Webinaire « Doctorants en géotechnique »

Clouage des sols : comportement sous sollicitation sismique de l'interface sol-clou

GHIDA HAWWA

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Who are We?

RRO Test deals with applied research issues identified in particular during expertise on real projects or works.

Scope of Action:

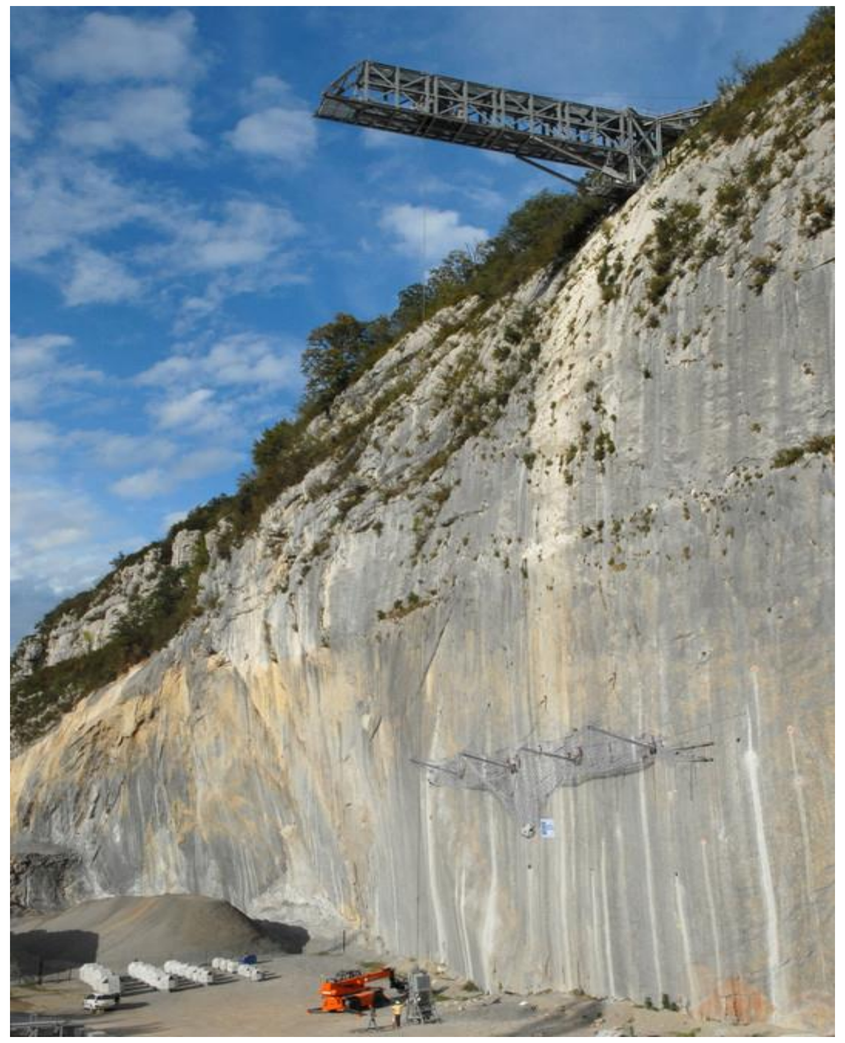
- Observation and monitoring of sites and geotechnical structures in full scale.
- Behavior ,dimensioning, and design of geotechnical structures.

Methods of Research:

- Experimental testing (scale 1:1 or on site as possible).
- Analytical (calculations).
- Numerical approaches (CESAR-LCPC,OPTUM CE…).

On-going Research:

- Ground-frame friction for the foundations of the bolt and nail type.
- Seismic behavior of ground reinforcements by nailing.
- Behavior, design and dimensioning of the structures for protection against rockfall,
- Vulnerability of civil engineering structures required by a hard impact at moderate speed.
- Behavior and diagnosis of masonry works.
- High-precision instrumentation for monitoring works and sites by optical fiber.



Rocks fall station in Montagnole

Dynamic nail pull-out device

Soil Nailed Walls:

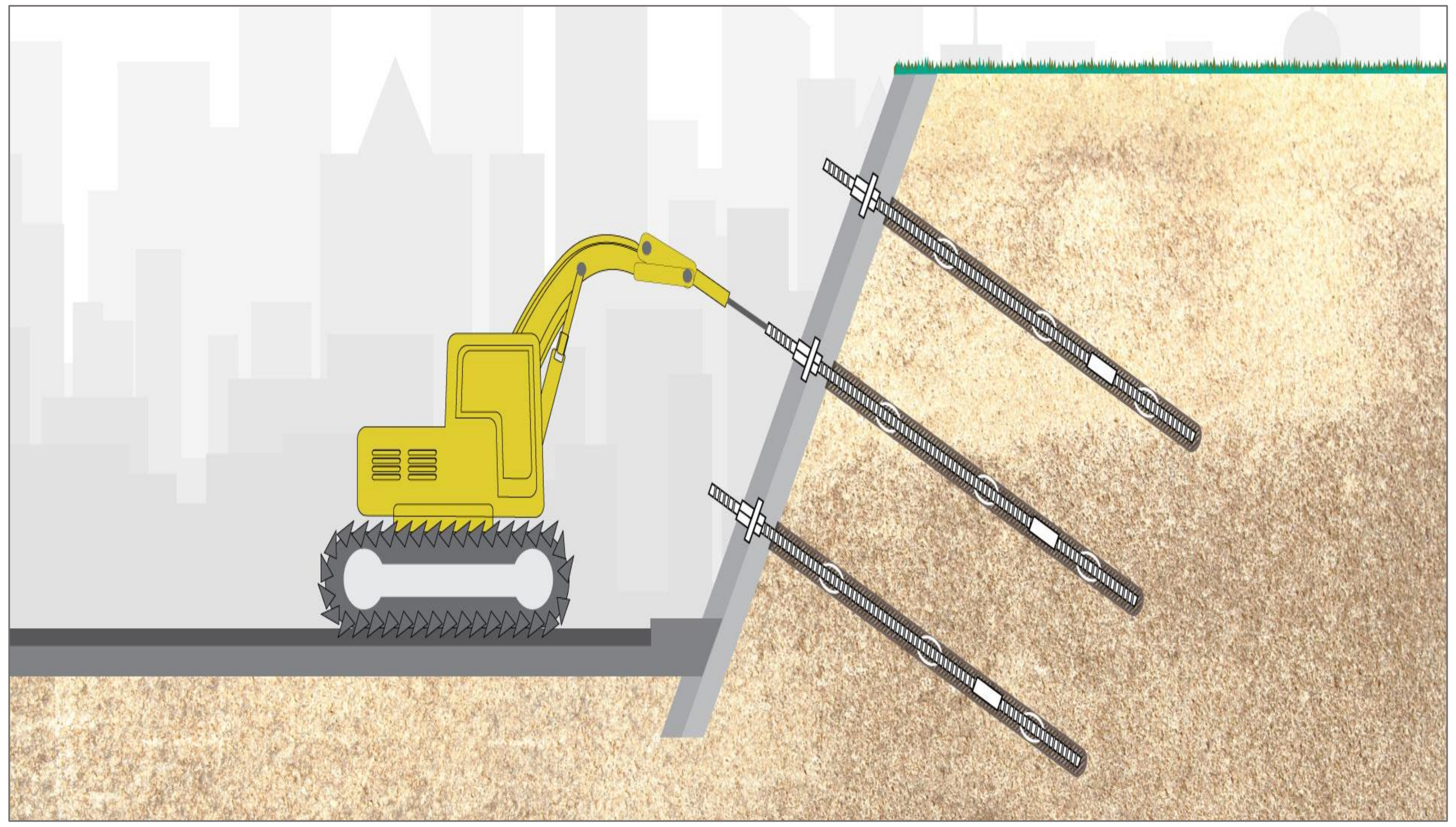
- **Soil retaining structures where soil is reinforced by sealed grouted steel bars.**

Economically:

- Reduced cost
- Rapid construction
- Easy implementation

Performance:

- Remarkable seismic performance.



soil nail walls construction

Stability of Soil Nailed Walls:

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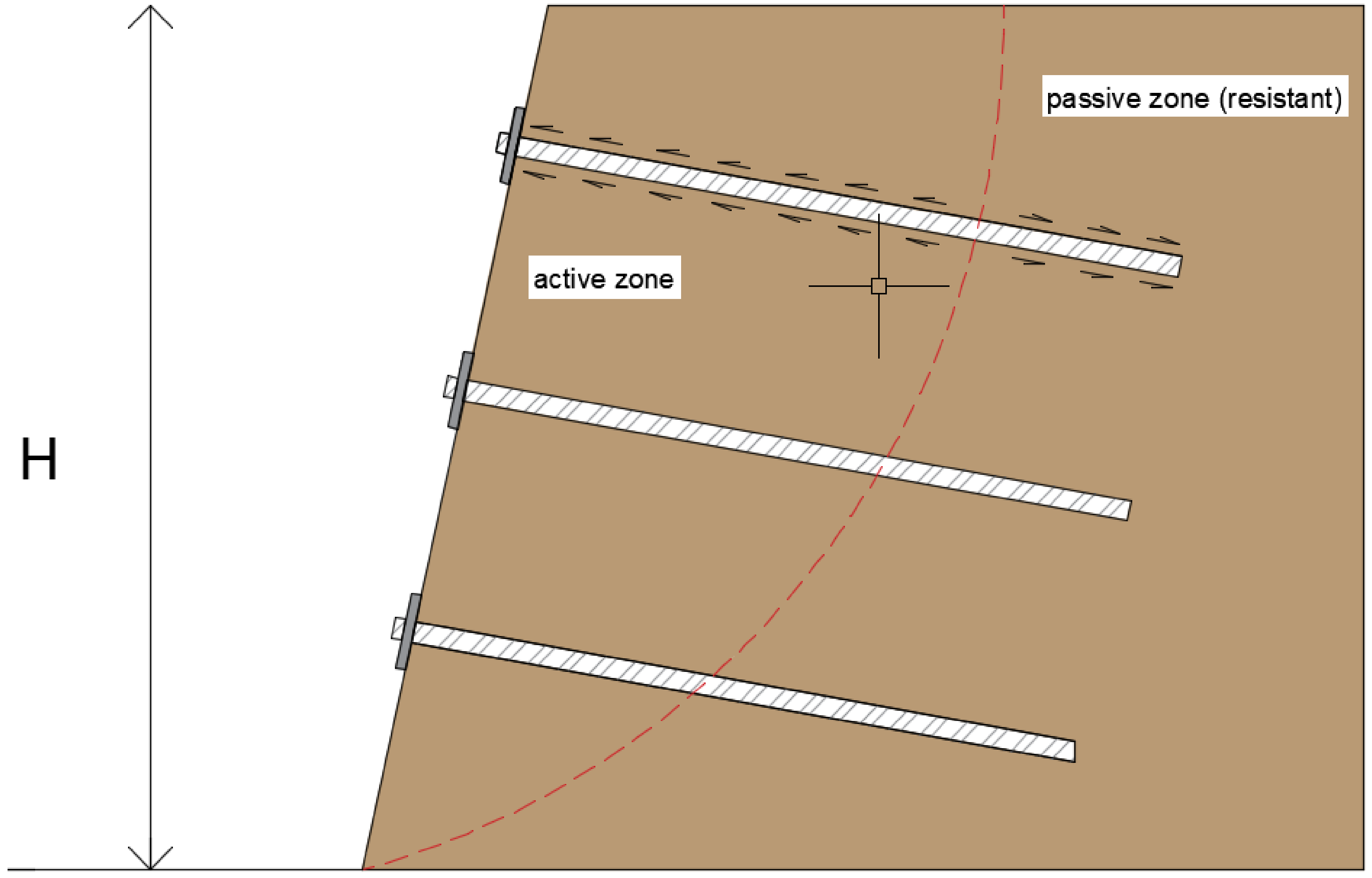
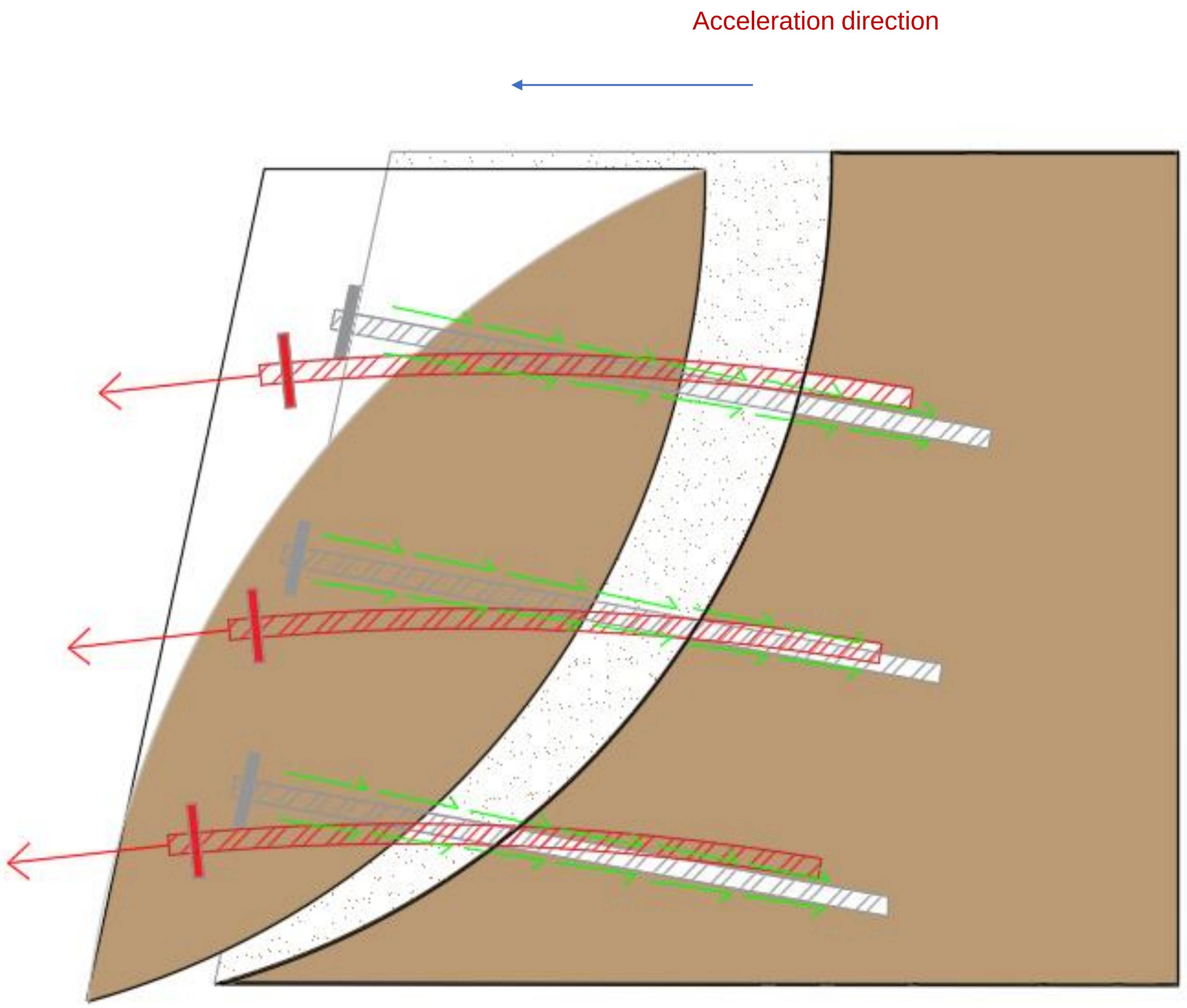


Stability of soil-nailed walls



failure of soil-nailed walls by pull out of nails

Stability of Soil Nailed Walls: local behavior

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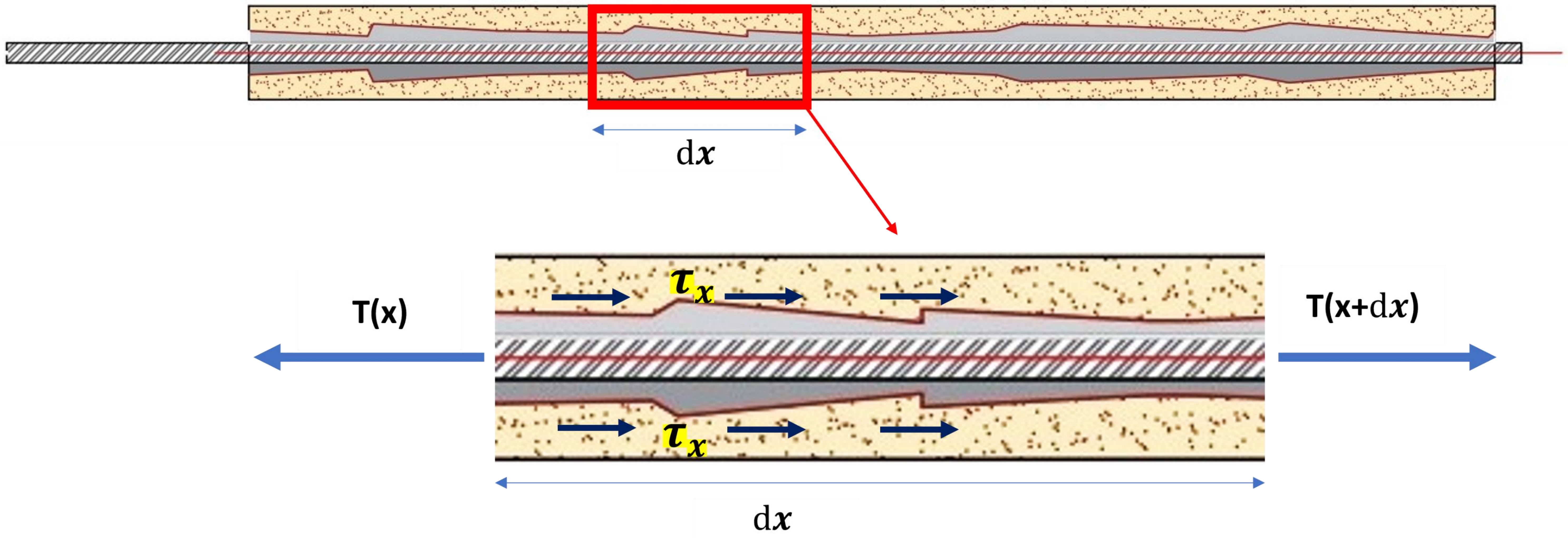
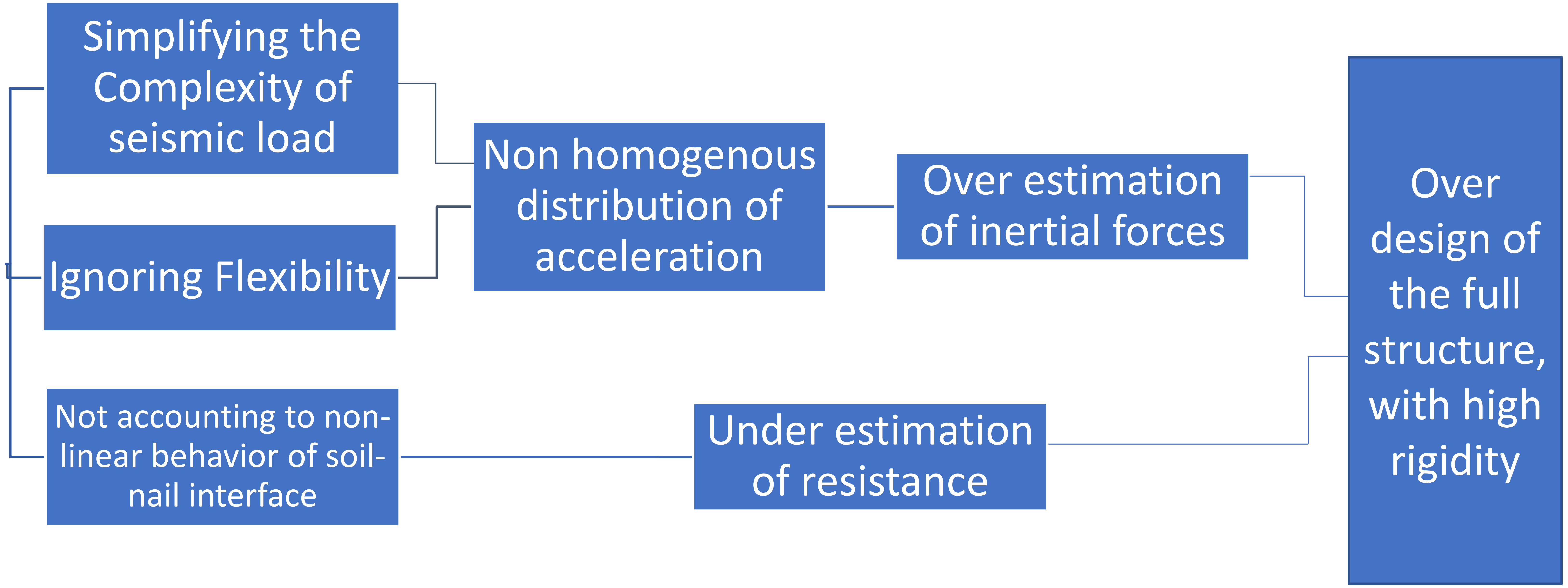


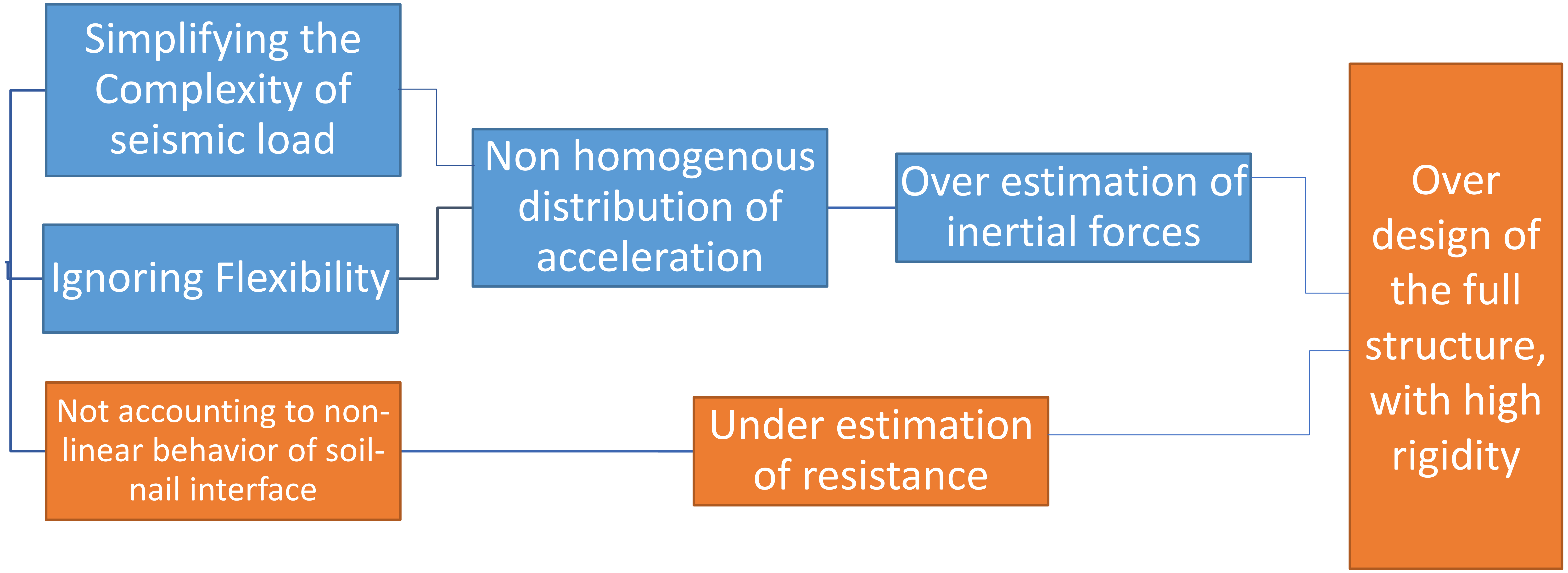
Illustration of soil-nail interface friction

Displacement between soil and nail → Friction (τ_x) → Stability

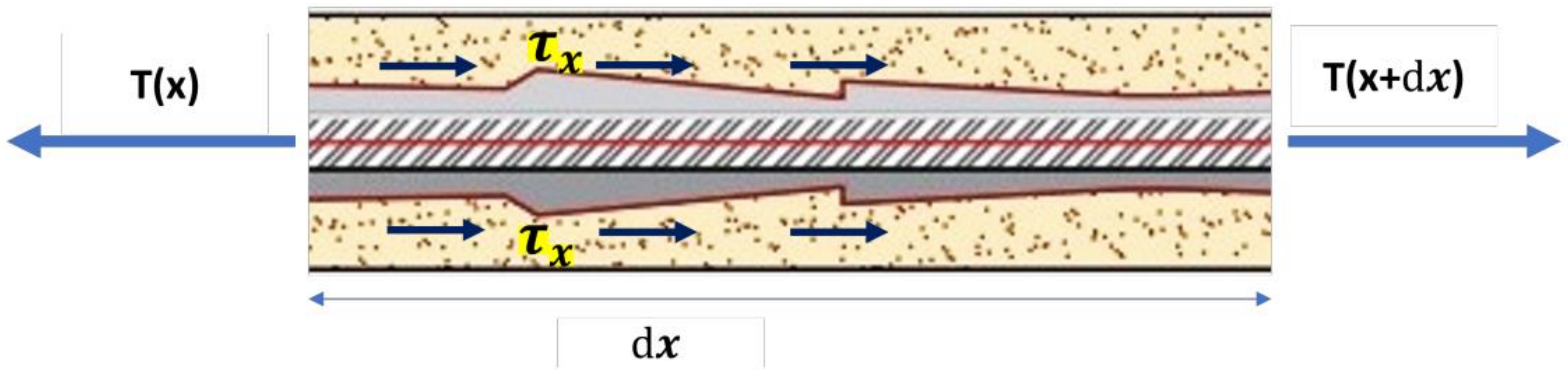
Seismic Behavior: limits of design methods

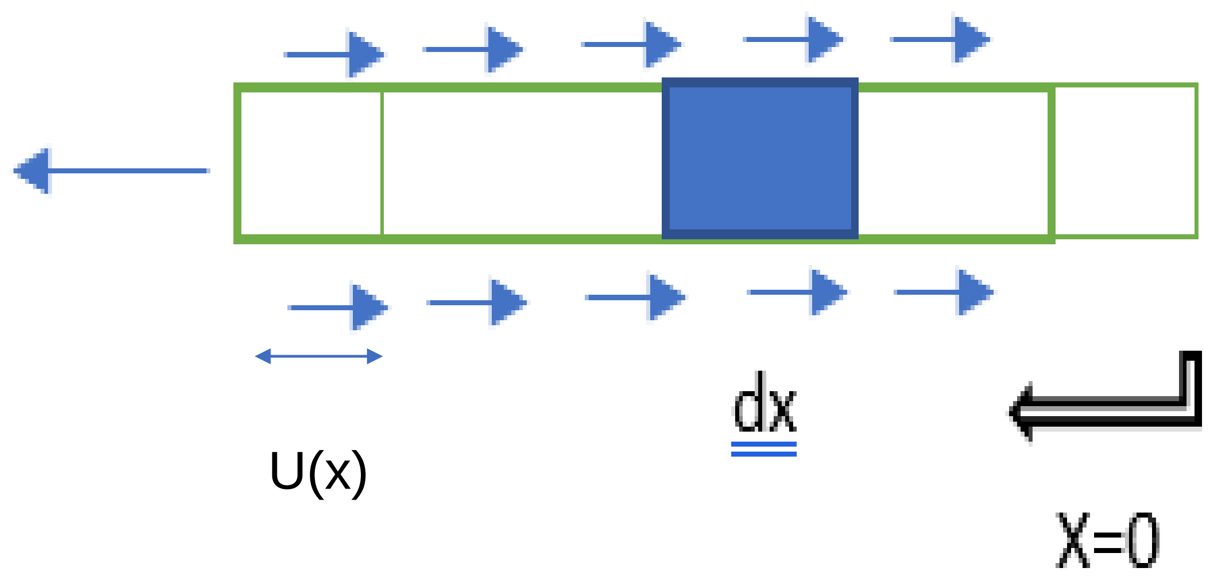


Seismic Behavior: limits of design methods



The Interface Behavior: static problem





At equilibrium:

$$T(x) - T(x + \Delta x) - \pi\tau_x D = 0$$

And according to Hook's law:

$$\sigma = E\varepsilon$$

$$\frac{d\,T_x}{S} = E\frac{d_u}{d_x}$$

The equations add up to form a 2nd order deferential equation:

$$ES\frac{d^2U}{dx^2} - \pi\tau_x D = 0$$

$$\frac{d^2U}{dx^2} = \frac{\pi\tau_x D}{ES}$$

The Interface Behavior: dynamic problem

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In dynamic problem:

At equilibrium acceleration shall be considered:

$$ES\frac{d^2U(x,t)}{d_x{}^2} - \pi\tau_x D = \rho S\frac{d^2U(x,t)}{d_t{}^2}$$

Where :

S: surface area of the nail section

E: young modulus of the steel

D:diameter of cross section

$$ES\frac{d^2u(x,t)}{d_x{}^2} - \pi\tau_x D = \rho S\frac{d^2u(x,t)}{d_t{}^2}$$

The main problem is that interface friction τ_x in case of dynamic loading is unknown

$Identifying\ parameters\ influencing\ \tau_x$:

- Frequency
- Amplitude
- Confining pressure
- Soil properties

Aim of the Study:

Understanding local interface behavior

Identifying the parameters on which friction at interface depends

?

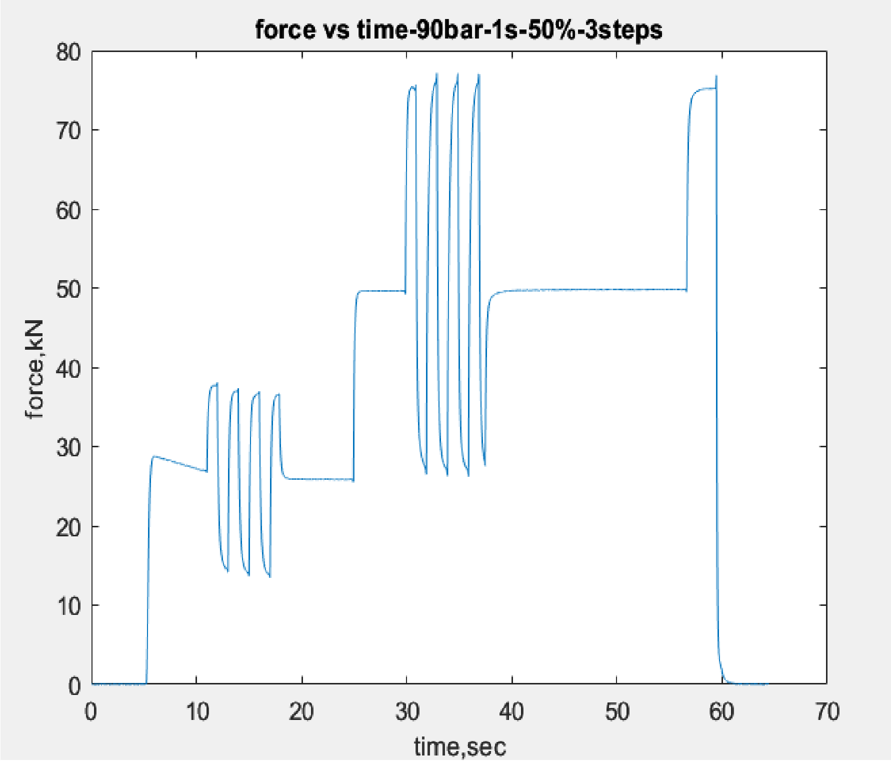
Through dynamic pull-out tests.

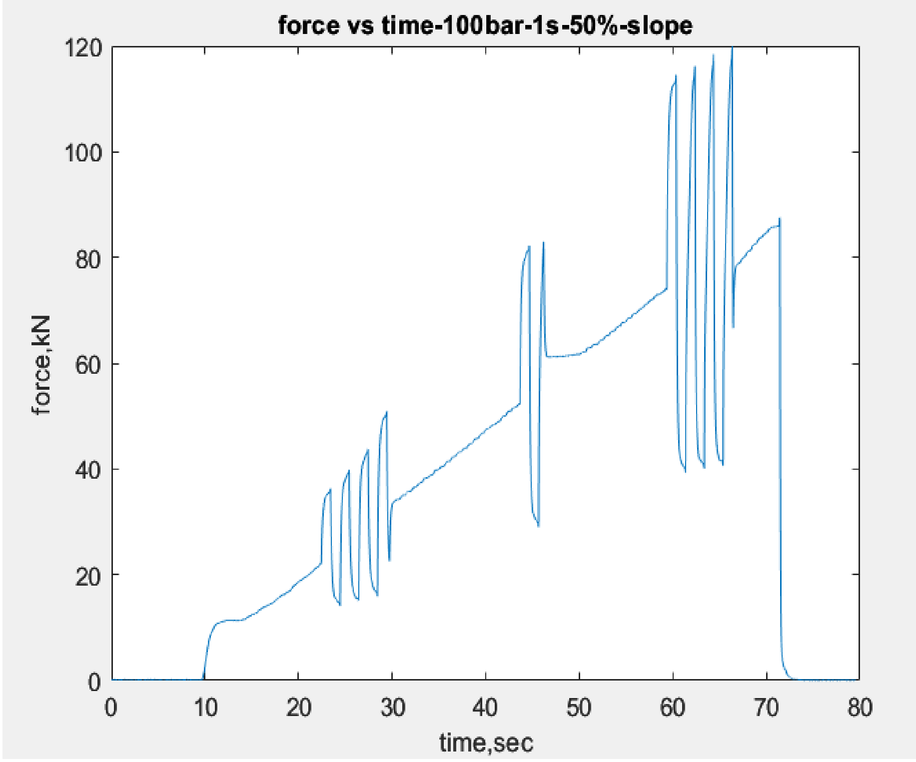
The Dynamic pull-out device:

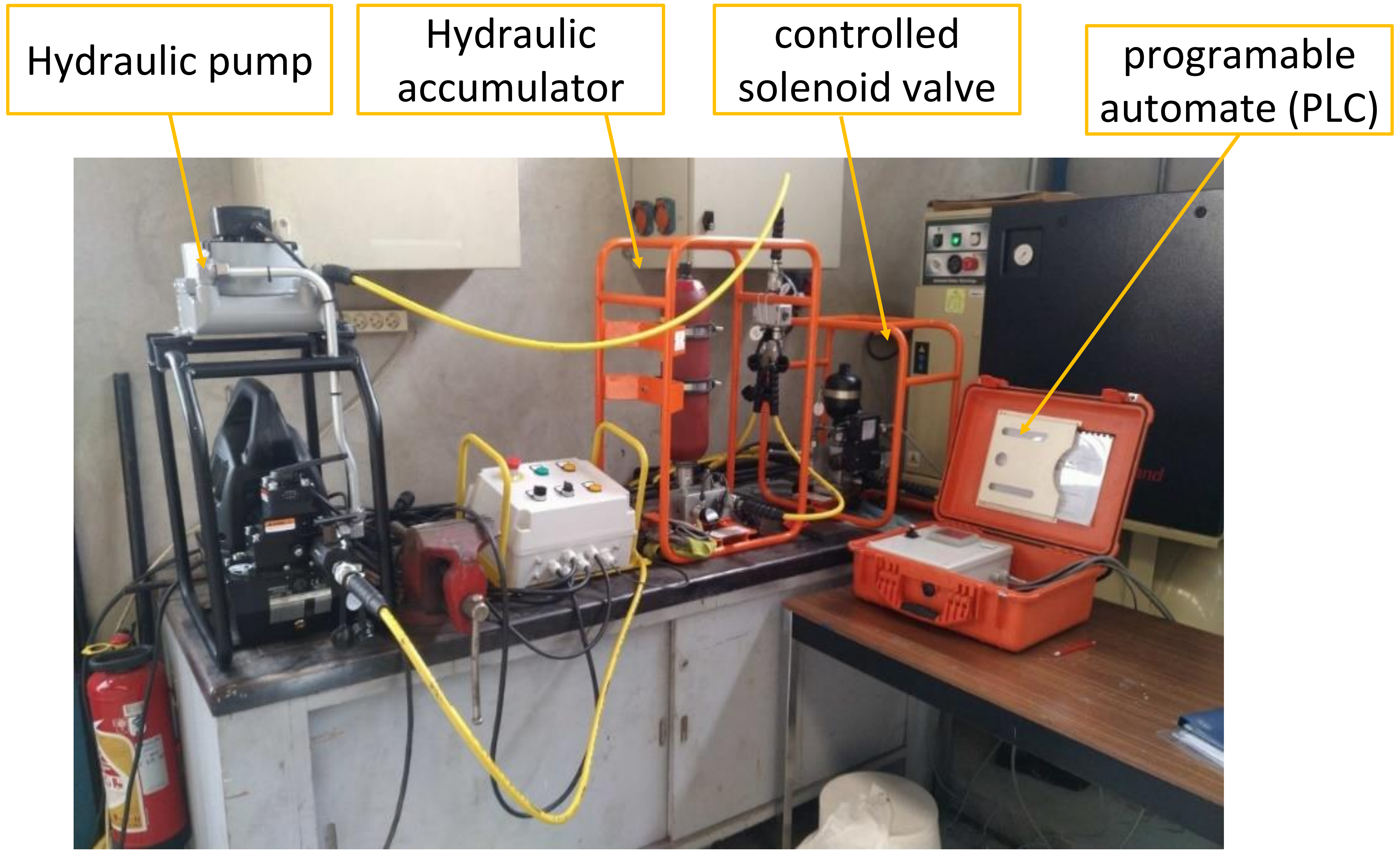
Operating Mode:

- Impose static tension load in two different configurations: incremental loading pullout tests **(steps configuration)** or during a linear increase of the tensile force **(slope configuration).**
- Superimposition of vibrational pulses centered around the static load with an amplitude at percentage of the static load (1-50% of the static tension).

Static Load		Dynamic pulse	
Duration	Magnitude	Frequency	amplitude







The dynamic pull-out device

Experimental Setup: connections and monitoring

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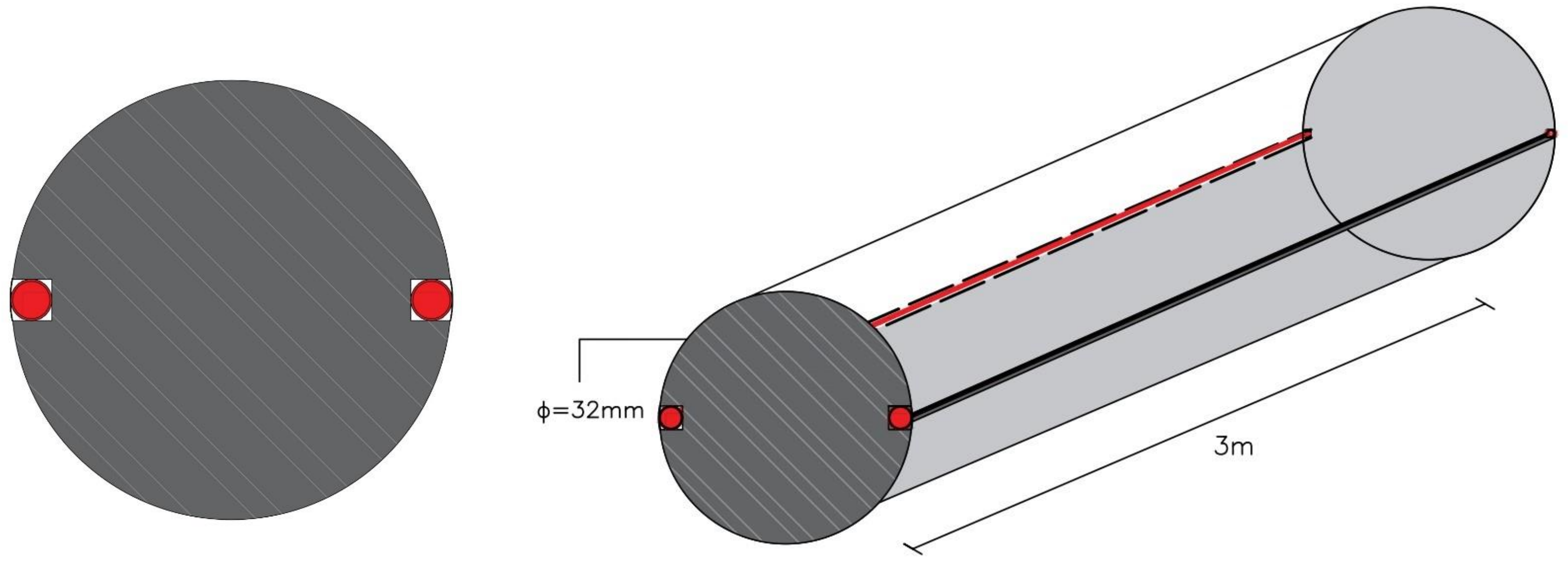
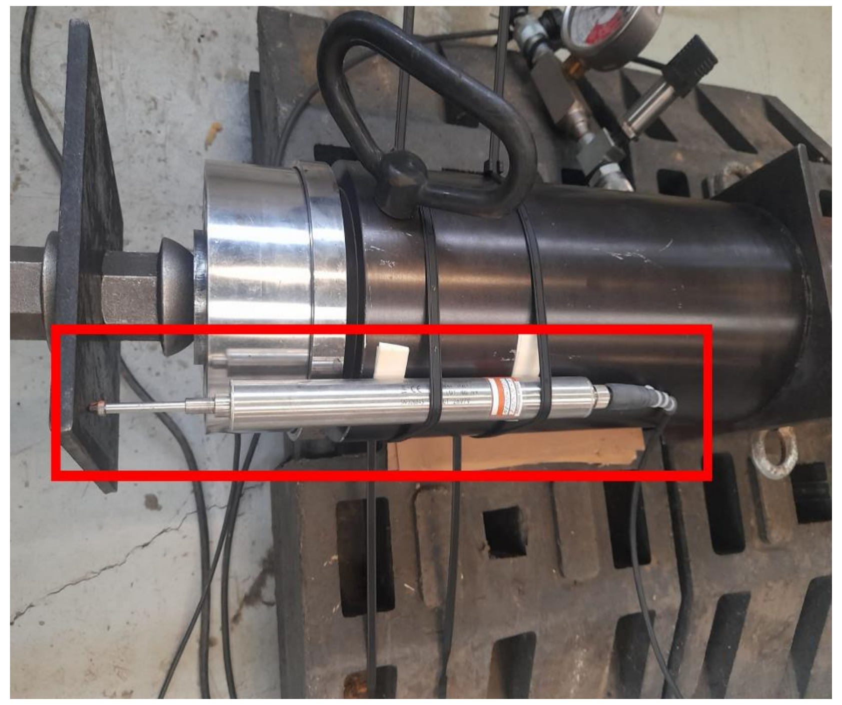
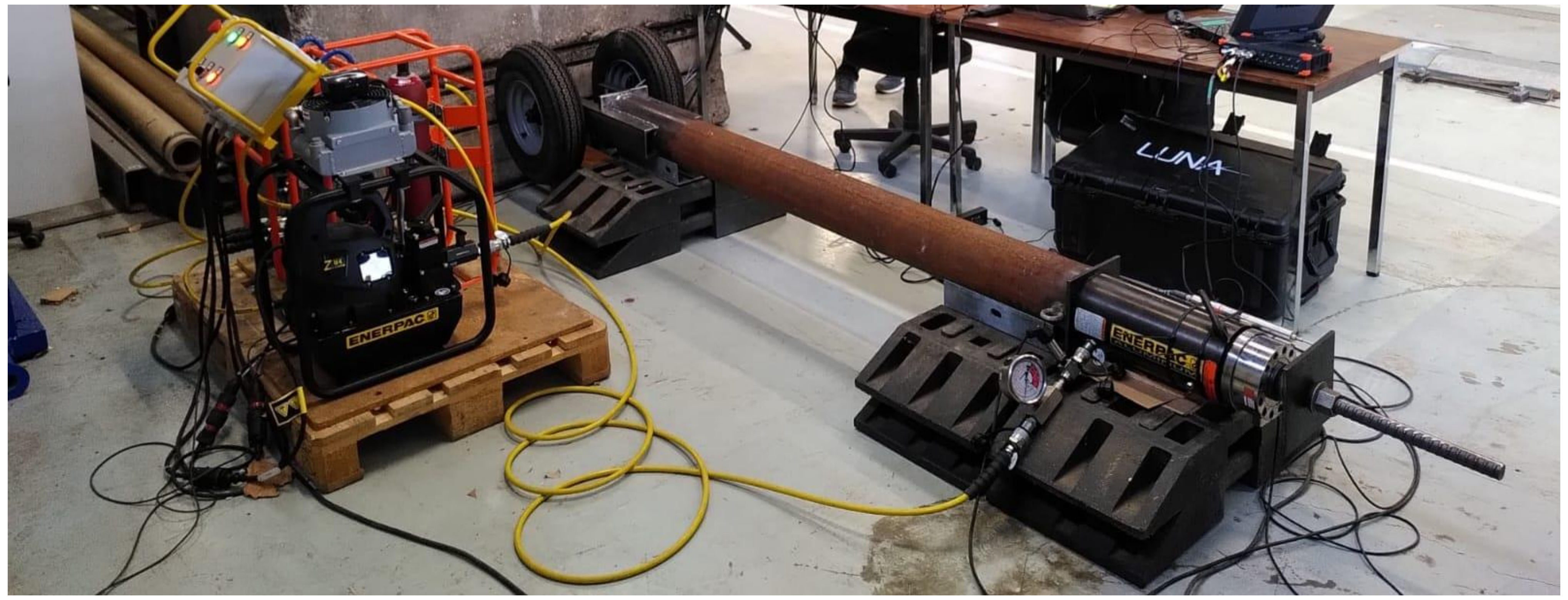
Connection of optical fiber along the steel bar:



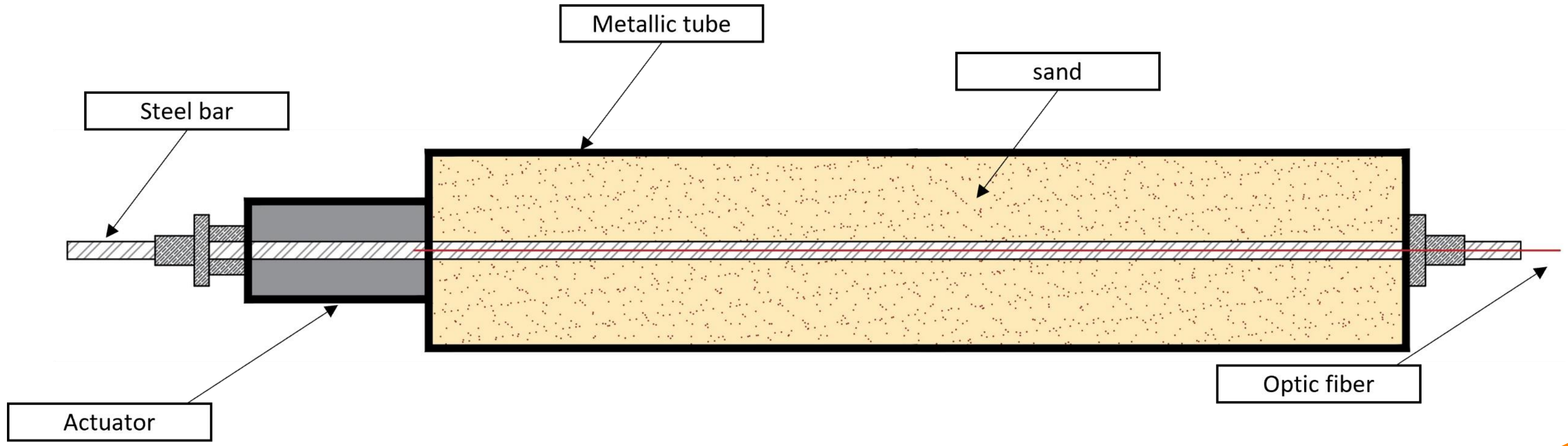
Double optical fiber connected along the two flat sides of the steel bar



Displacement and load sensors connected at the head of the nail



Employed setup connections



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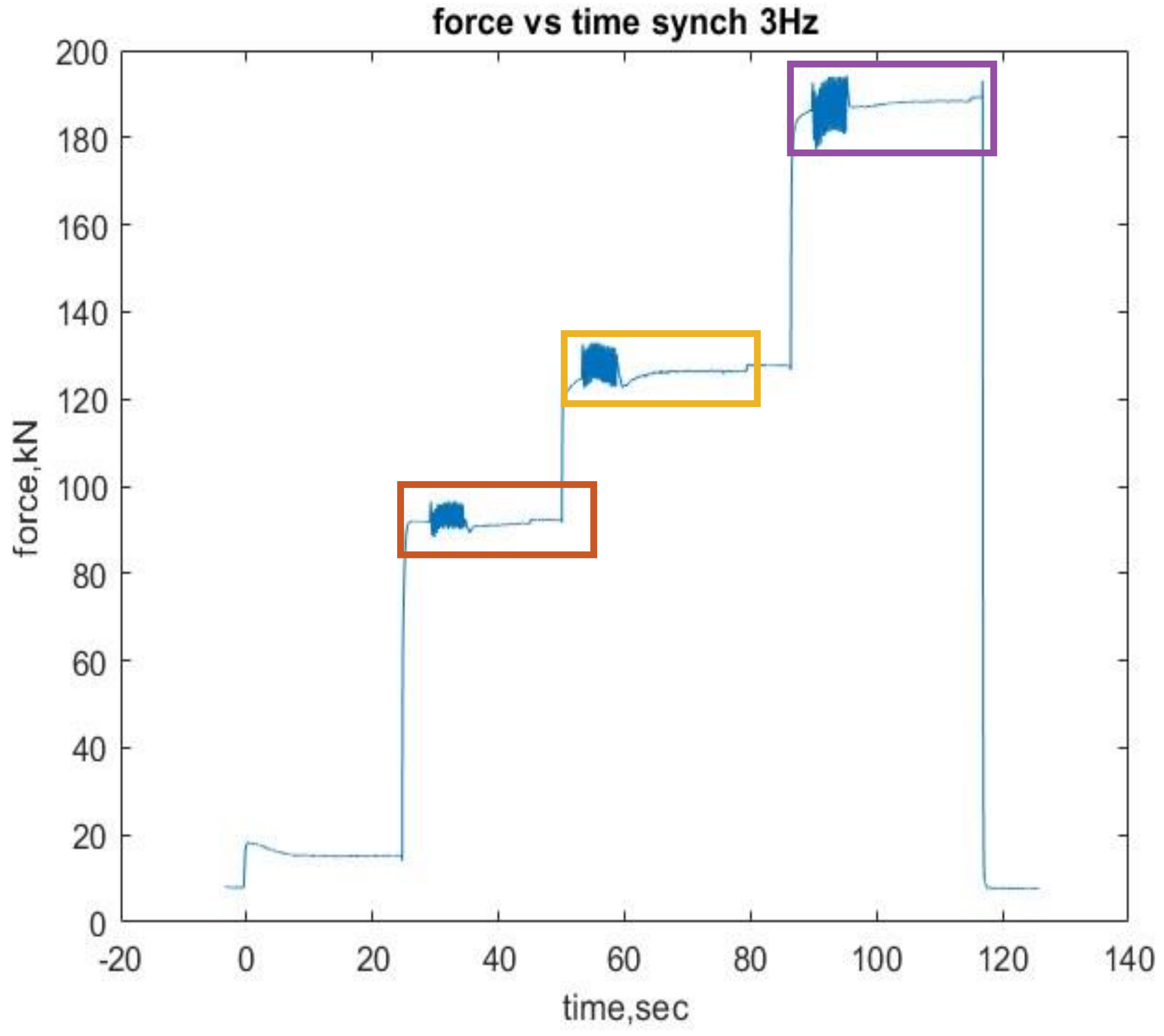
Test Protocol:

Test Name	Static load		Dynamic load (pulse)	
	Pressure(bar)	Duration (sec/step)	Amplitude(%)	Frequency(Hz)
Test0	10-100-140-213	30	-	-
Test 1-5%	10-100-140-213	30	5	1
Test 2-5%				2
Test 3-5%				3
Test 4-5%				4
Test 5-5%				5

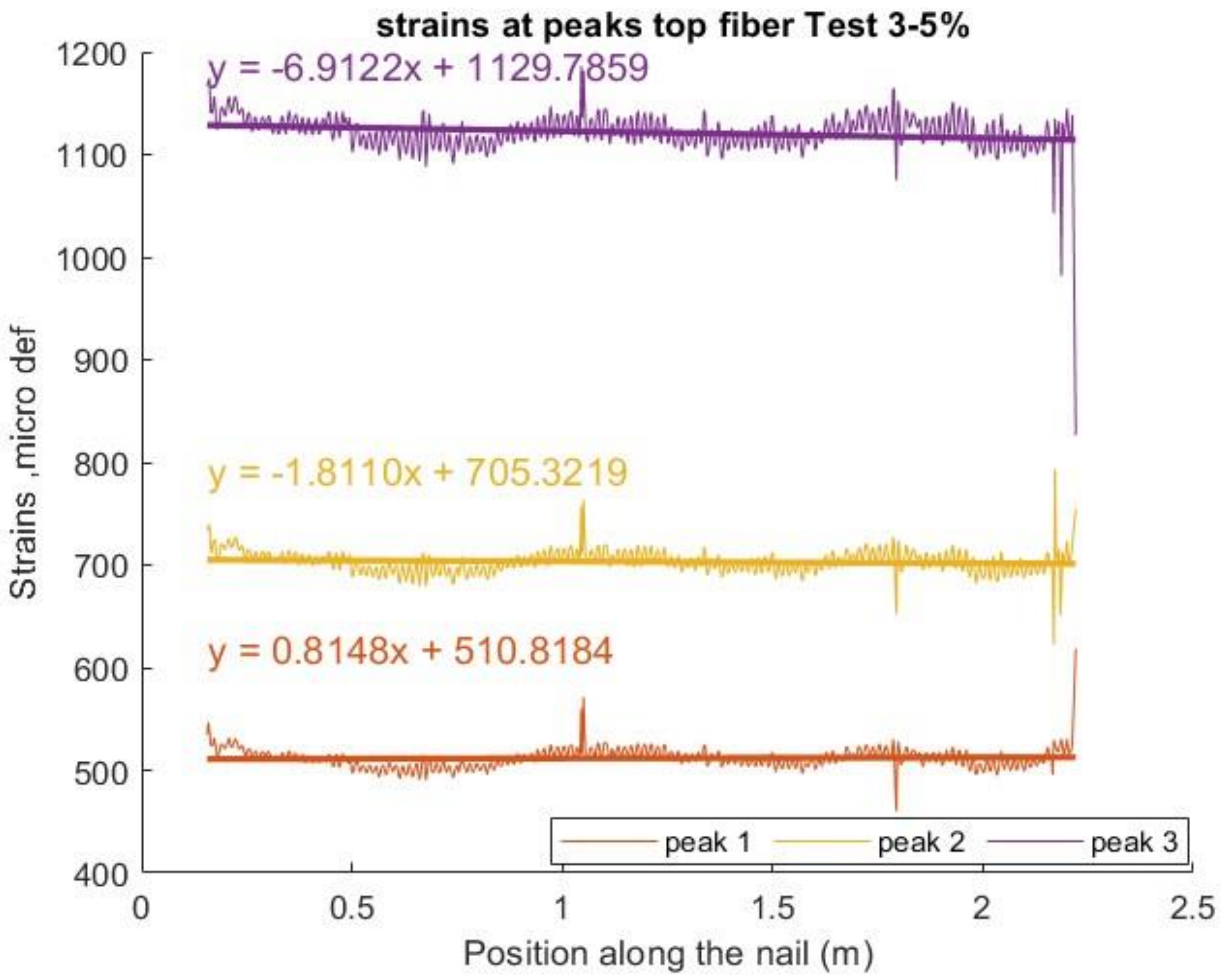
The duration of the pulse is **5sec** (manual timer is used)



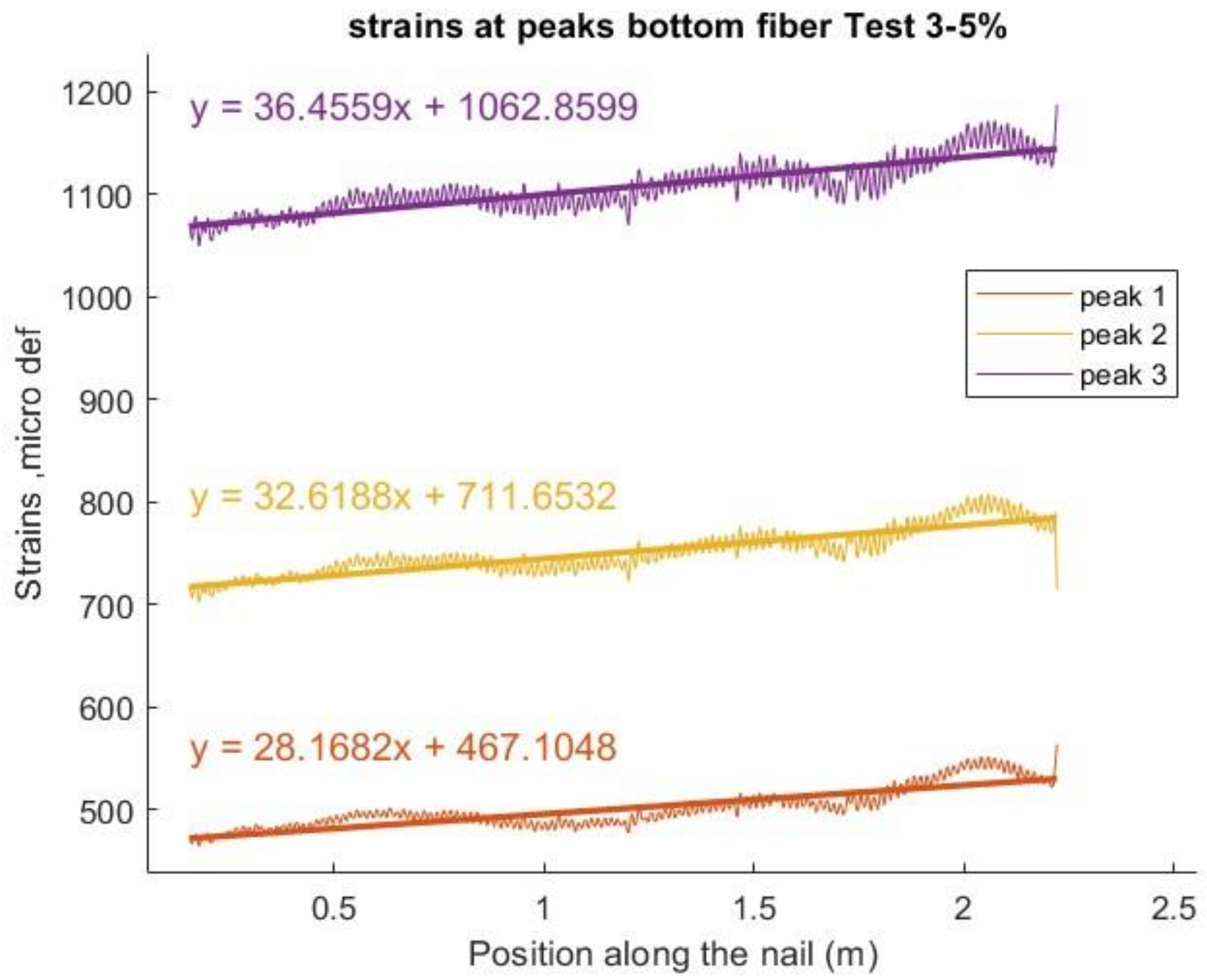
Pressure(bar)	10	100	140	213
Load(KN)	15,18	92	126	188

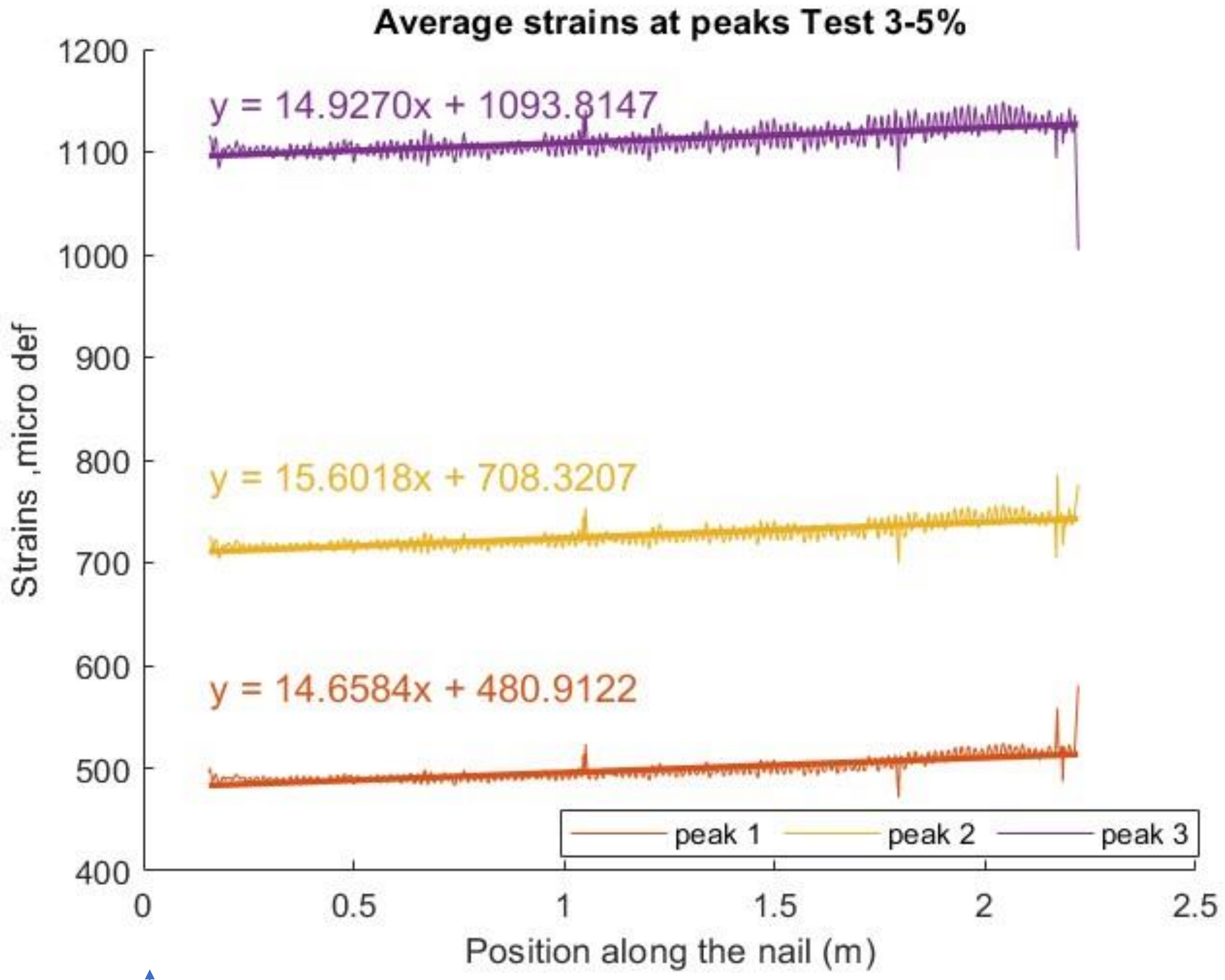
Measured Strains: top vs bottom fiber

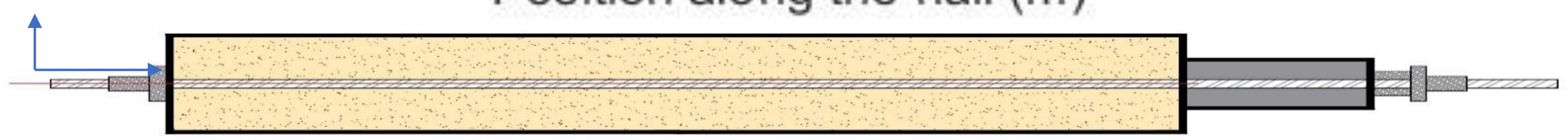
Test 3-5% Top fiber



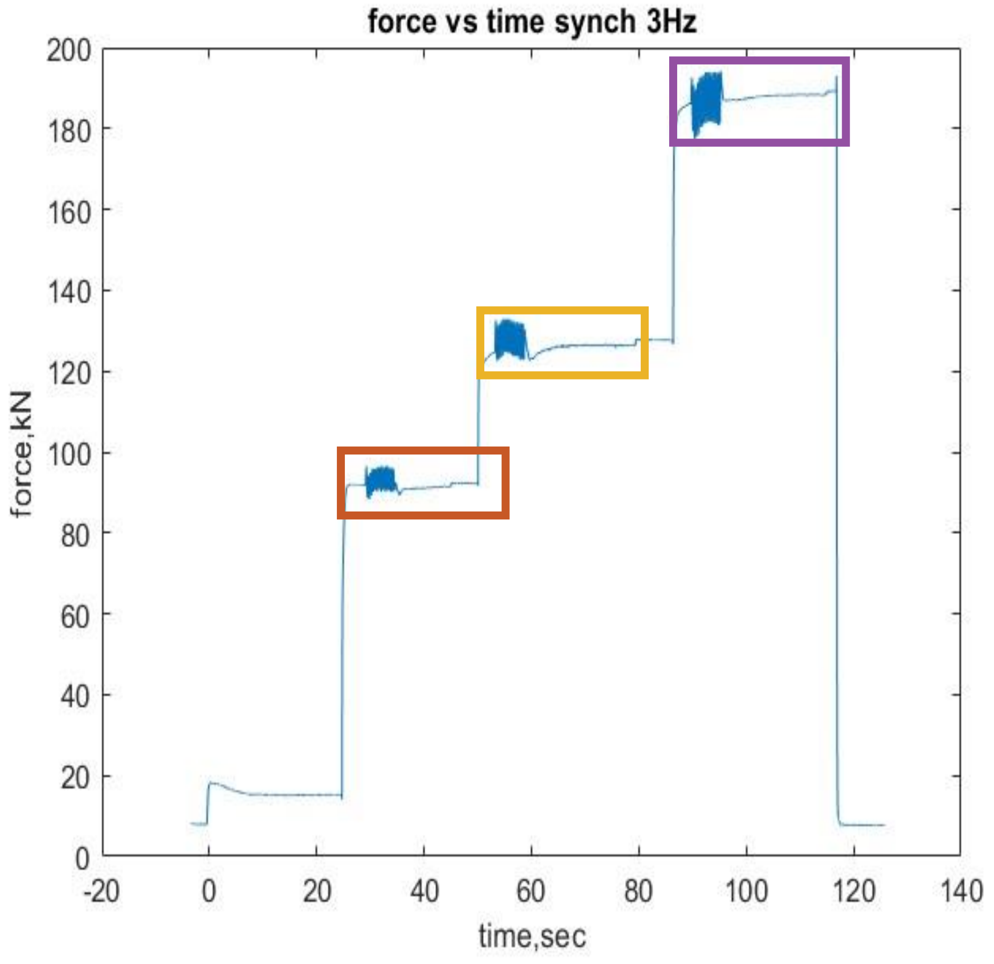
Test 3-5% Bottom fiber







Test 3-5% average of fibers



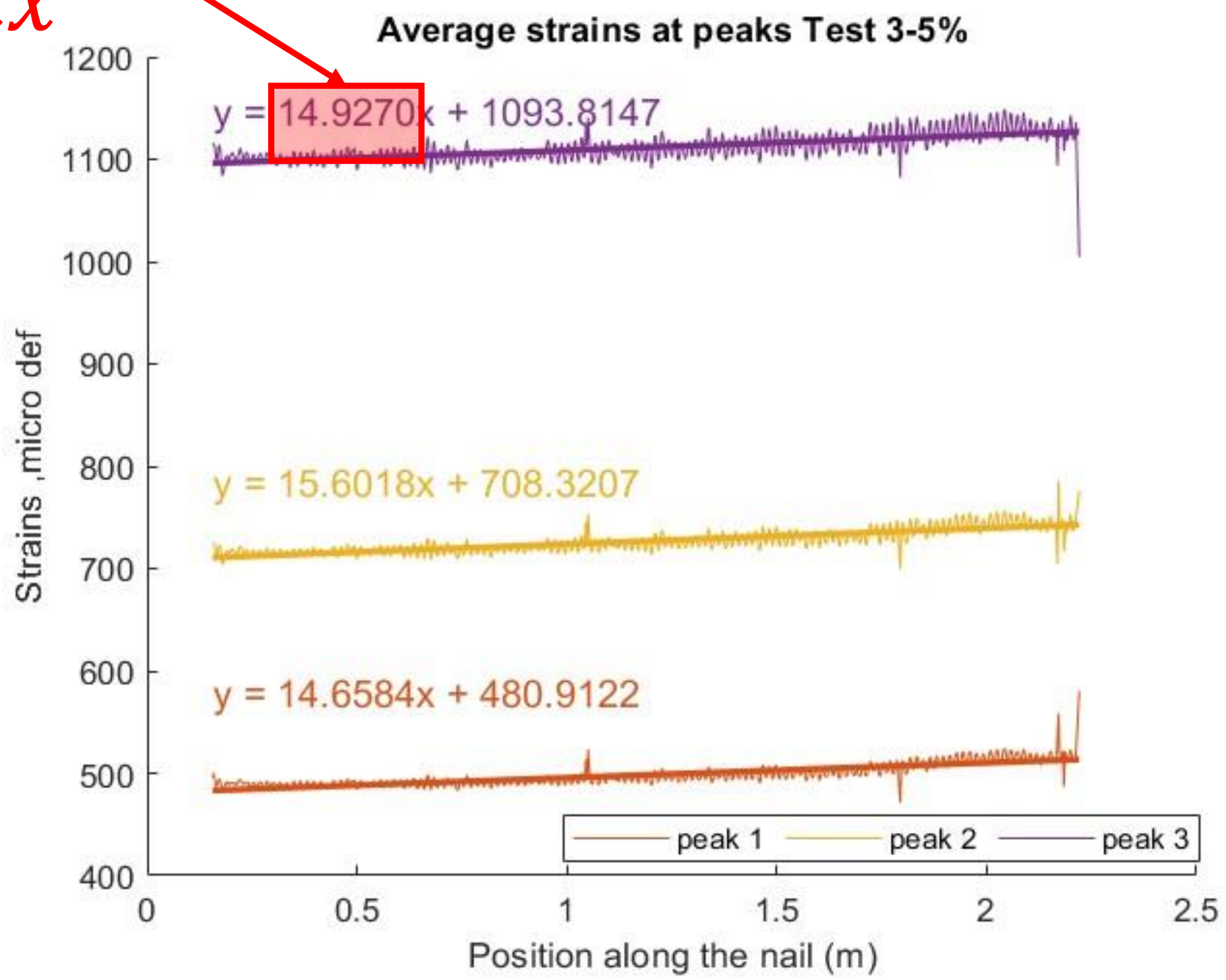
Evaluation of Interface friction coefficient τ:

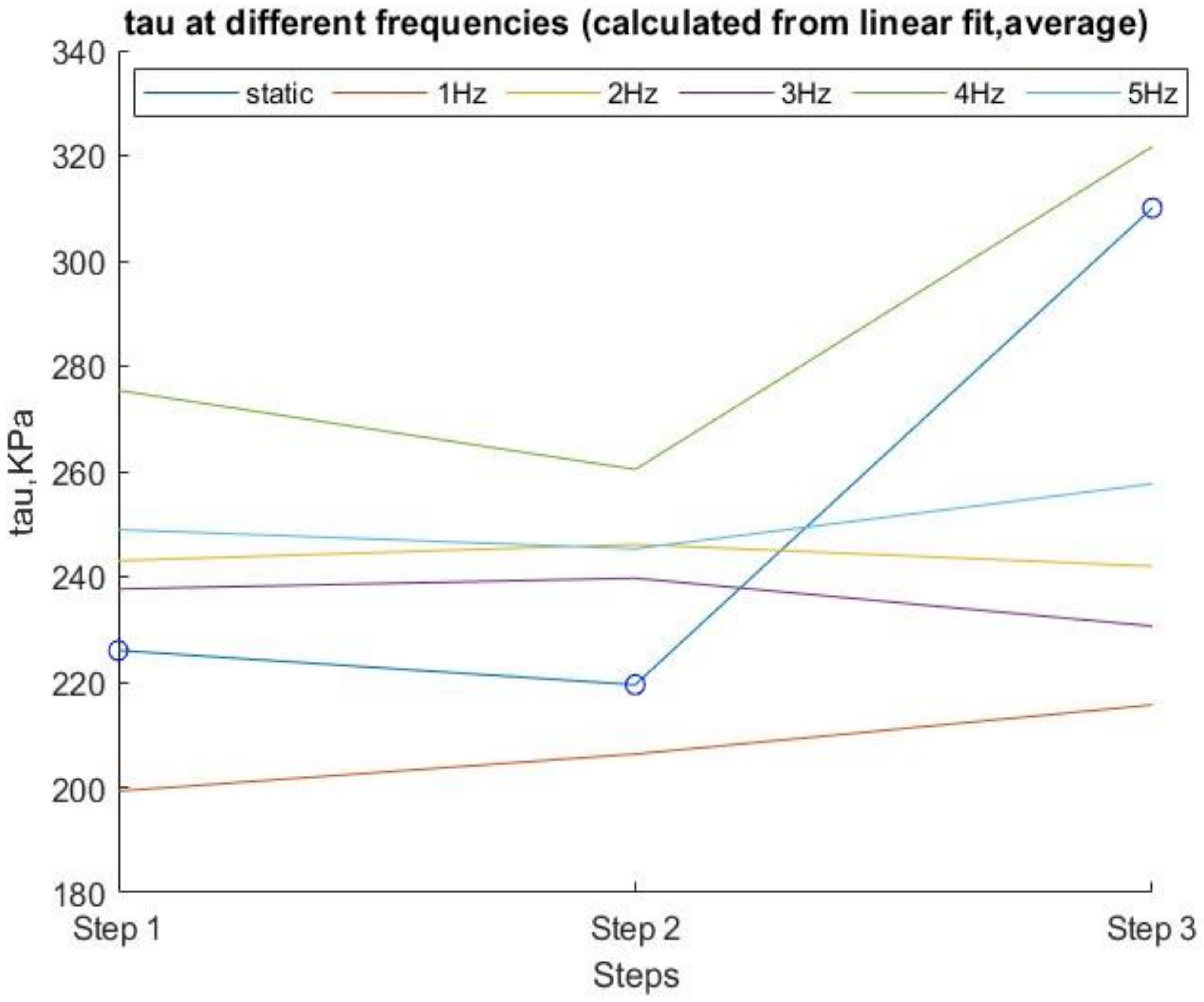
- Tau(τ) is computed from **the linear fit** of strains at relative step and relative frequency, according to:

$$\tau = \frac{EA}{D\pi}\frac{d\varepsilon}{dx}$$

Where $\frac{d\varepsilon}{dx}$ is the slope of the linear fit.

$\frac{d\varepsilon}{dx}$





Average Strains

Increasing the Friction at interface: How?

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$$F \sim \sigma \tan(\varphi) \frac{\pi d^2}{4}$$

The following equation allows us to see the factors influencing the friction force (F) occurring at the interface:

Increasing Friction at the interface

- Increasing the dimension of the inclusion
- Increasing the restricted dilatancy through increasing the interface's roughness
- increasing the confinement

Increasing the Interface roughness:

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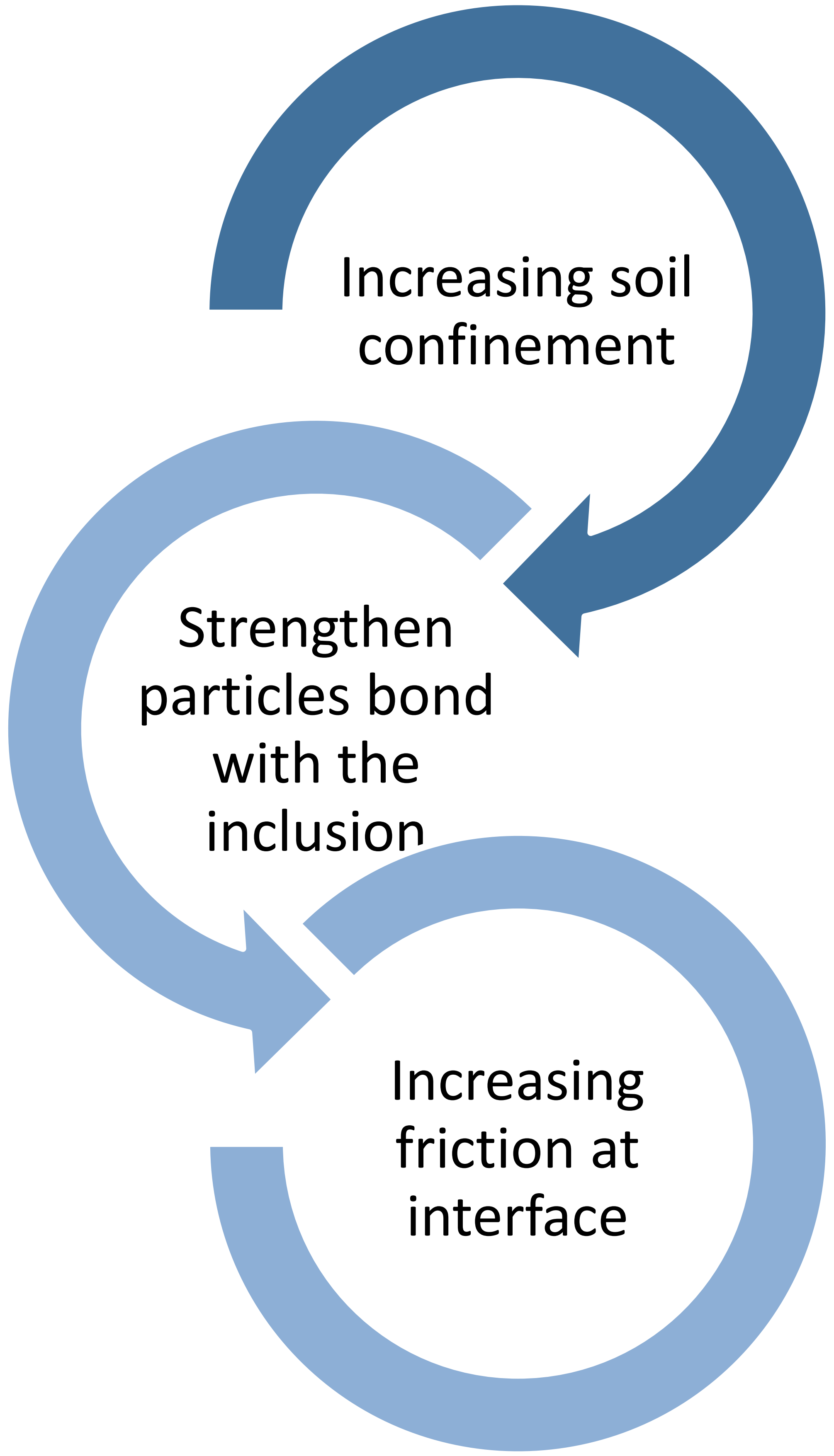
Grouting of the nail:

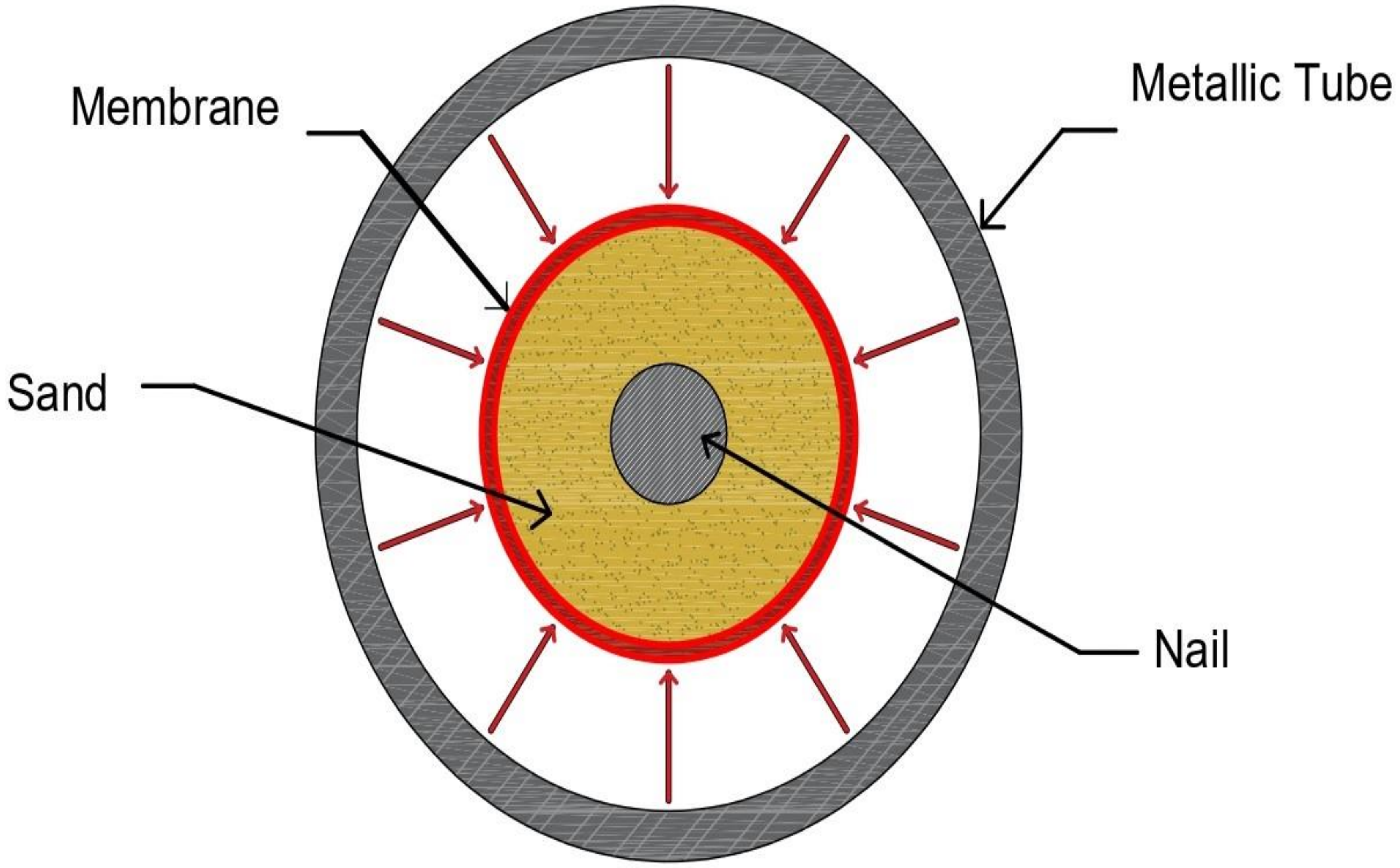
Sticking Sand particles to grout done in PVC (aid of glue).

- W/C=0,45

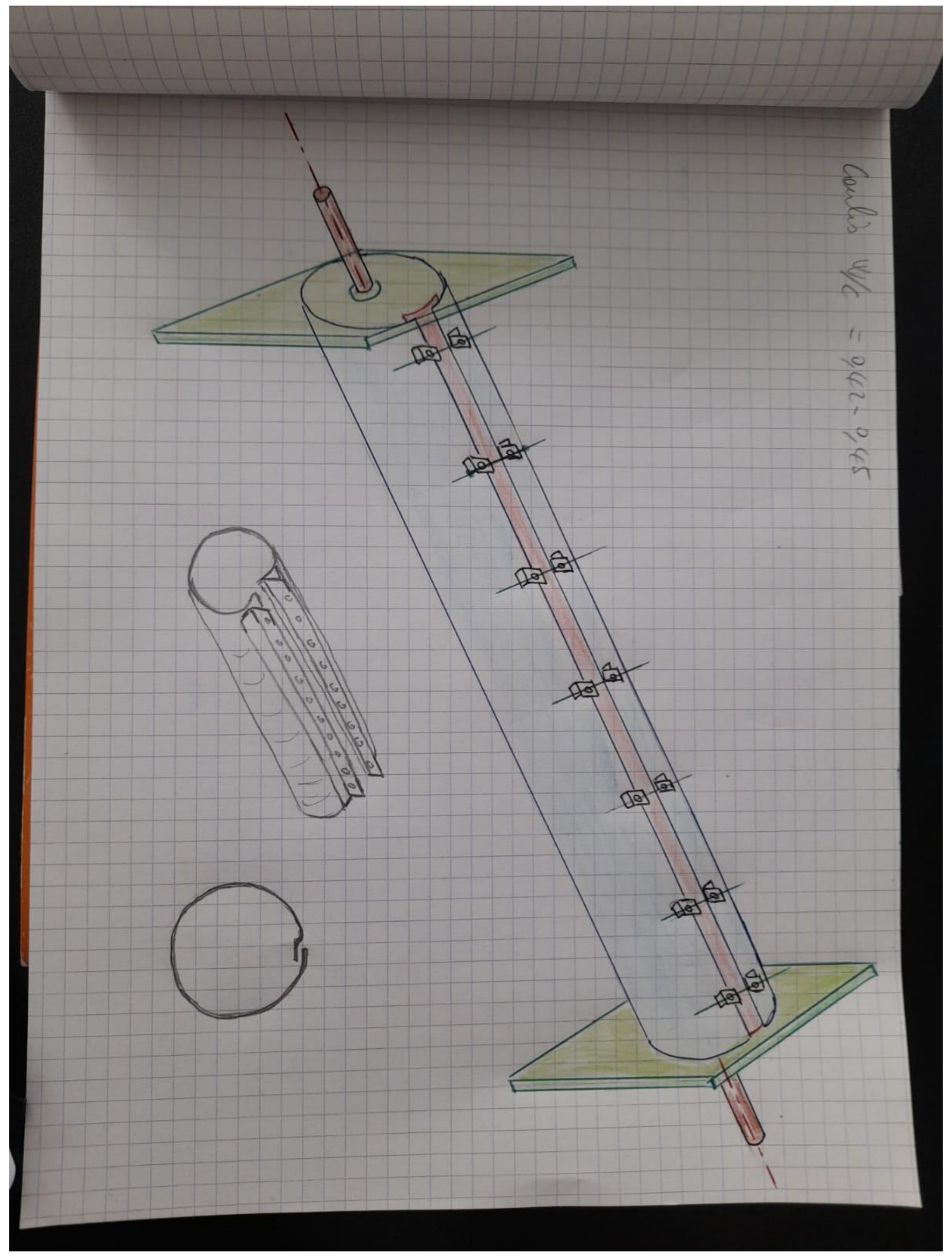
Increasing the Soil confinement:



Pressure application by fluid flow through an elastic membrane.



Adjustable compressible tube



Thank you for your attention

Ghida Hawwa: www.linkedin.com/in/ghida-hawwa-598634224

ghida.hawwa2@univ-eiffel.fr

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Measured Strains: at different frequencies

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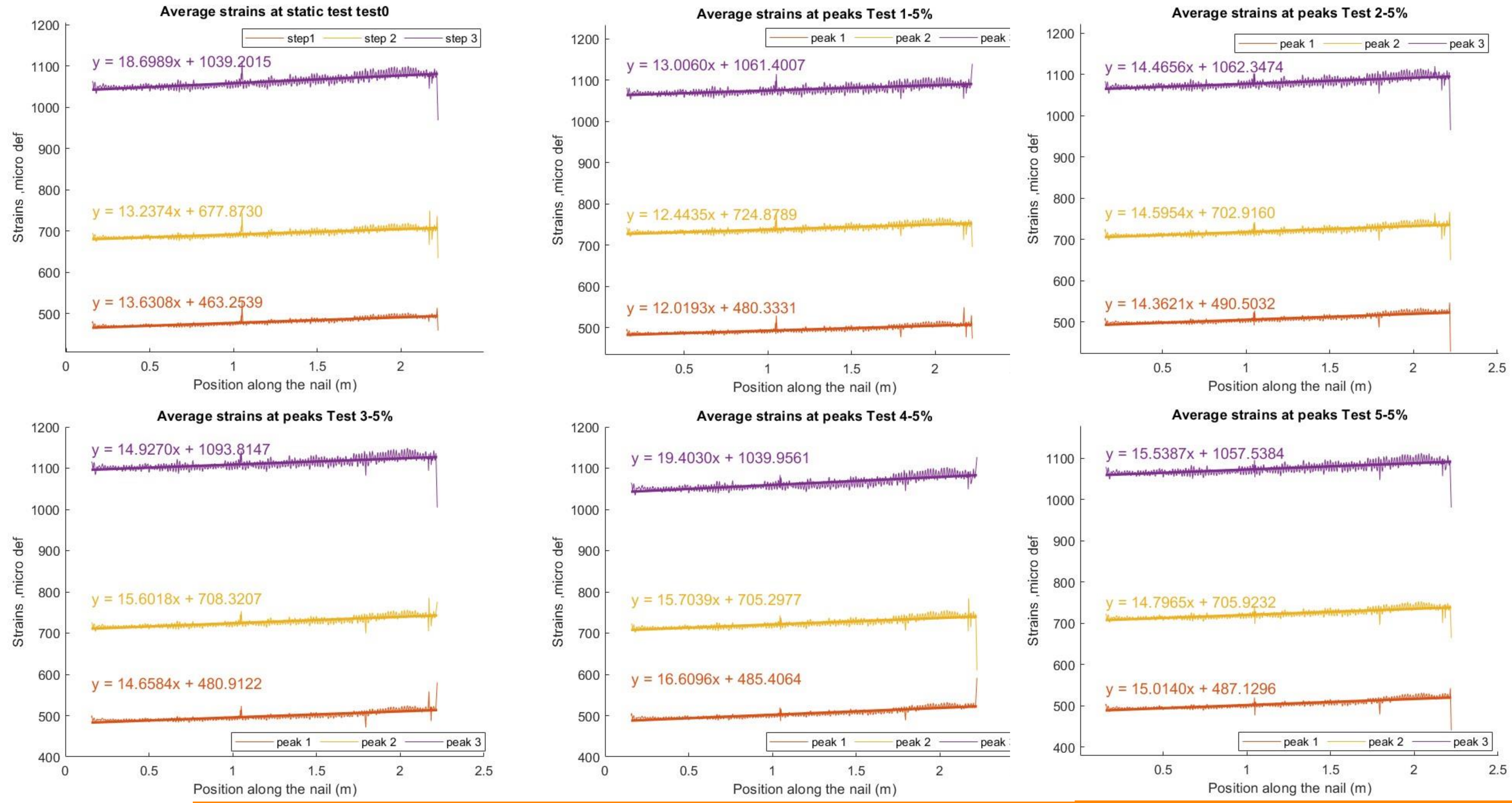

Friction model proposed by FRANK and ZHAO:

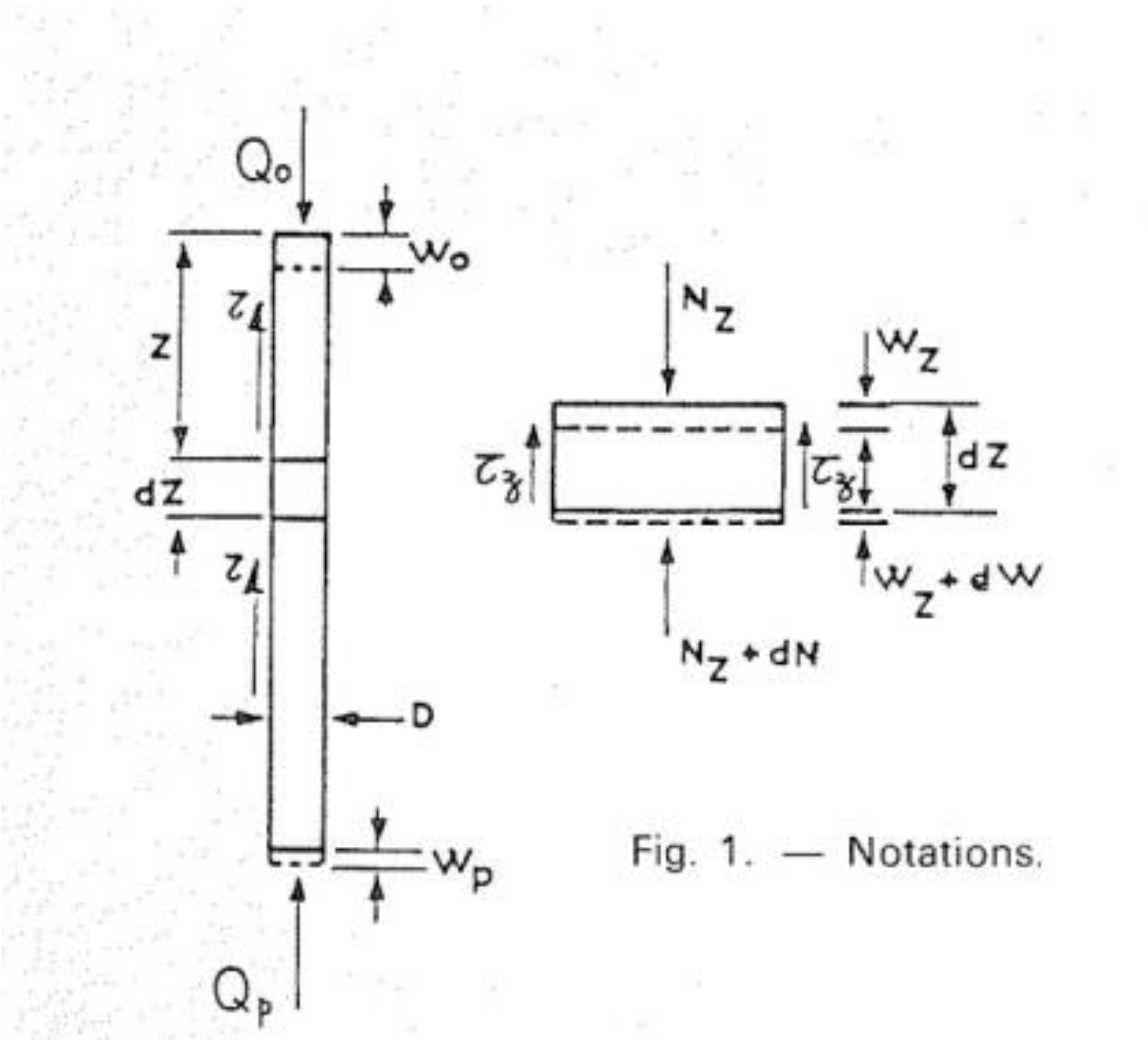

Fig. 1. — Notations.