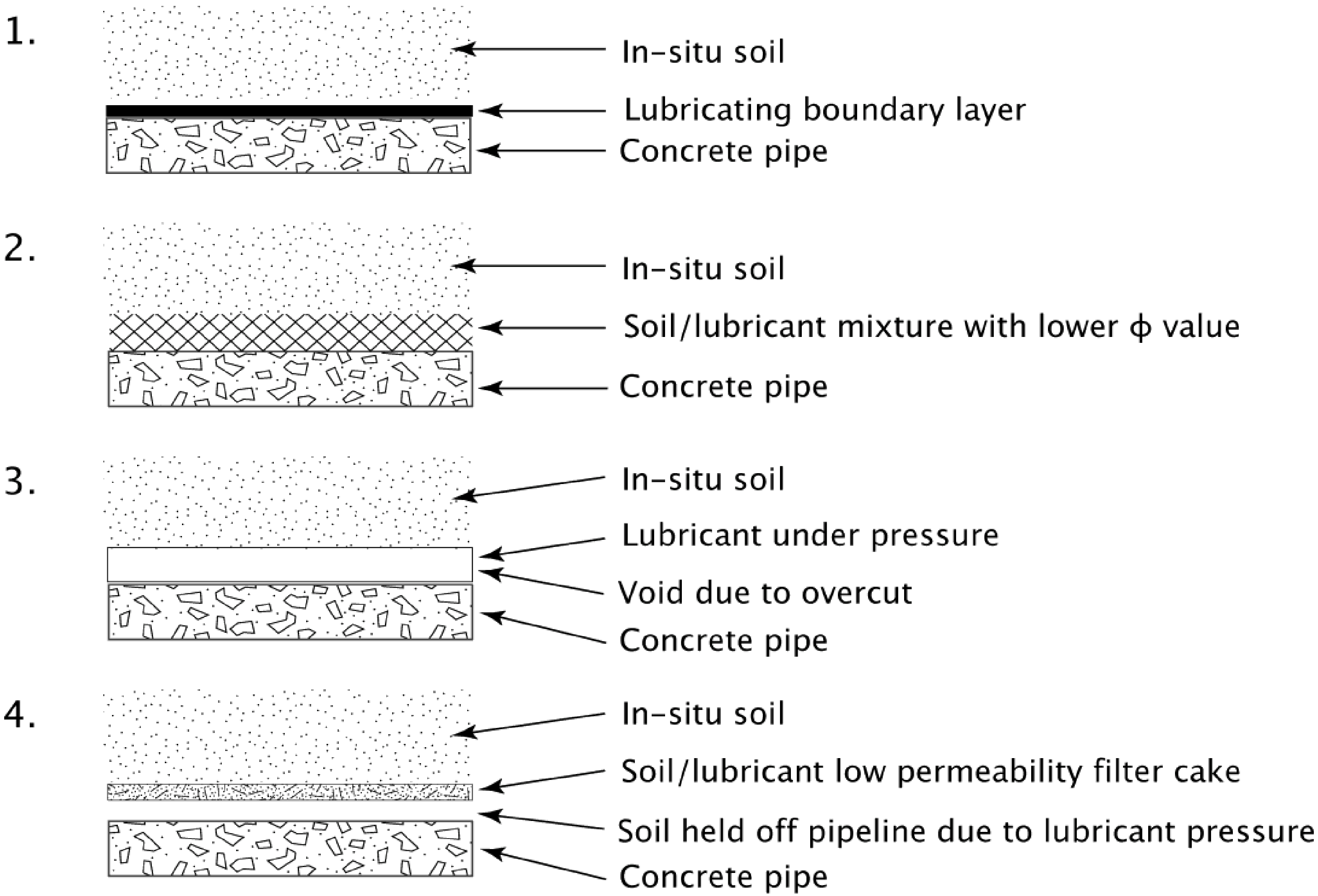
Project	Segment [feet]	Description	Type of Lubrication	Interface Friction Coefficient [-]
South Lake Tahoe Highway 50 Crossing	0-150	Non-Lubricated	None	0.6
	150-240	Lubricated	Mass Application	0.06

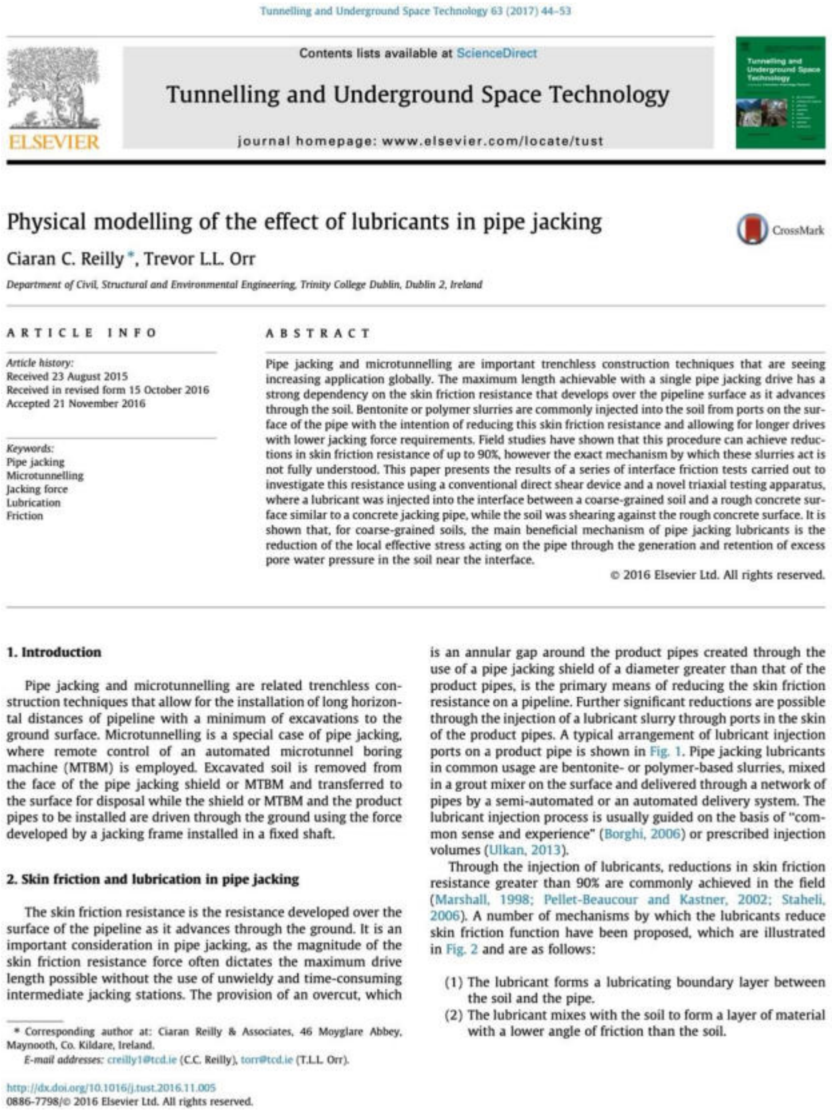


- Very dense well-graded sand
- City of South Lake Tahoe storm line, 1.5m OD
- 90% reduction in total jacking force
- Repeated in literature

Staheli, 2006

Lubrication





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Physical modelling of the effect of lubricants in pipe jacking

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ABSTRACT

Pipe jacking and microtunnelling are important trenchless construction techniques that are seeing increasing application globally. The maximum length achievable with a single pipe jacking drive has a strong dependency on the skin friction resistance that develops over the pipeline surface as it advances through the soil. Bentonite or polymer slurries are commonly injected into the soil from ports on the surface of the pipe with the intention of reducing this skin friction resistance and allowing for longer drives with lower jacking force requirements. Field studies have shown that this procedure can achieve reductions in skin friction resistance of up to 90%, however the exact mechanism by which these slurries act is not fully understood. This paper presents the results of a series of interface friction tests carried out to investigate this resistance using a conventional direct shear device and a novel triaxial testing apparatus, where a lubricant was injected into the interface between a coarse-grained soil and a rough concrete surface similar to a concrete jacking pipe, while the soil was shearing against the rough concrete surface. It is shown that, for coarse-grained soils, the main beneficial mechanism of pipe jacking lubricants is the reduction of the local effective stress acting on the pipe through the generation and retention of excess pore water pressure in the soil near the interface.

1. Introduction

Pipe jacking and microtunnelling are related trenchless construction techniques that allow for the installation of long horizontal distances of pipeline with a minimum of excavations to the ground surface. Microtunnelling is a special case of pipe jacking, where remote control of an automated microtunnel boring machine (MTBM) is employed. Excavated soil is removed from the face of the pipe jacking shield or MTBM and transferred to the surface for disposal while the shield or MTBM and the product pipes to be installed are driven through the ground using the force developed by a jacking frame installed in a fixed shaft.

2. Skin friction and lubrication in pipe jacking

The skin friction resistance is the resistance developed over the surface of the pipeline as it advances through the ground. It is an important consideration in pipe jacking, as the magnitude of the skin friction resistance force often dictates the maximum drive length possible without the use of unwieldy and time-consuming intermediate jacking stations. The provision of an overcut, which is an annular gap around the product pipes created through the use of a pipe jacking shield of a diameter greater than that of the product pipes, is the primary means of reducing the skin friction resistance on a pipeline. Further significant reductions are possible through the injection of a lubricant slurry through ports in the skin of the product pipes. A typical arrangement of lubricant injection ports on a product pipe is shown in Fig. 1. Pipe jacking lubricants in common usage are bentonite- or polymer-based slurries, mixed in a grout mixer on the surface and delivered through a network of pipes by a semi-automated or an automated delivery system. The lubricant injection process is usually guided on the basis of "common sense and experience" (Borghi, 2006) or prescribed injection volumes (Ulkan, 2013).

Through the injection of lubricants, reductions in skin friction resistance greater than 90% are commonly achieved in the field (Marshall, 1998; Pellet-Beaucour and Kastner, 2002; Staheli, 2006). A number of mechanisms by which the lubricants reduce skin friction function have been proposed, which are illustrated in Fig. 2 and are as follows:

(1) The lubricant forms a lubricating boundary layer between the soil and the pipe.
(2) The lubricant mixes with the soil to form a layer of material with a lower angle of friction than the soil.

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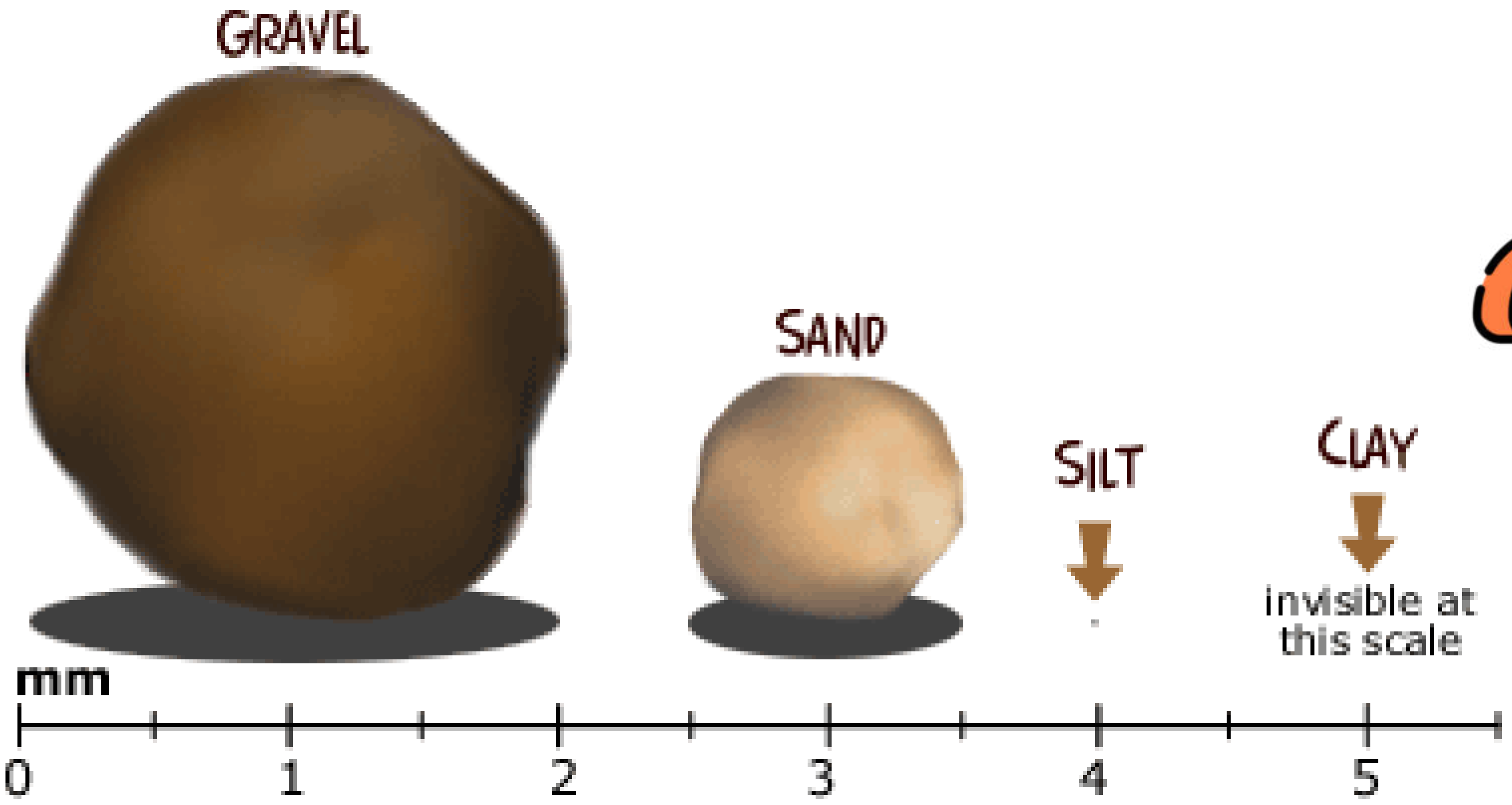
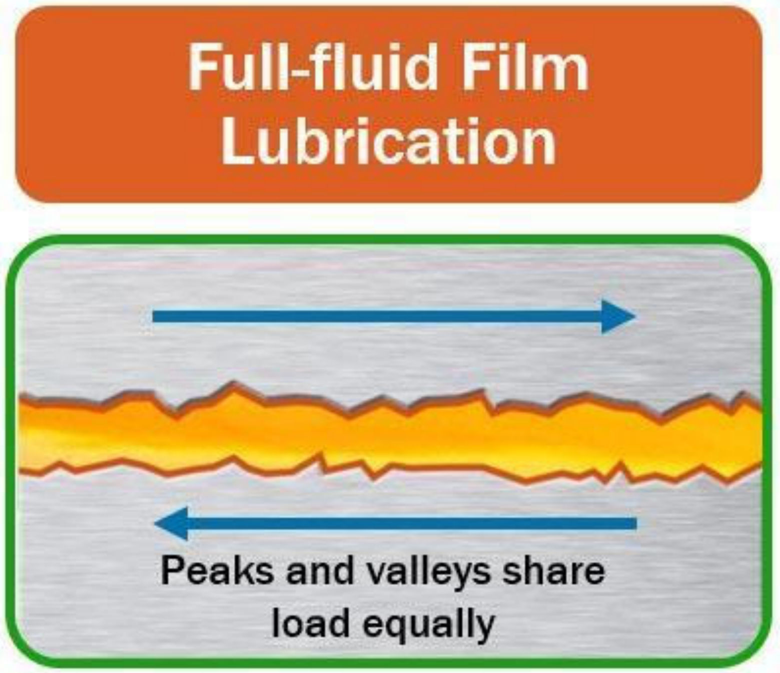
Link to paper:
https://app.box.com/s/prps9u3kclstwo5hqwsmvx7lrq1ce1u7

Reilly & Orr, 2017

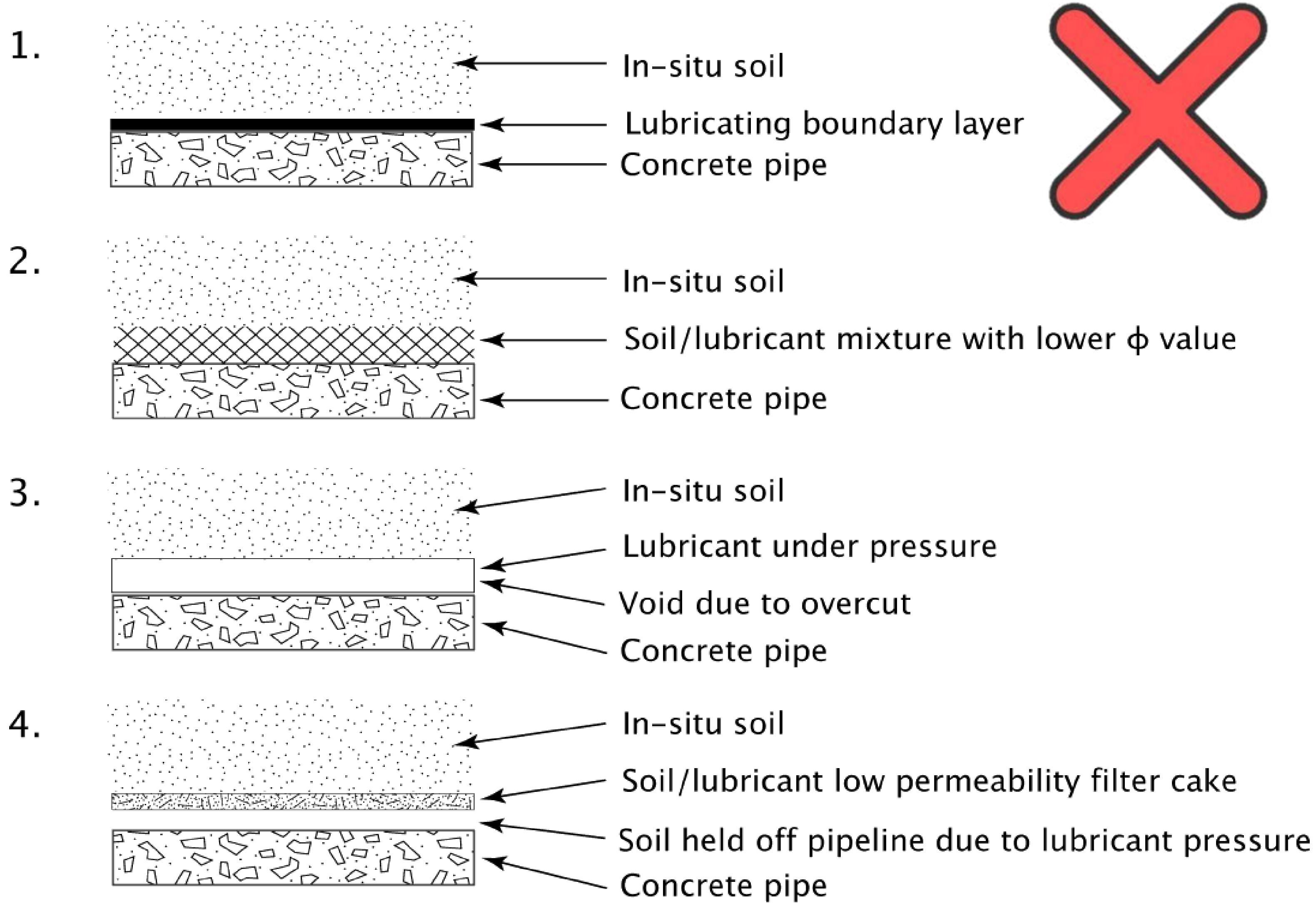
Lubrication?





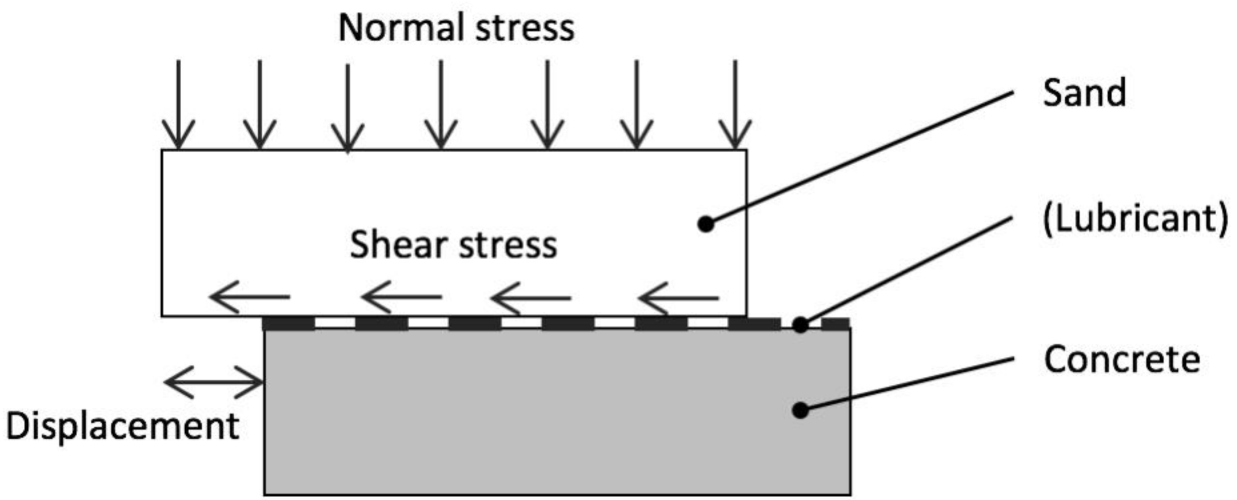
https://www.machinerylubrication.com/Read/30741/lubrication-regimes

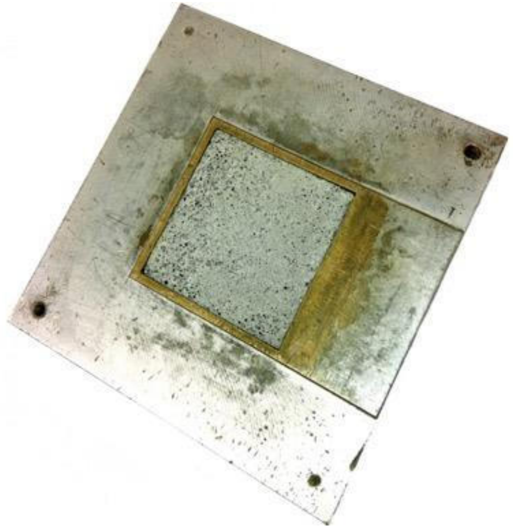
Mechanism



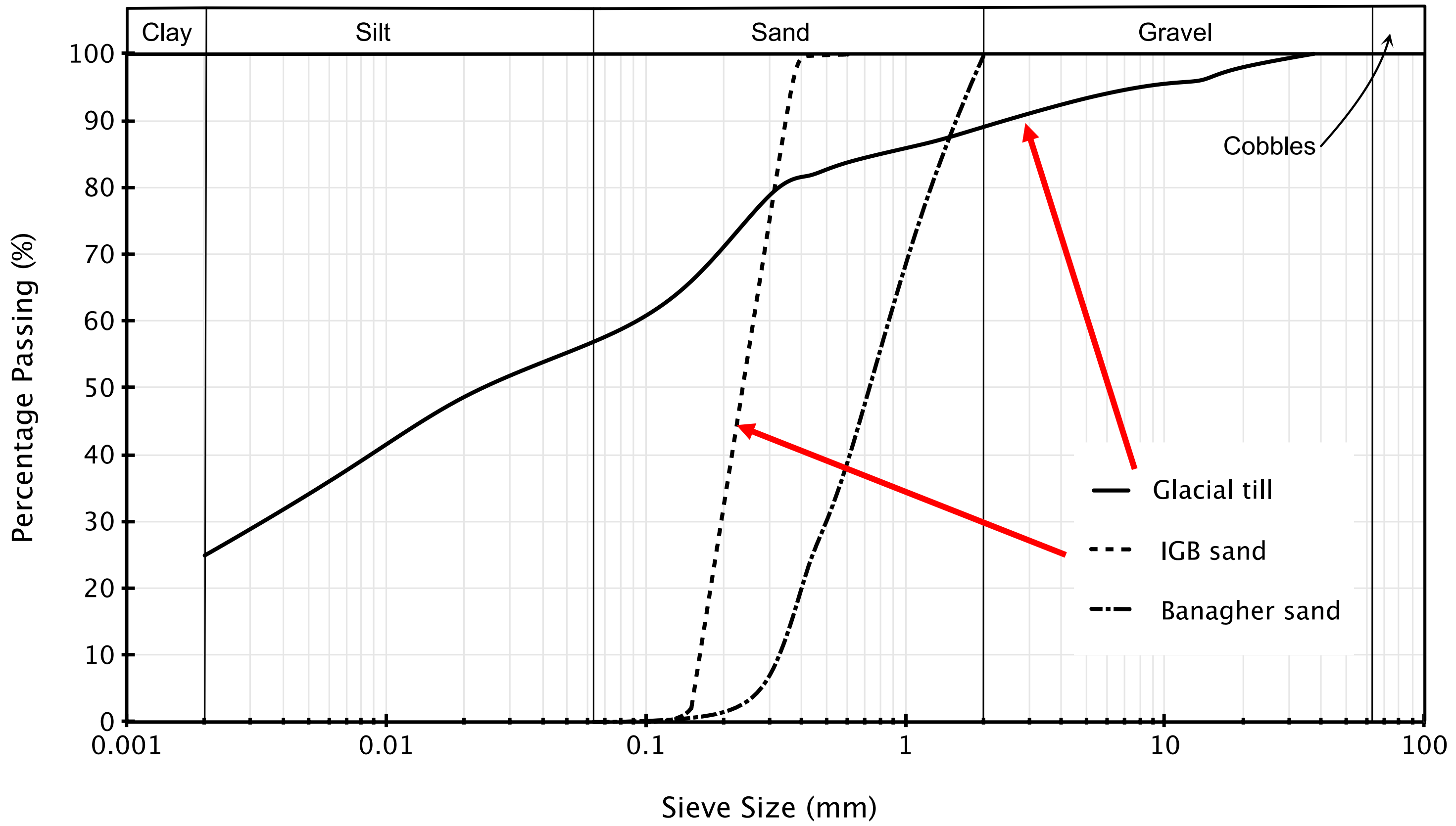
1.
In-situ soil
Lubricating boundary layer
Concrete pipe
2.
In-situ soil
Soil/lubricant mixture with lower ϕ value
Concrete pipe
3.
In-situ soil
Lubricant under pressure
Void due to overcut
Concrete pipe
4.
In-situ soil
Soil/lubricant low permeability filter cake
Soil held off pipeline due to lubricant pressure
Concrete pipe

Low strength mixture?



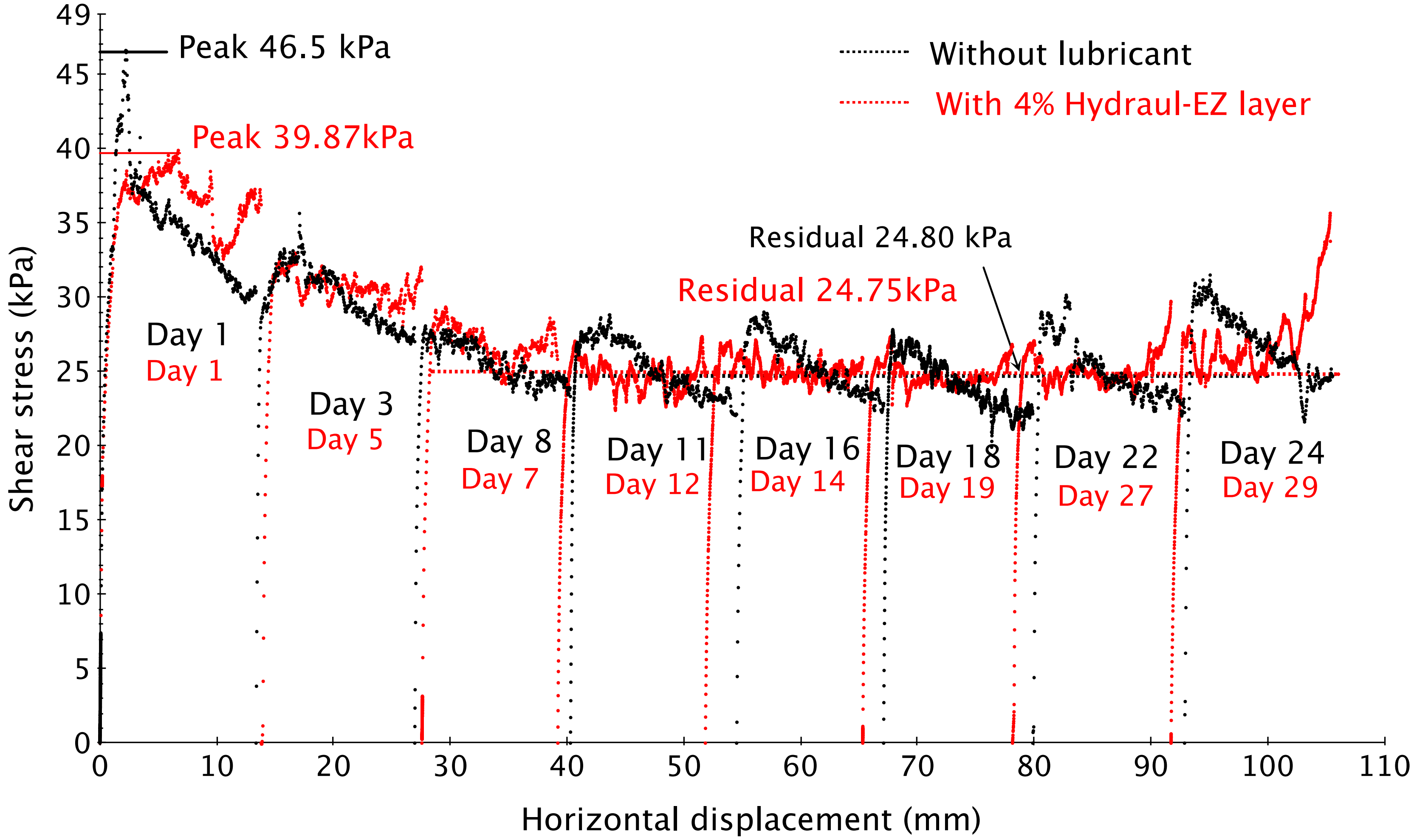


Low strength mixture?

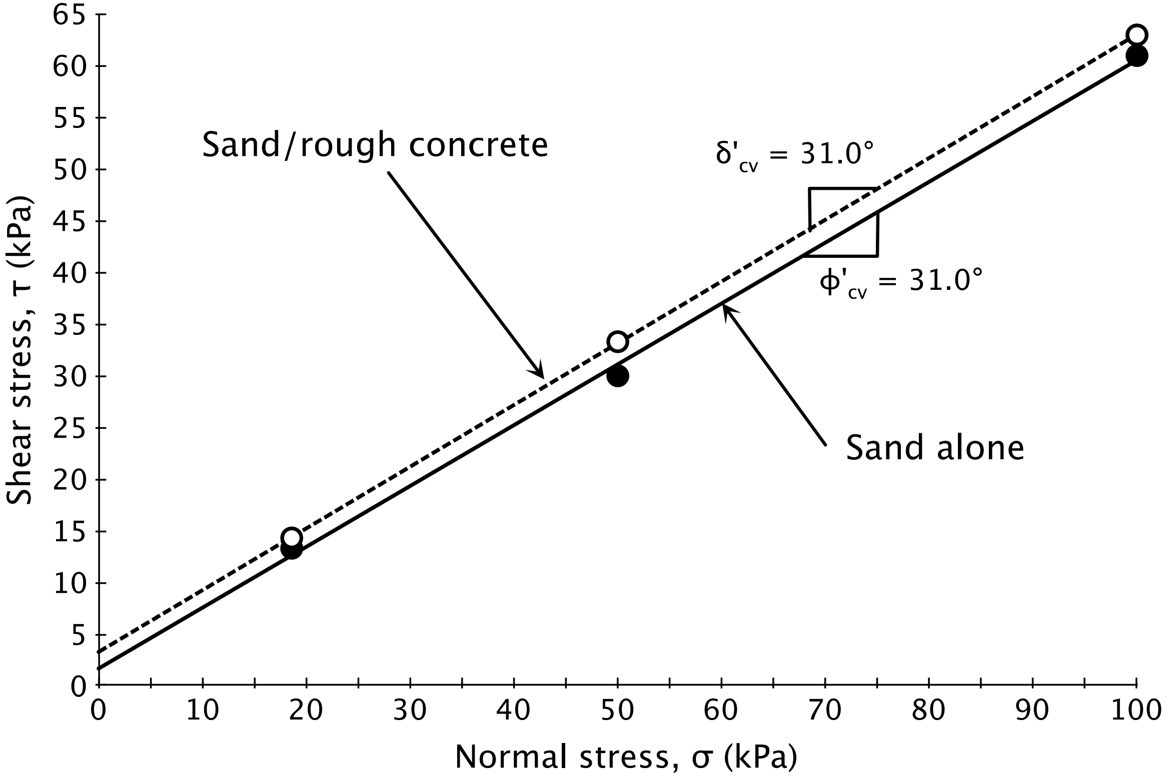


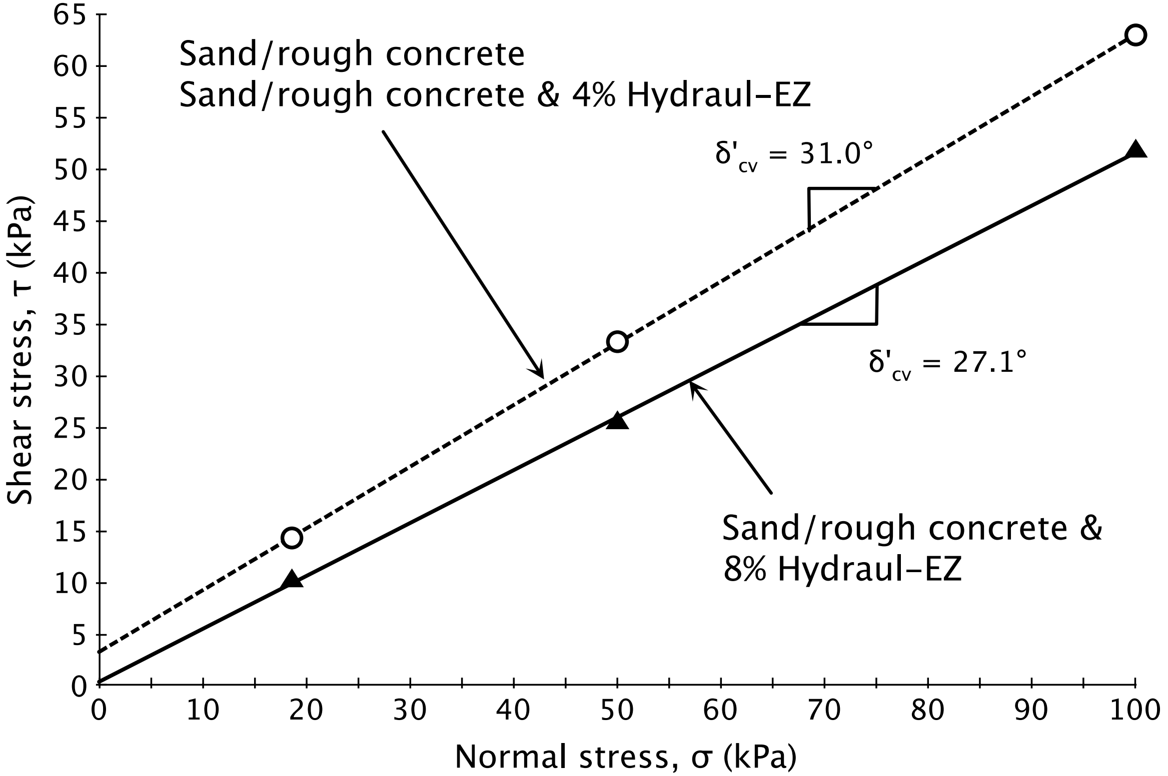
Tests with glacial till (fine-grained) and fine sand (coarse grained)

Glacial till (fine-grained)

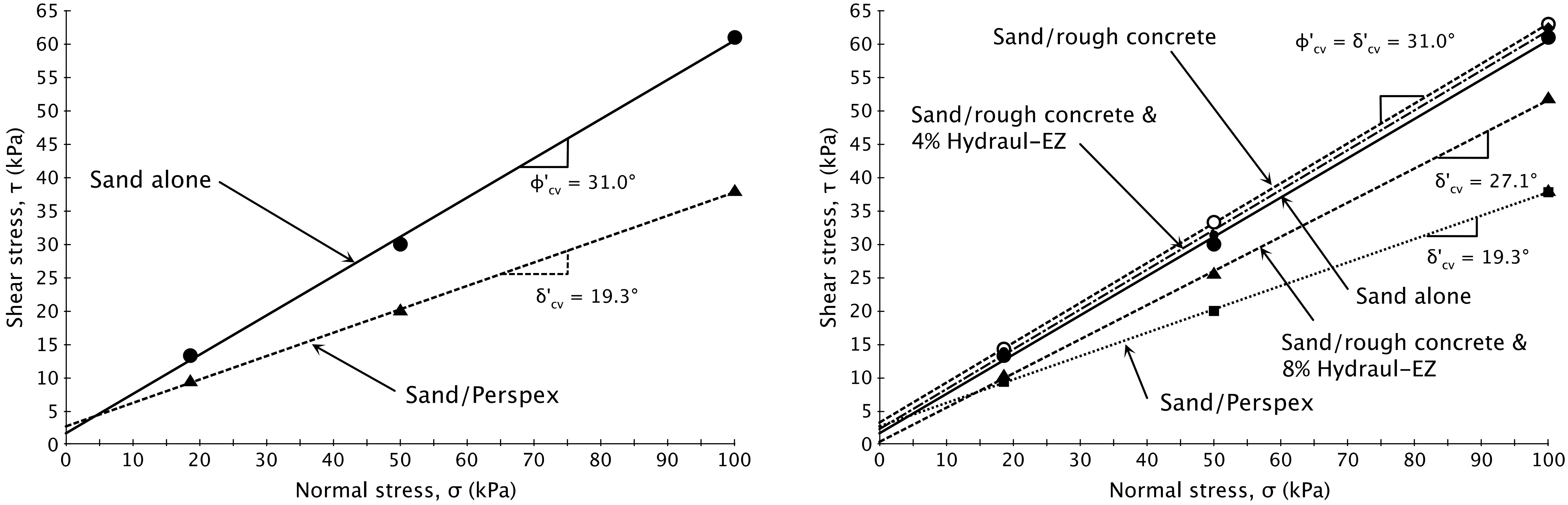


IGB sand (coarse-grained)

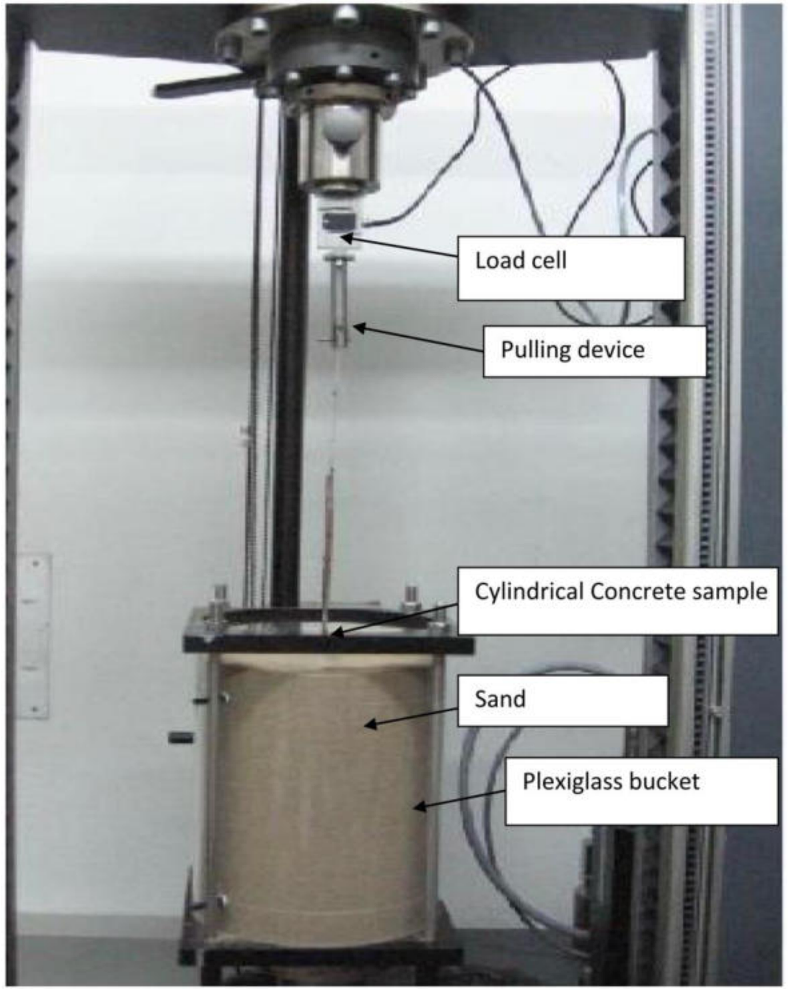




IGB sand (coarse-grained)

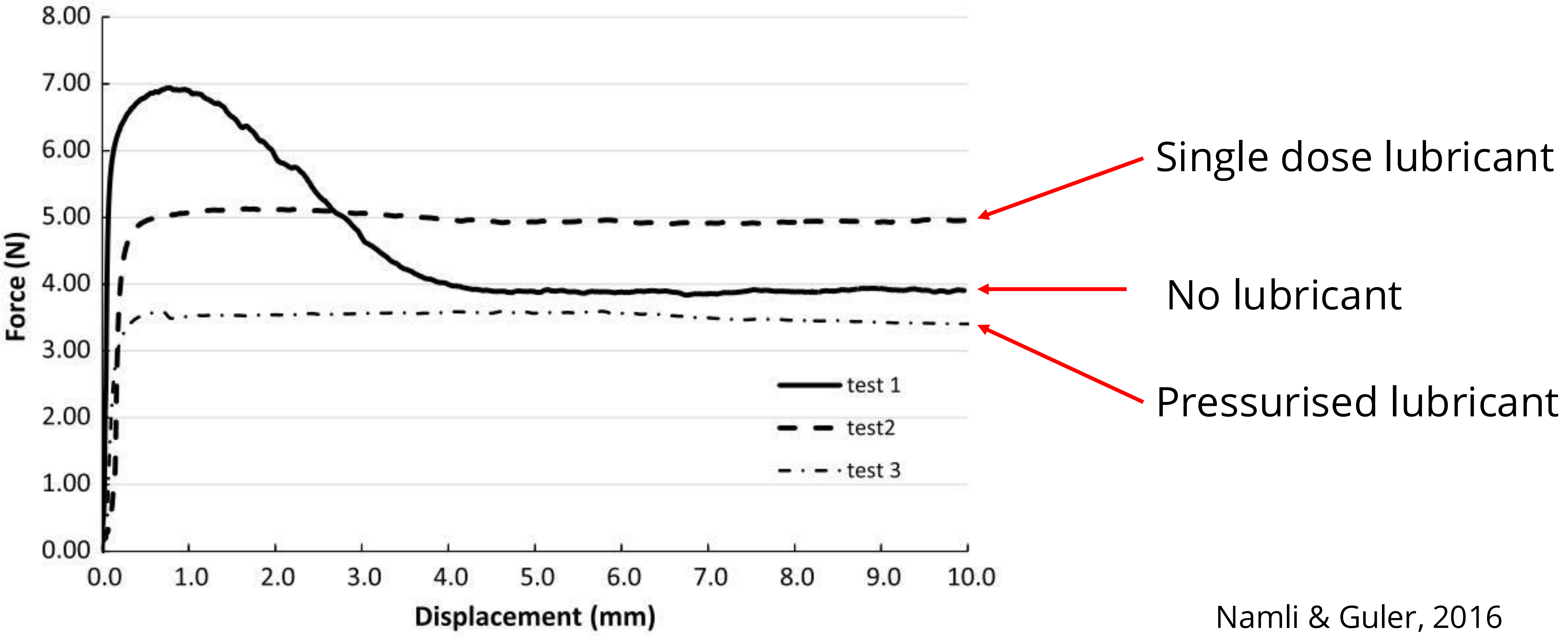


Low strength mixture?



Namli & Guler, 2016

Low strength mixture?



Namli & Guler, 2016

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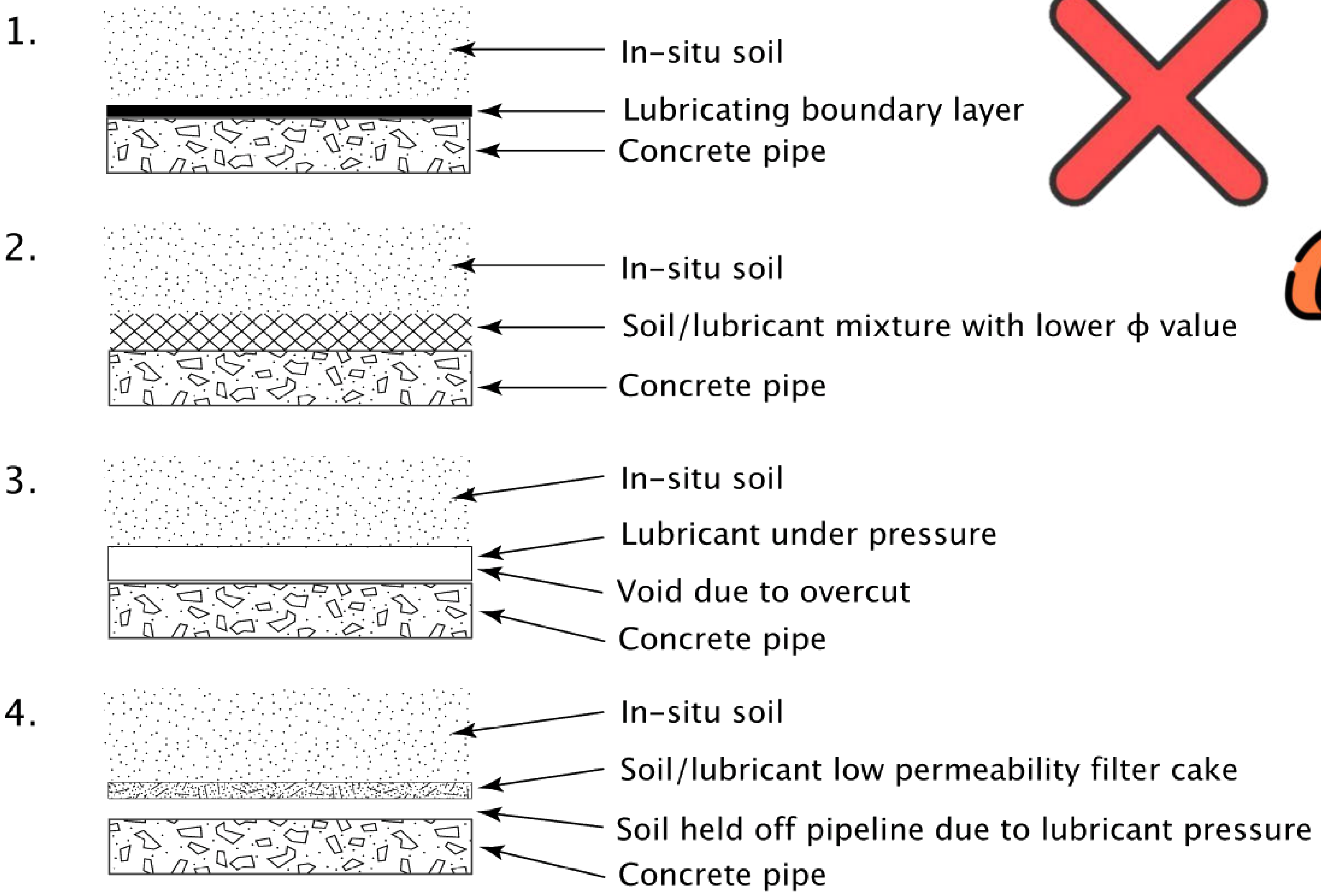
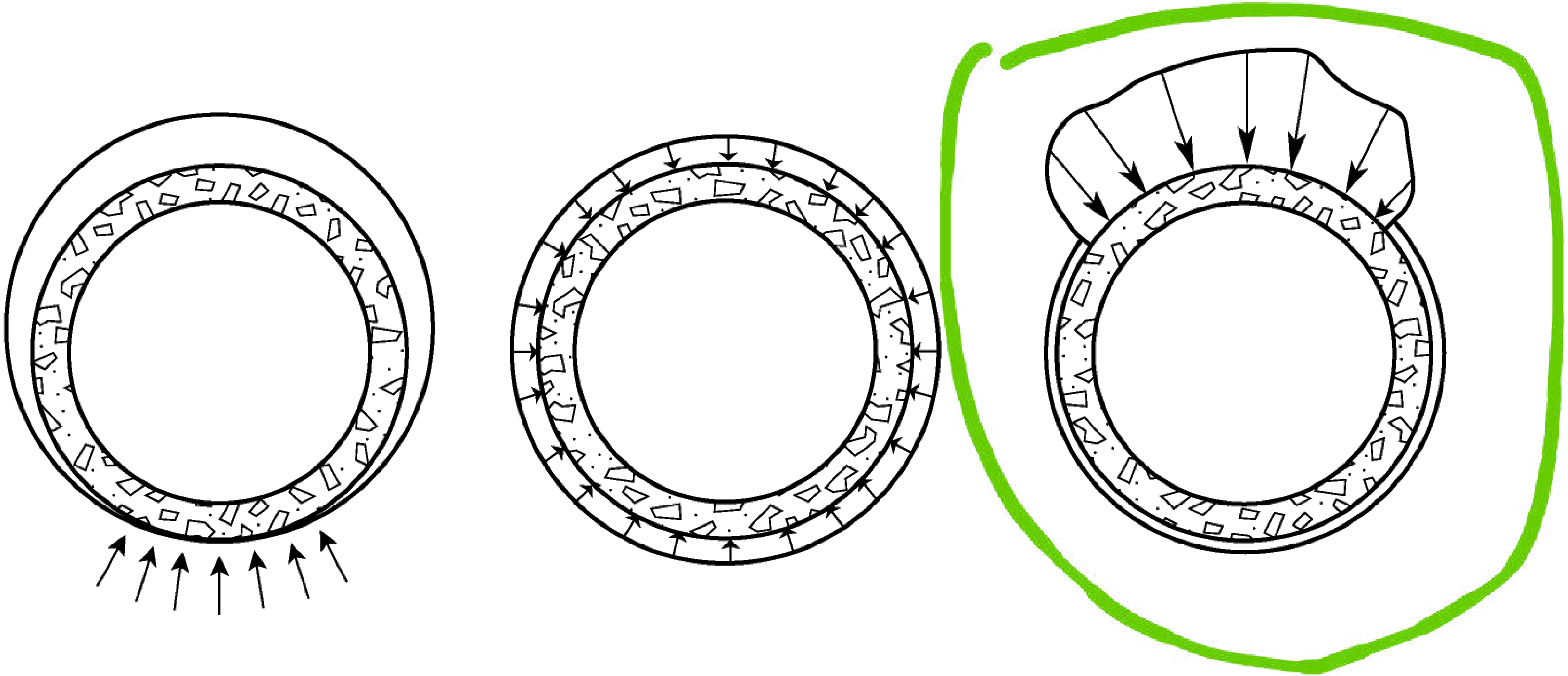
Mechanism

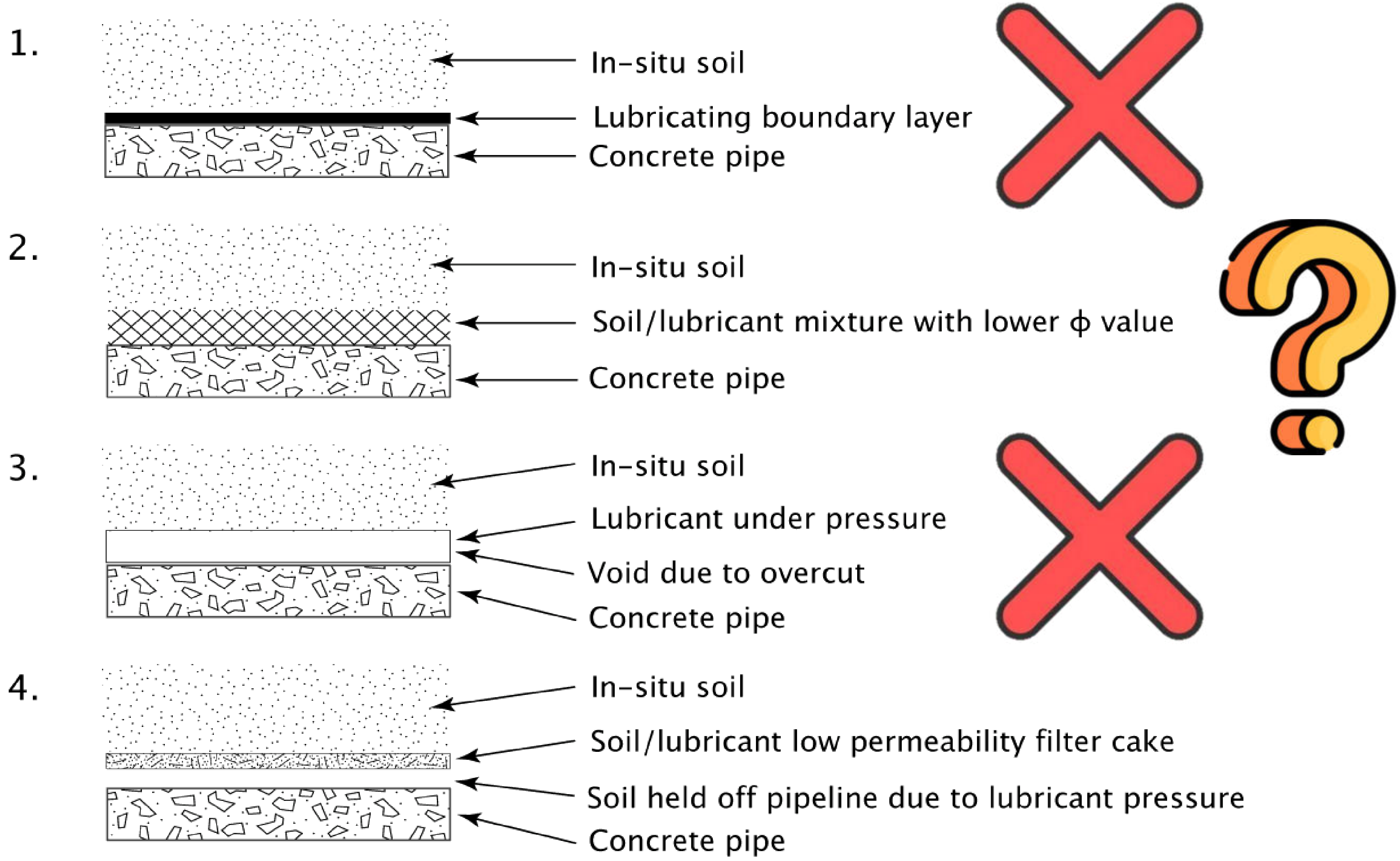


Overcut stable?



Research has shown mixed and variable contact between bore walls & pipe

Mechanism



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Lubricant pressure

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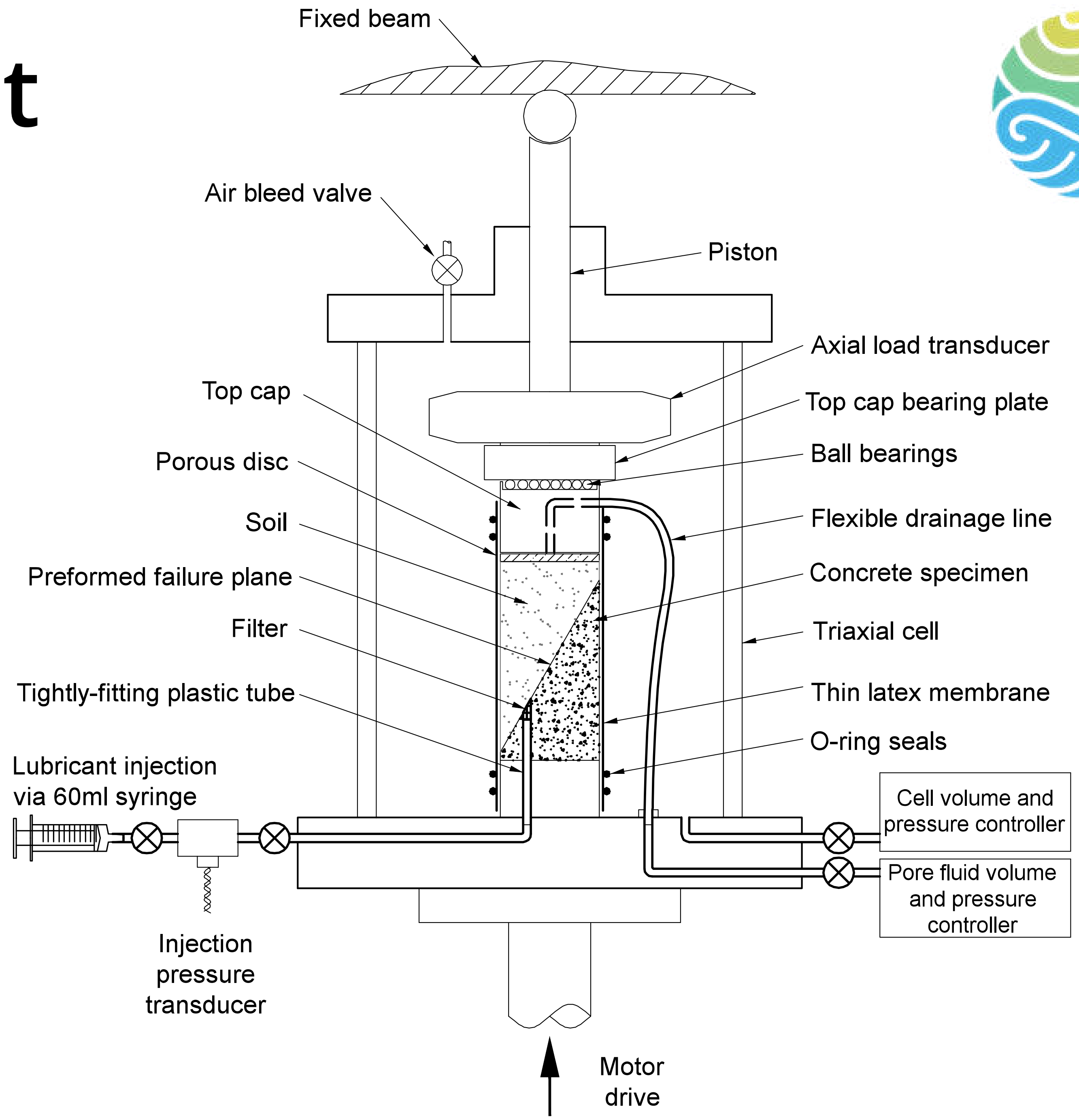
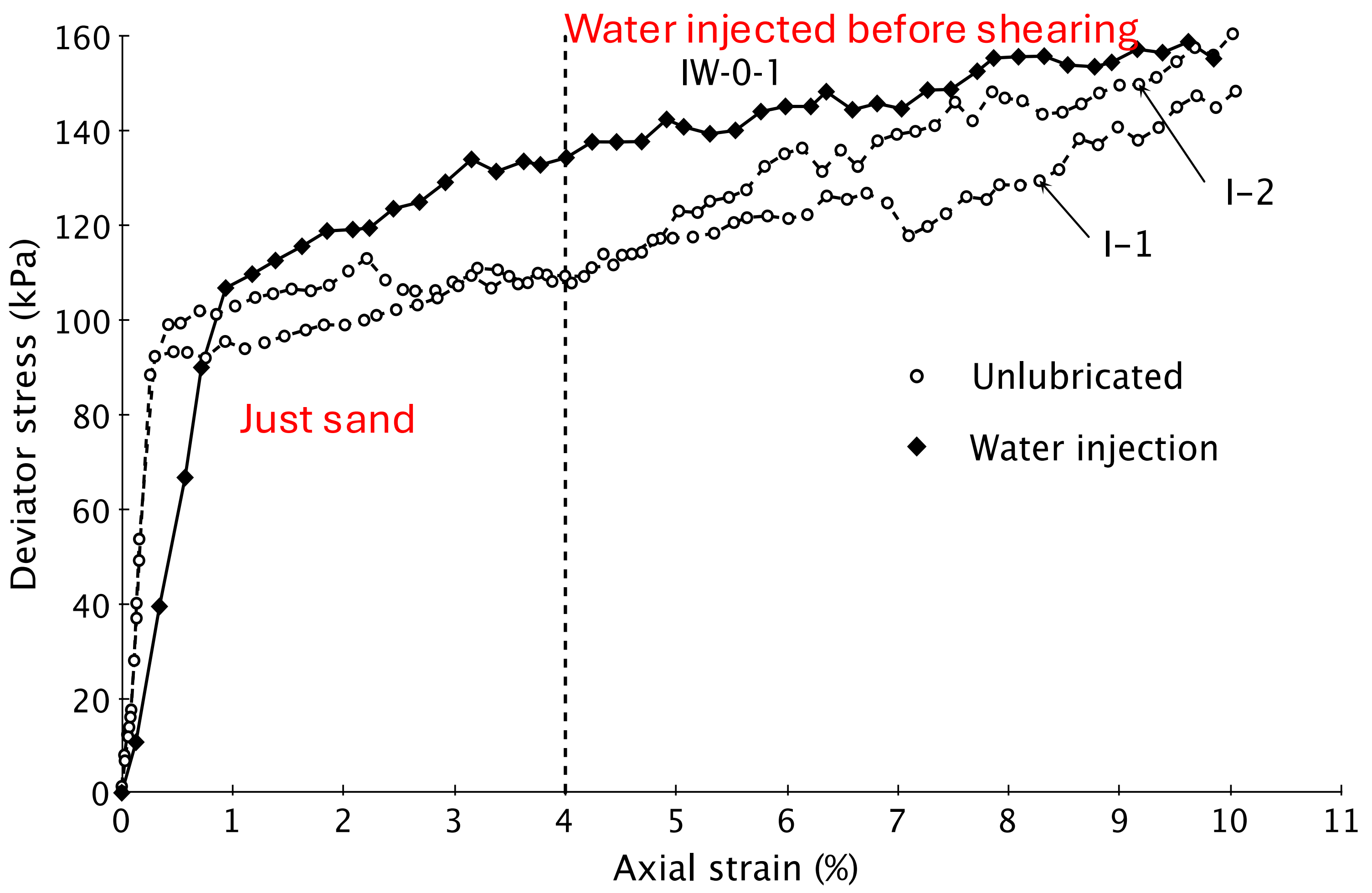


Lubricant pressure

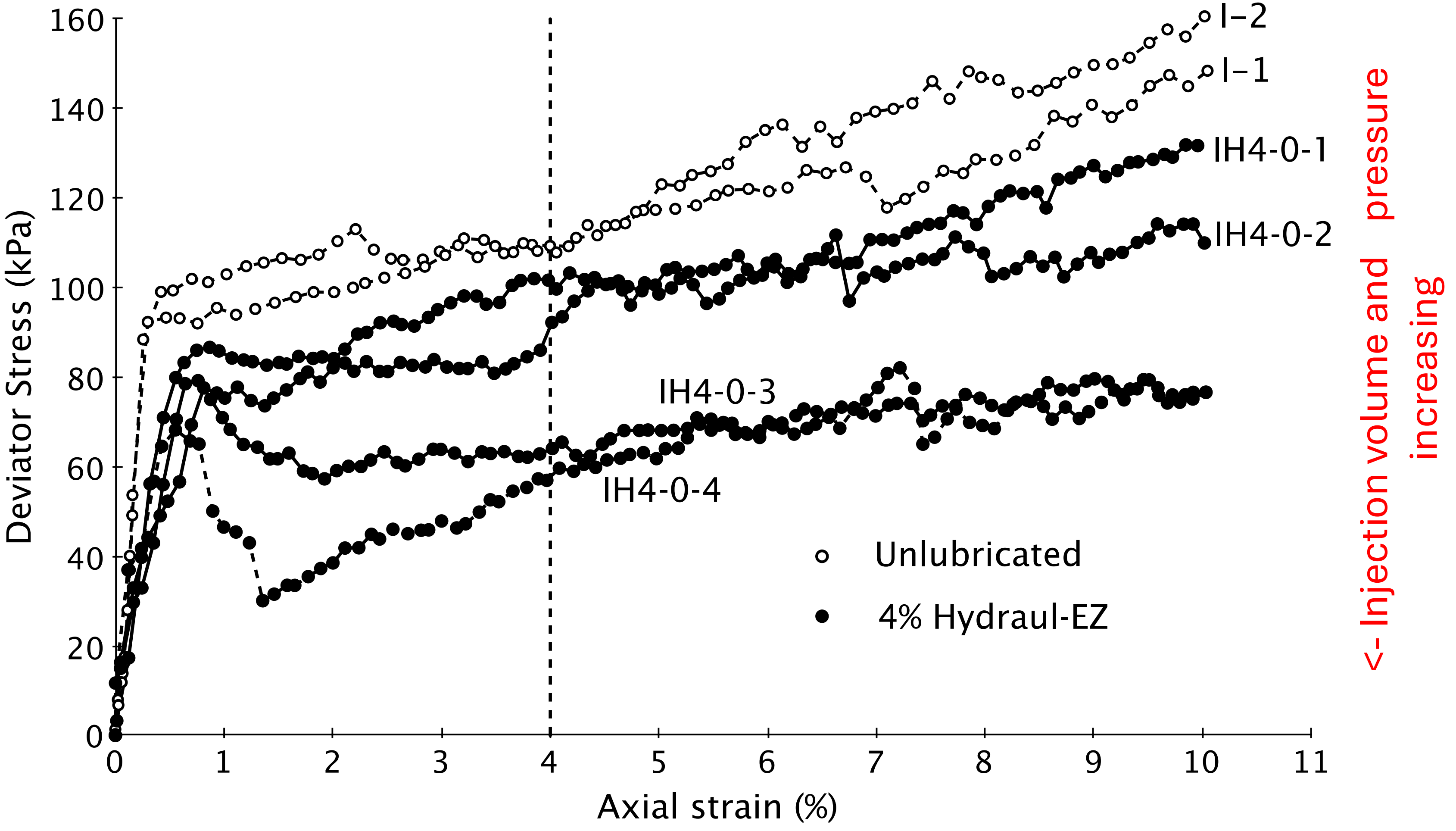
Concrete specimen

Failed combined specimen

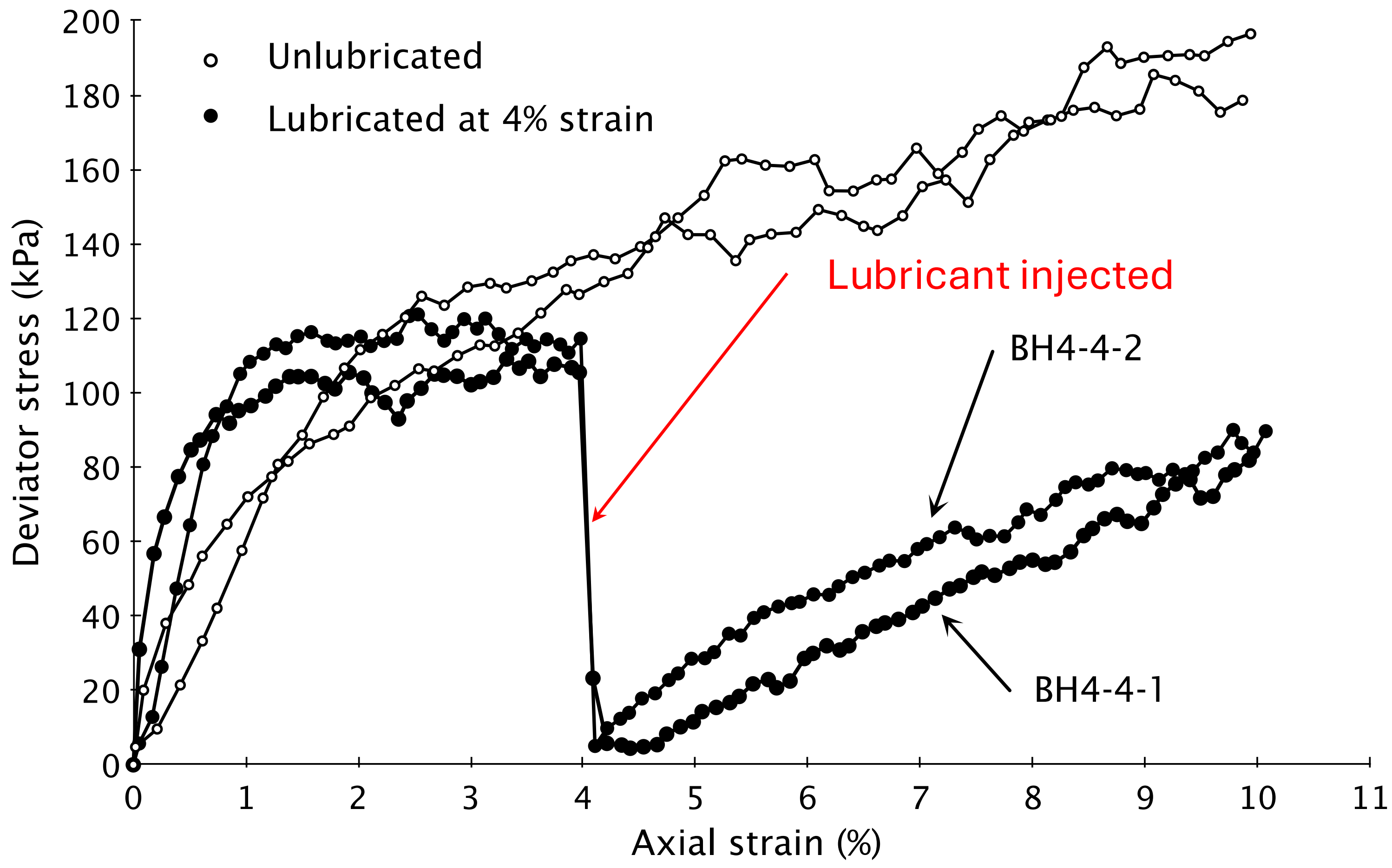
Water injection, before shearing



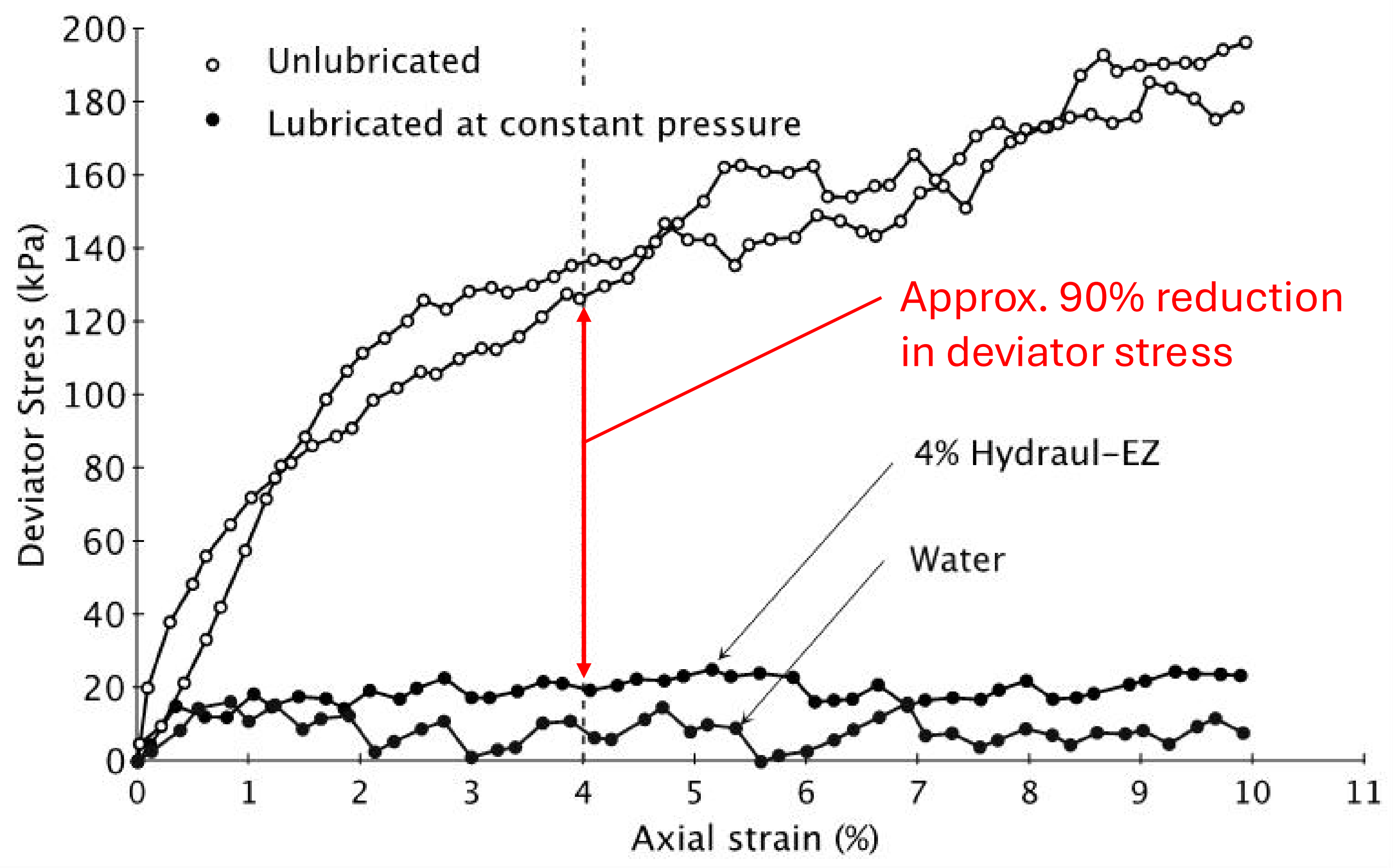
Lubricant injection, before shearing



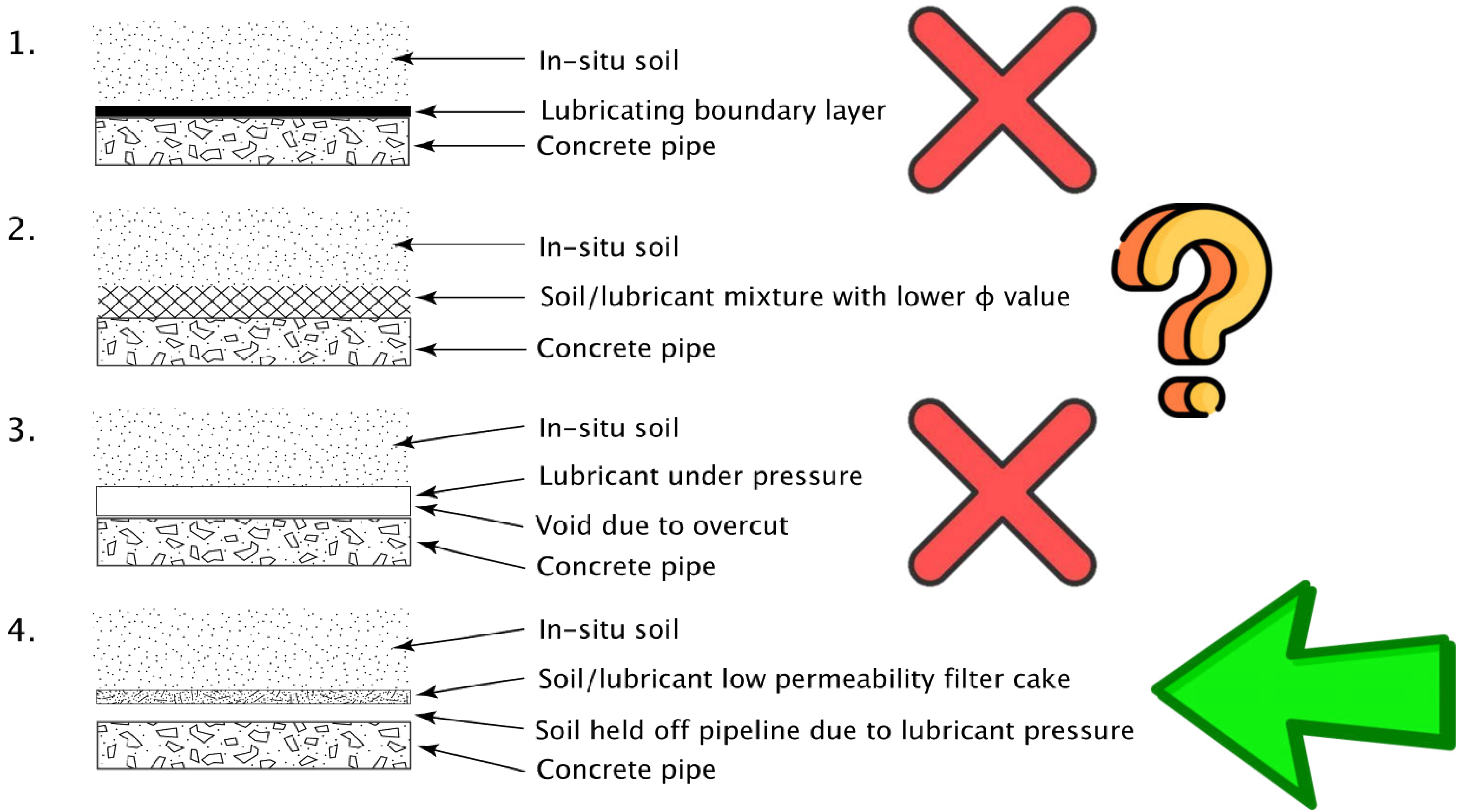
Lubricant injection, during shearing



Lubricant injection, constant volume



Mechanism



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4.
In-situ soil
Soil/lubricant low permeability filter cake
Soil held off pipeline due to lubricant pressure
Concrete pipe

Applications

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- More precise and engineered lubricant delivery

- Further research to refine the science => instrumentation of actual pipes

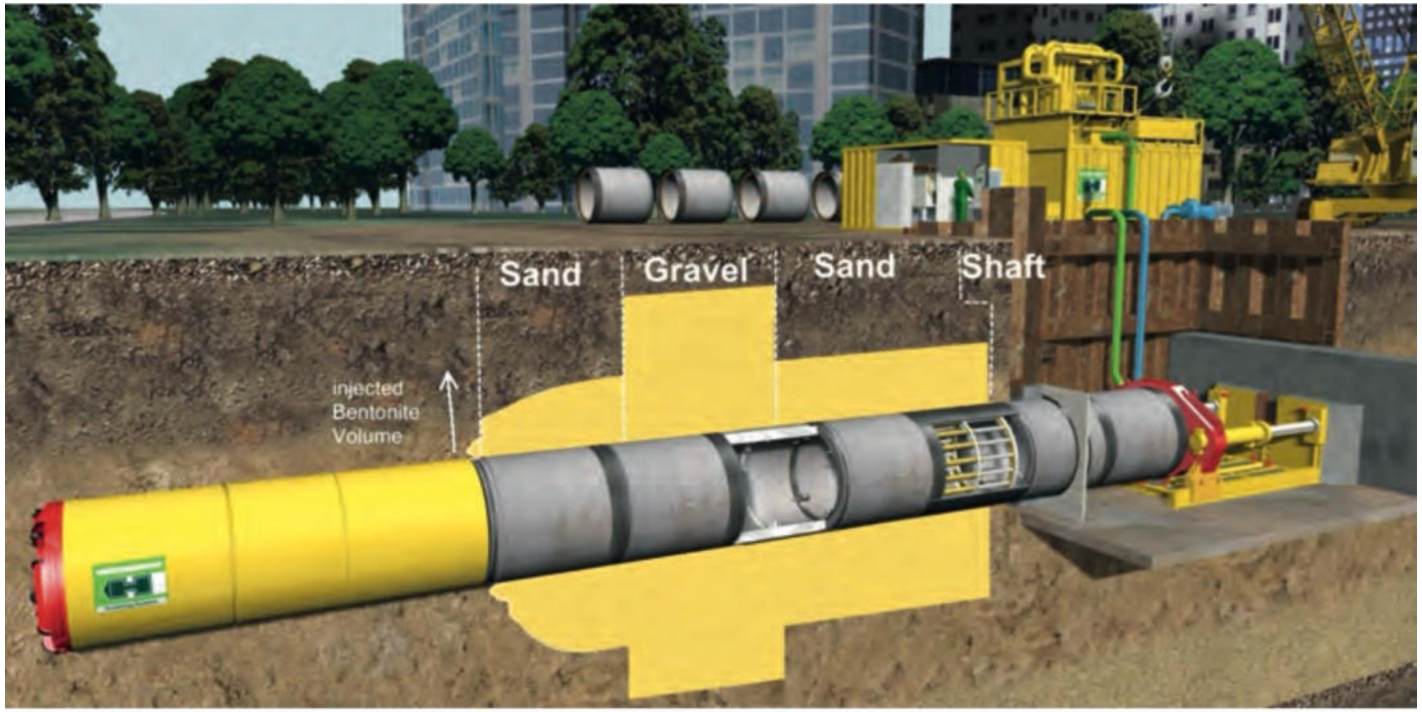


Fig. 7.31 Route-related bentonite distribution with the use of a volume-controlled bentonite lubrication ssytem. (Source: Herrenknecht AG).

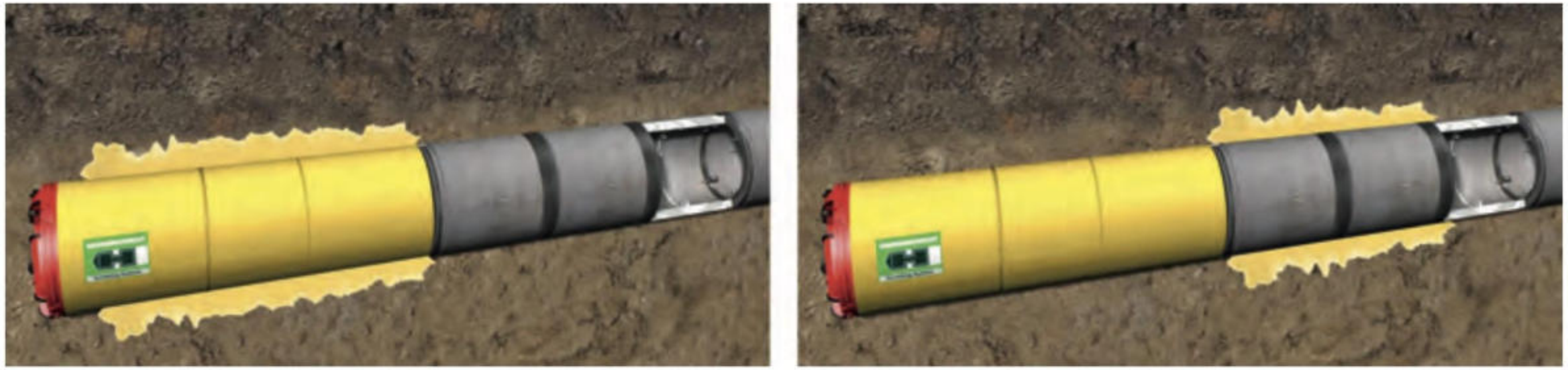


Fig. 7.34 Transfer of the initial injection: left normal initial injection, right initial injection in case of great danger of the shield rolling. (Source: Herrenknecht AG).

Praetorius & Schößer, 2017, Bentonite Handbook

Instrumentation

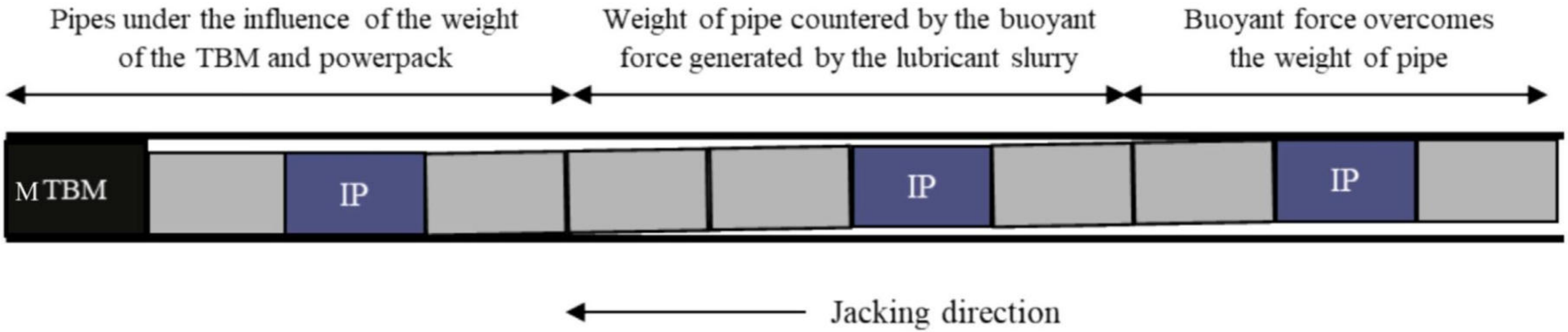
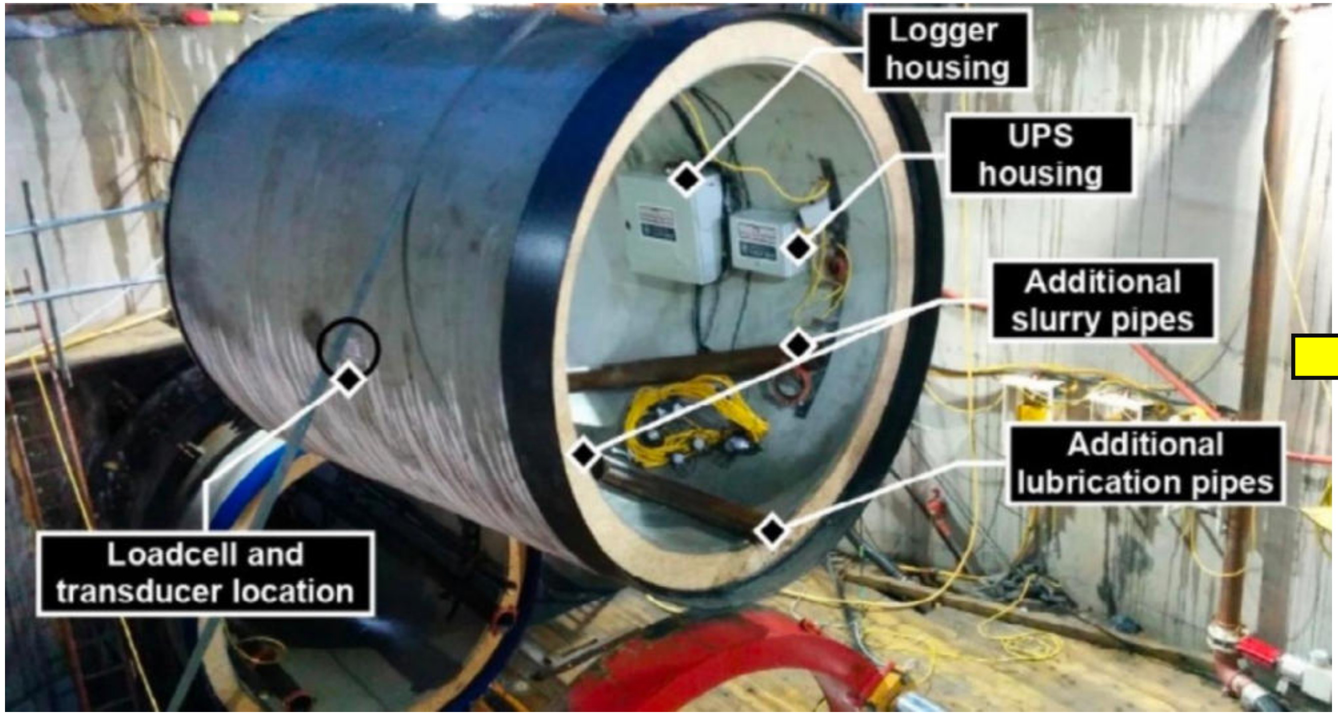


Fig. 7. Hypothesized position of a jacked pipeline in the borehole and recommended locations of instrumented pipes (IPs).

Wadood et al., 2025

Instrumentation



Phillips et al., 2019

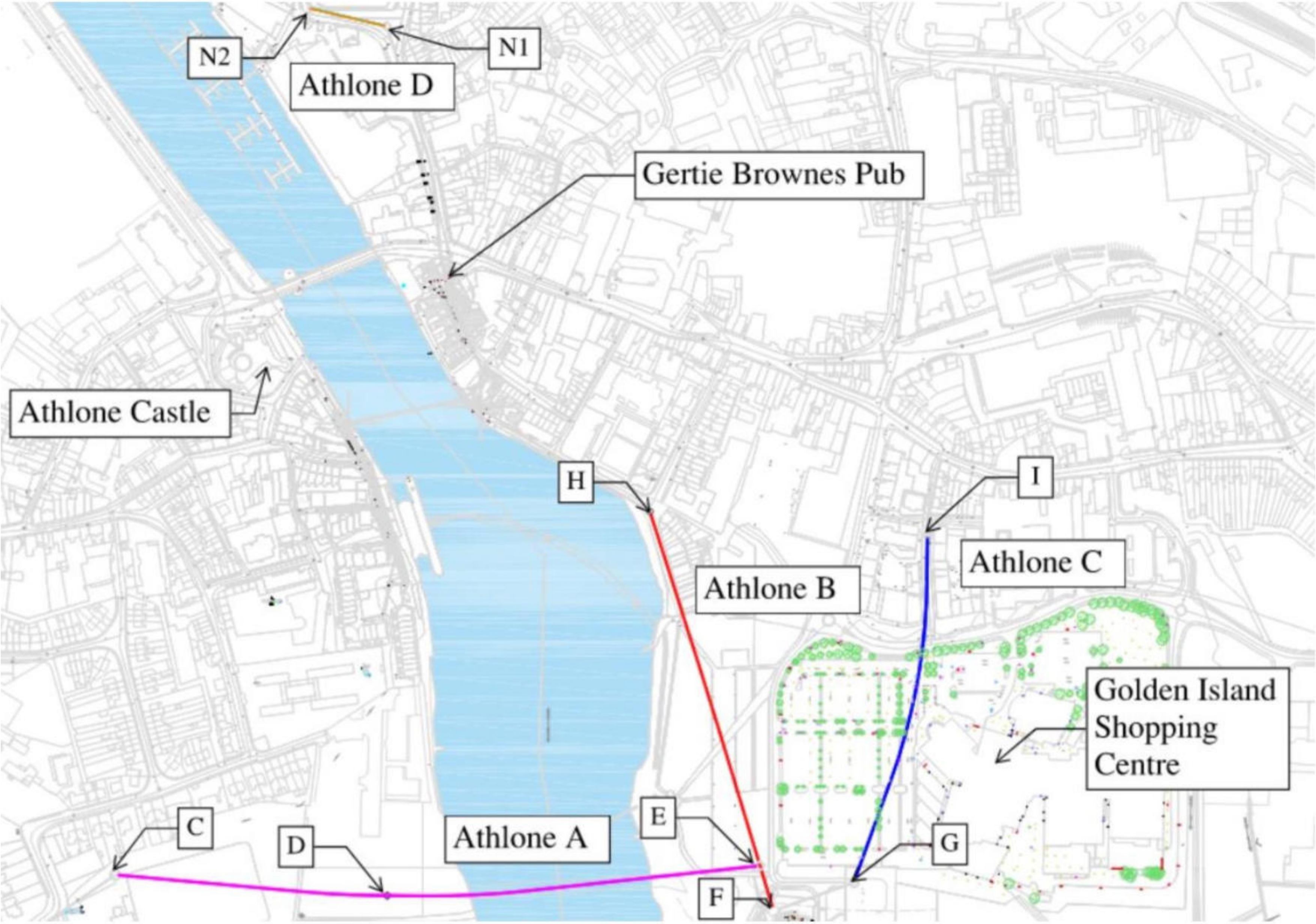


Figure 5-2: Overview of Drives analysed in Athlone

Paper on Athlone Main Drainage to be presented at ICSMGE June 2026: Wadood, McCabe, Sheil & Royston, 2026, *Development and deployment of instrumented microtunnelling jacking pipes for the Athlone Main Drainage Scheme, Ireland: practical aspects and lessons learned.*

Image: Coleman & Flynn, 2025, ME thesis

Conclusion

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- Jacking force is critical for pipe jacking & microtunnelling.
- Lubrication allows for up to 90% reduction in skin friction resistance in pipe jacking and microtunnelling, enabling longer drives & improved reliability.
- Mechanisms reviewed – effective stress reduction at interface considered most relevant.
- Research in the field has led to results in industry, but still more to do.

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Review Article

Field monitoring and instrumentation in microtunnelling/pipe jacking: A review and future directions

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Abstract

The popularity of trenchless techniques as a means of utility pipeline installation in urban environments, specifically microtunnelling/pipe-jacking, has increased in recent years due to its minimally-disruptive nature and reduced carbon footprint in comparison to conventional open-cut excavation methods. The response of pipes during the jacking process is complex and is governed by several factors, including ground conditions, the amount and distribution of lubrication, pipe and annulus size, pipeline misalignments and jacking force eccentricity, among others. Design practice remains based on empirical equations and previous drives through similar geology, resulting in uncertainty in jacking force estimates, thereby restricting adoption of the technique. In order to improve our understanding of the pipe-jacking process, pipes incorporating sensors providing real-time measurements of earth pressures, pore water pressures, axial strains and hoop strains can be used; but the number of such studies reported in the literature is small and the potential of instrumentation on routine projects is largely untapped. Moreover, jacking pipe monitoring practice lags behind the state-of-the-art instrumentation techniques used for monitoring other geotechnical infrastructure. The purpose of this paper is to provide a thorough review of learnings from instrumented pipe-jacking case studies and other supporting research, as well as to propose potential solutions to research gaps in the current state of design practice and field monitoring of pipe jacking projects.

Keywords: Trenchless technology; Microtunnelling; Pipe jacking; Instrumentation; Field monitoring

1 Introduction

The global population is projected to reach approximately 10 billion by the year 2050, by which time an additional 2.5 billion people are expected to be living in urban areas (United Nations, 2022). In rapidly expanding cities, exploitation of underground space will be paramount in mitigating congestion and improving urban resilience (Apoji et al., 2023). Large-diameter tunnels serve as integral underground structures, facilitating transportation networks such as roads, railways and pedestrian subways, while smaller diameter tunnels accommodate essential utilities like water, wastewater, gas, electrical cables and telecommunication connections (O'Dwyer, 2023).

Microtunnelling, also referred to as pipe-jacking (PJ), is nowadays preferred to traditional open-cut excavation methods for utility pipeline installation due to its minimally disruptive nature (Castro et al., 2007; Cui et al., 2015) and reduced carbon footprint (Lu et al., 2020; Swallow & Sheil, 2023). Initially limited to small diameters (<1200 mm) and short lengths (<200 m), recent equipment advancements have enabled the construction of PJ drives exceeding 1300 m in length and 4.5 m in diameter (Jiang et al., 2022), often incorporating curves (Zhang et al., 2022). Despite the potential benefits of PJ infrastructure, the widespread adoption of the technique has been hindered by many uncertainties and complexities involved in the PJ process (Broere, 2016). These are mostly related to the site-specific nature of PJ drives. Consequently, design

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