# Numerical analysis of a reinforced backfill under dynamic loading

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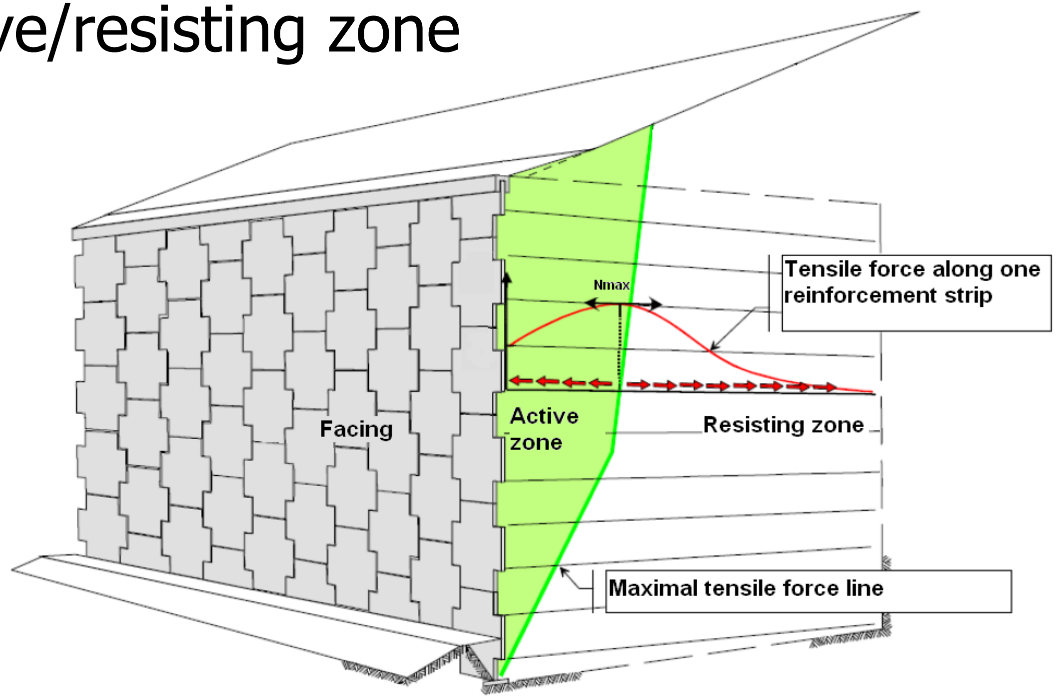
# Outline

- Introduction of the topic
- Presentation of a full-scale experimentation (2008)
- Numerical model using 3D-FEM
- Focus on apparent friction coefficients
- Perspectives

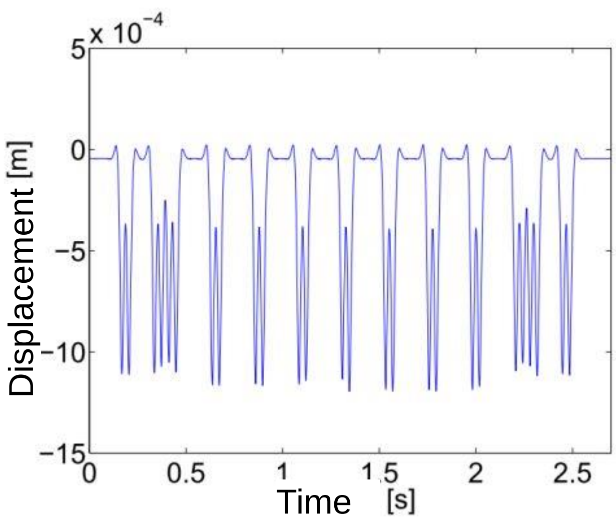
# Introduction

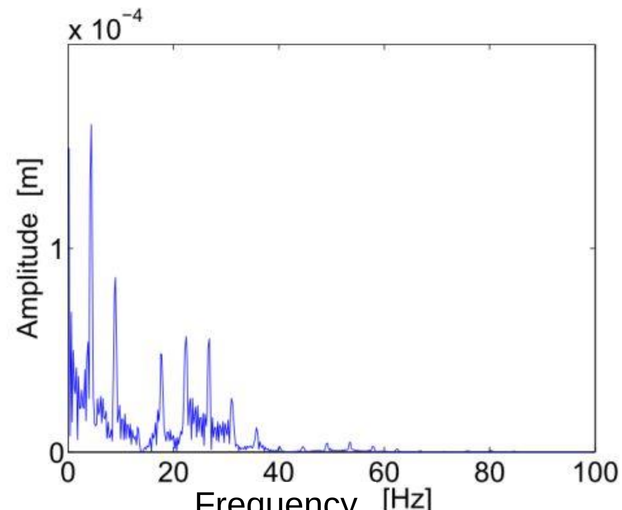
- Mechanically Stabilized Earth walls :
  - Stability ensured by friction between steel reinforcement and backfill
  - Active/resisting zone



# Introduction

- High speed train: dynamic loading
- Time scales:
  - Time of **passing of a single HST**
- Space scales:
  - **Local** : interface behavior
  - **Global** : modes of vibration of the whole embankment

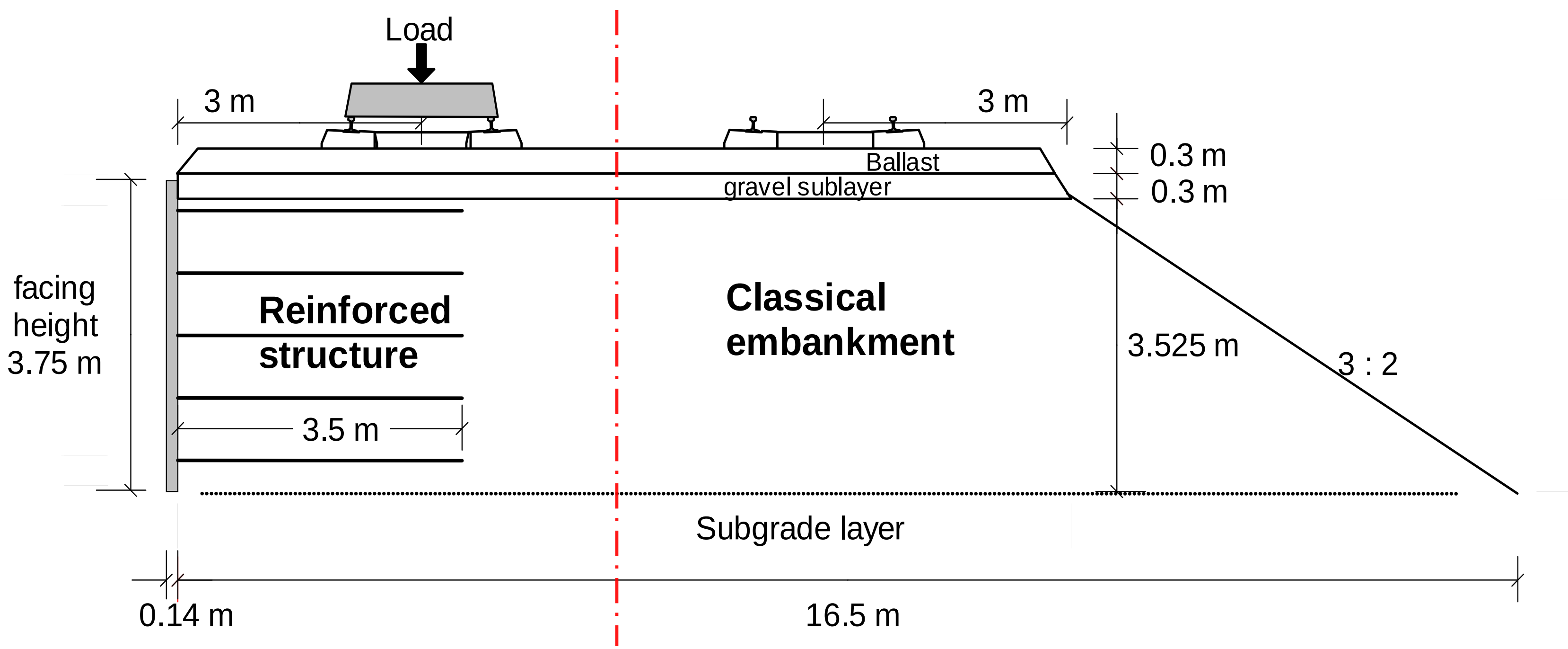



*Rail deflection for a HST at 300km/h*

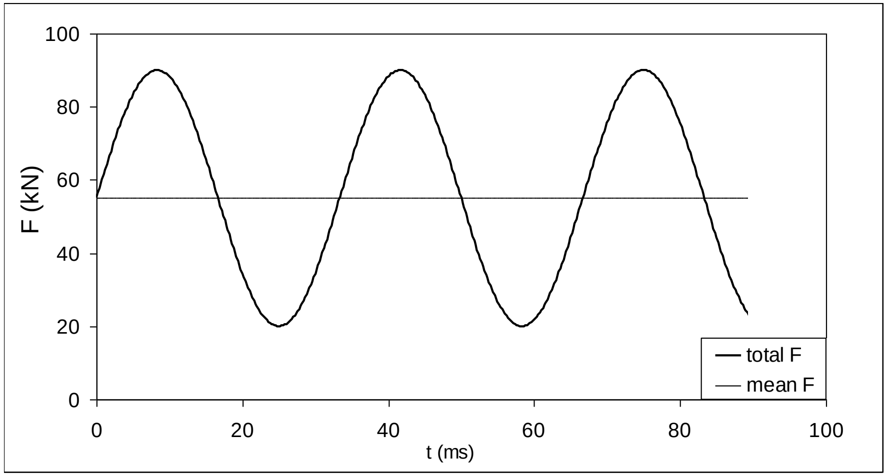
# Presentation of a full-scale experimentation (2008)

- Instrumented one-scale embankment (CER, IFSTTAR, SNCF)
- Some experimental results already published

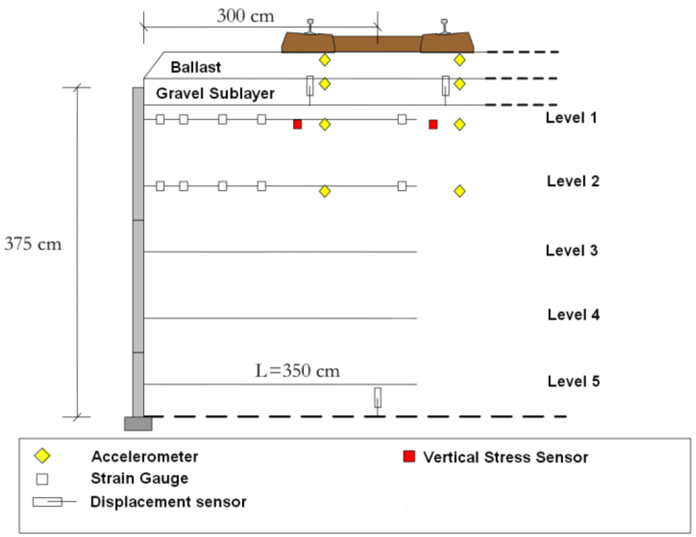


# Presentation of a full-scale experimentation (2008)

- Dynamic loads
  - A static part
  - A dynamically varying overloading
  - In harmonic steady state

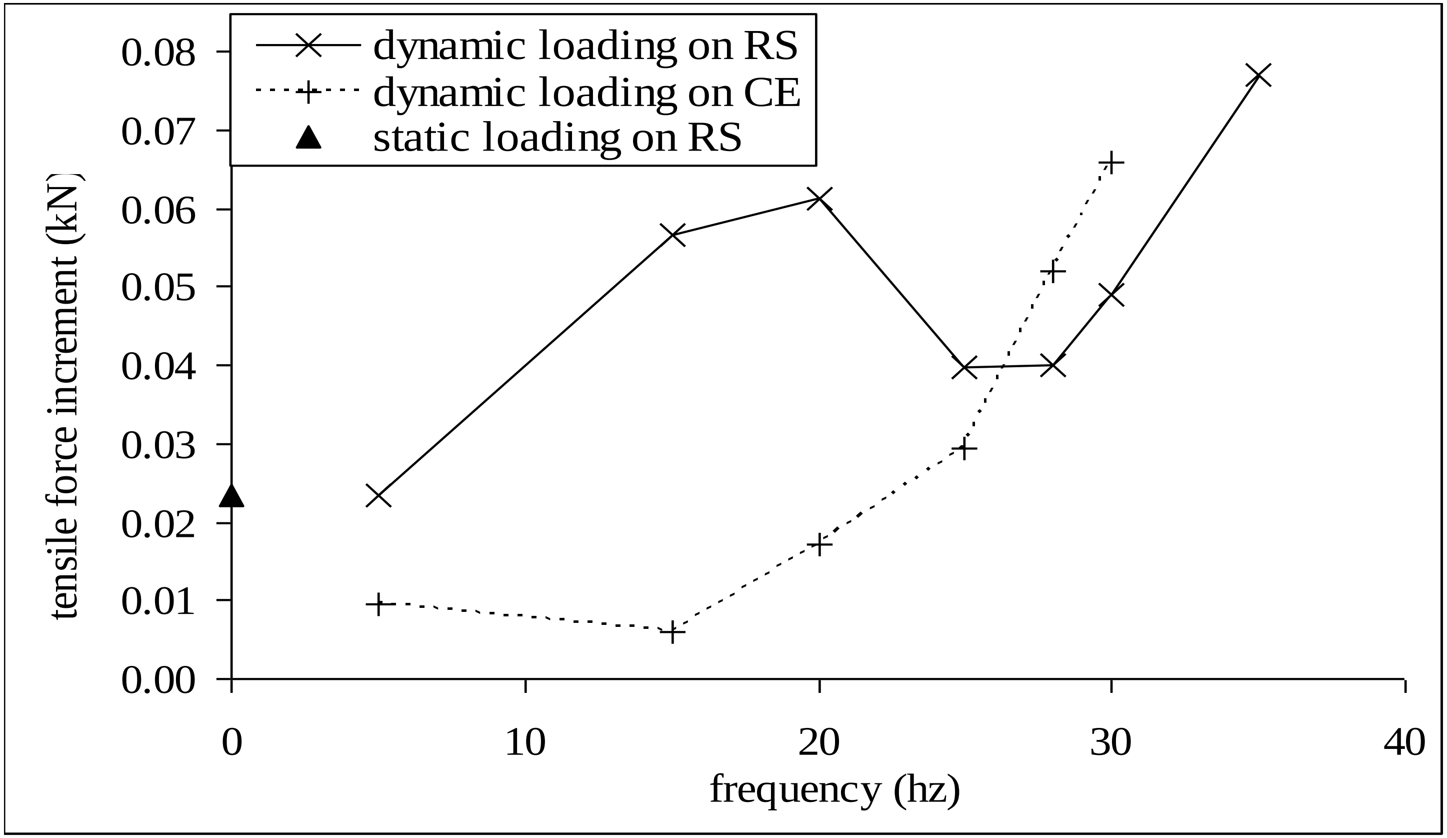



- Several sensors:
  - Accelerometers
  - Stresses sensors
  - Strain gauges glued on the reinforcements => tensile force
  - Displacements H and V



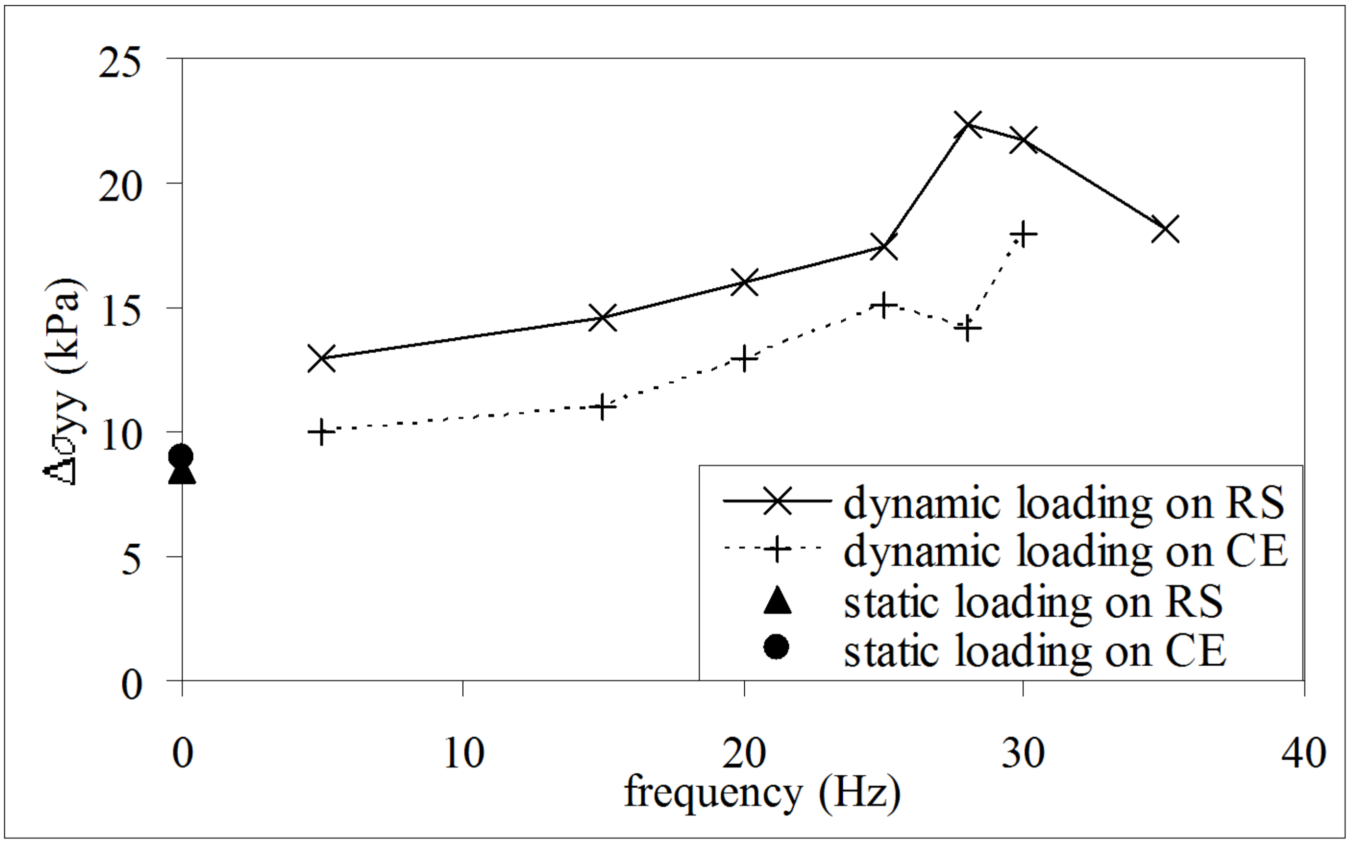
# Variation with frequency

- Mean incremental Tensile Force in the first 1.5m of a 1st layer strip.



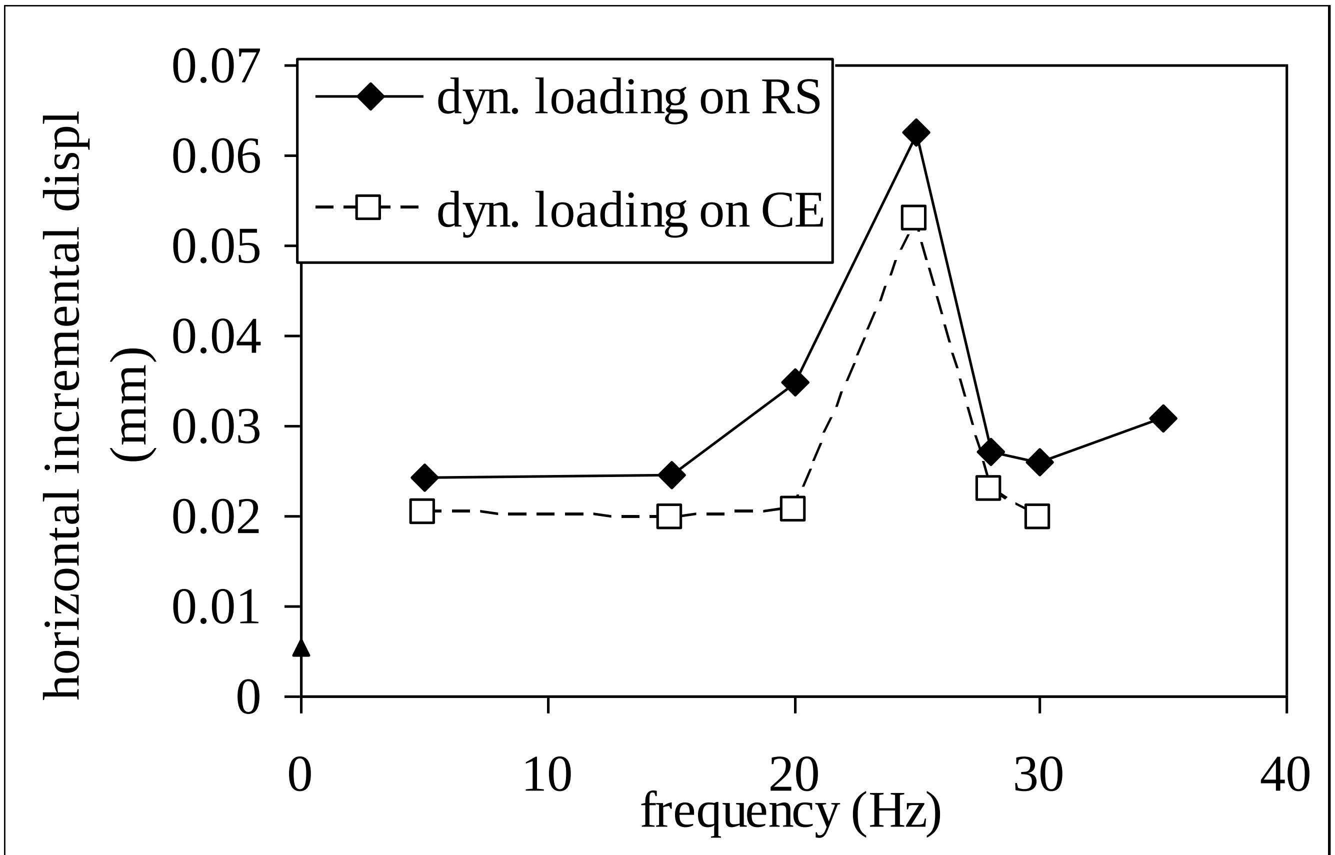
# Variation with frequency

- Spectrum of vertical stress increment at sublayer/backfill interface and right below the sleeper



# Variation with frequency

- Mean horizontal facing displacement of the top 2.6 m



# Experimental conclusions

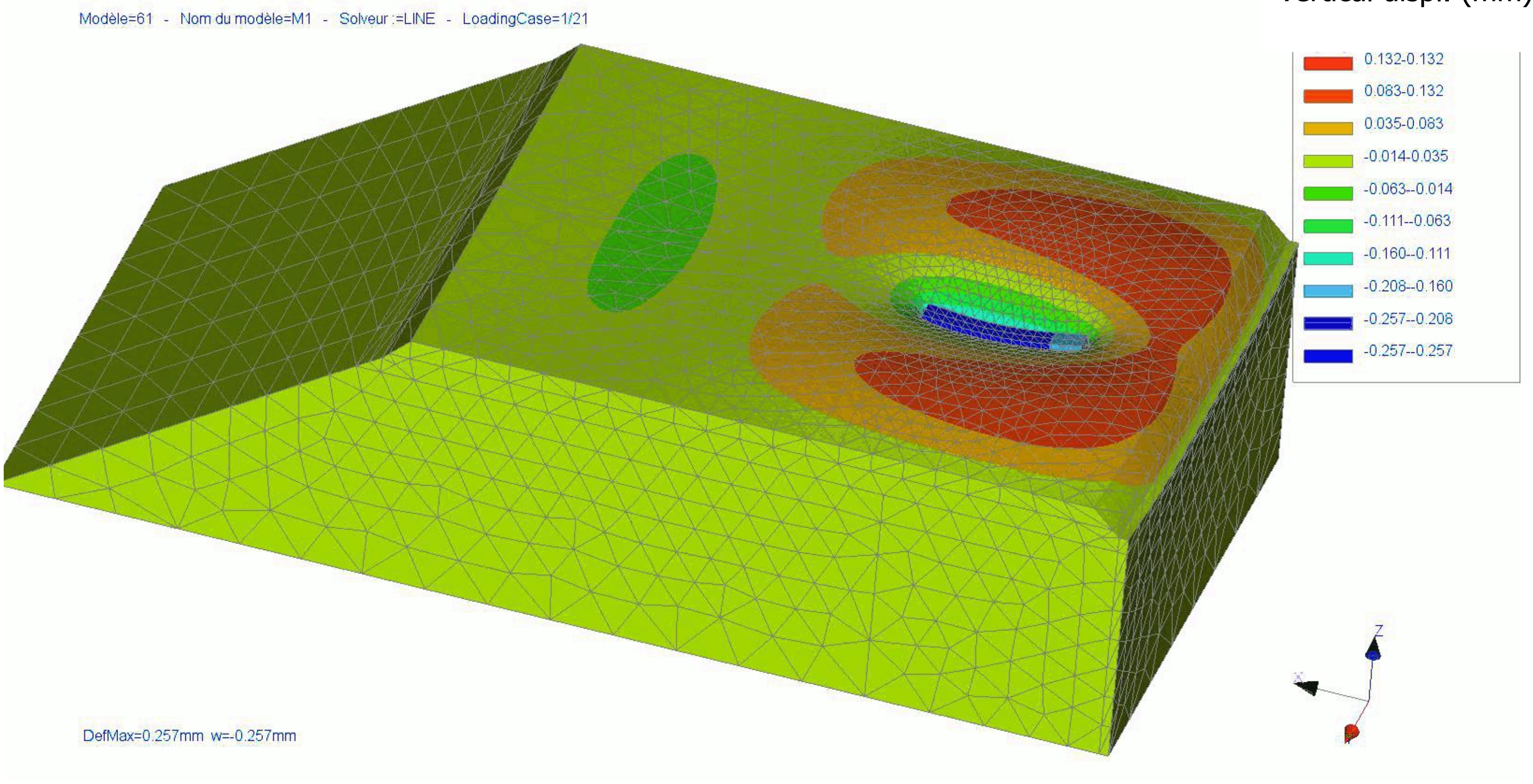
- Dynamic loading is sensible for the first two layers of reinforcements
- At this depth:
  - Tensile forces and displacements are strongly frequency-dependent but have small amplitude
  - Increments of vertical stress are less frequency-dependent but have an important amplitude

# 3D-FEM model

- CESAR-LCPC software
- Only **dynamic over-loading modeled** using **visco-elastic** constitutive law.
- Facing model: transversal isotropic
- Young's modulus varying with depth (to take into account actual earth pressure)
- Discrete reinforcements with interface stiffness consideration

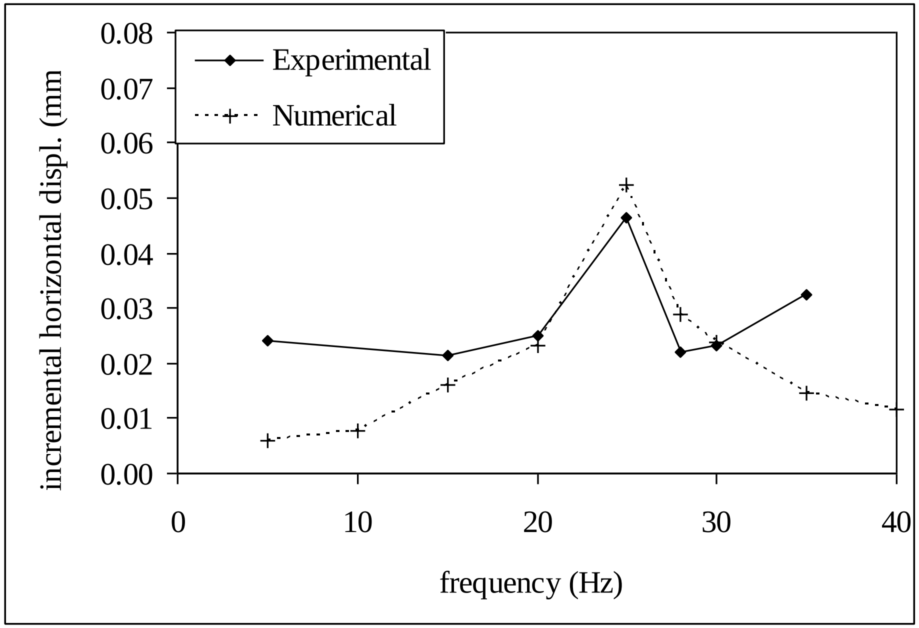
# Numerical Model

Vertical displ. (mm)

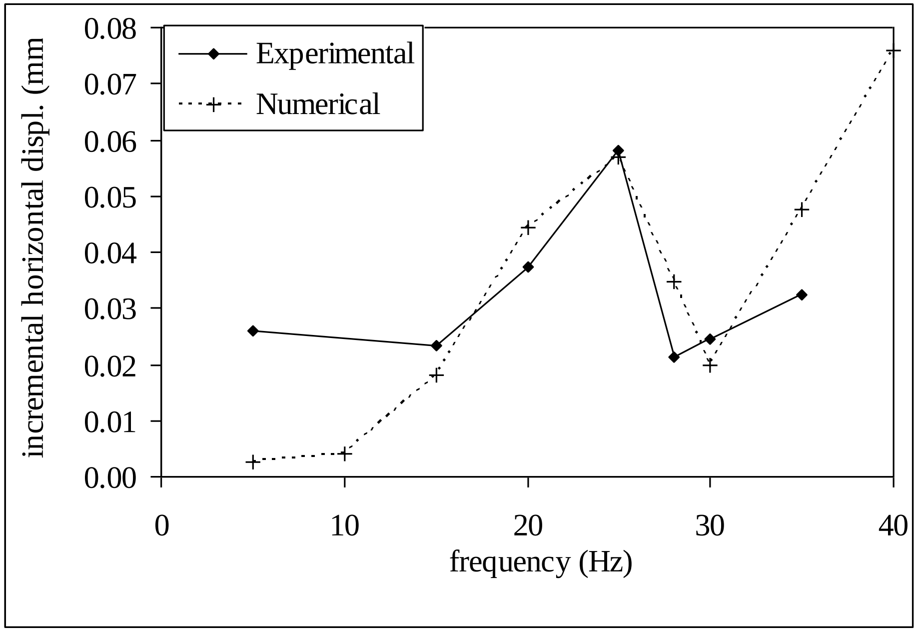


# Results: facing horizontal displacements

- -2.6 m from top

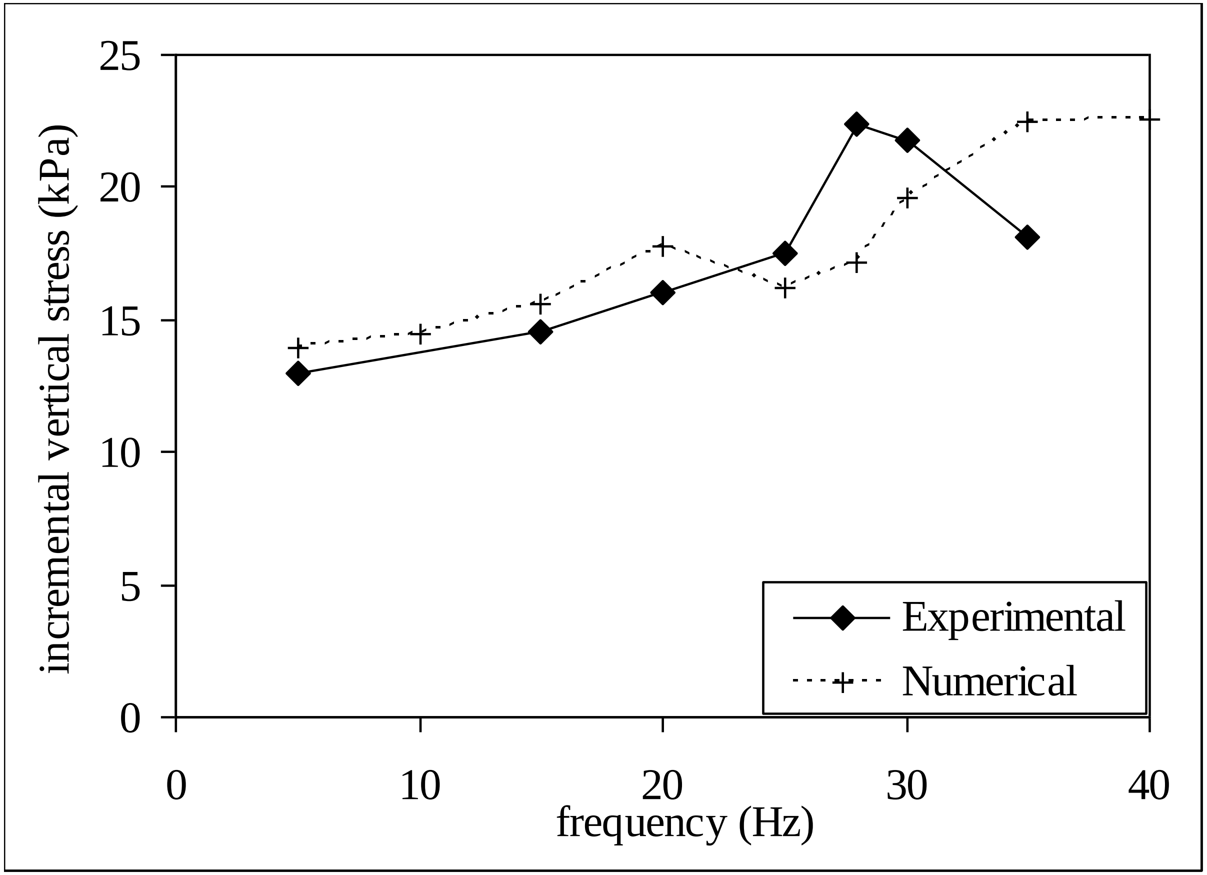



- -35 cm from top



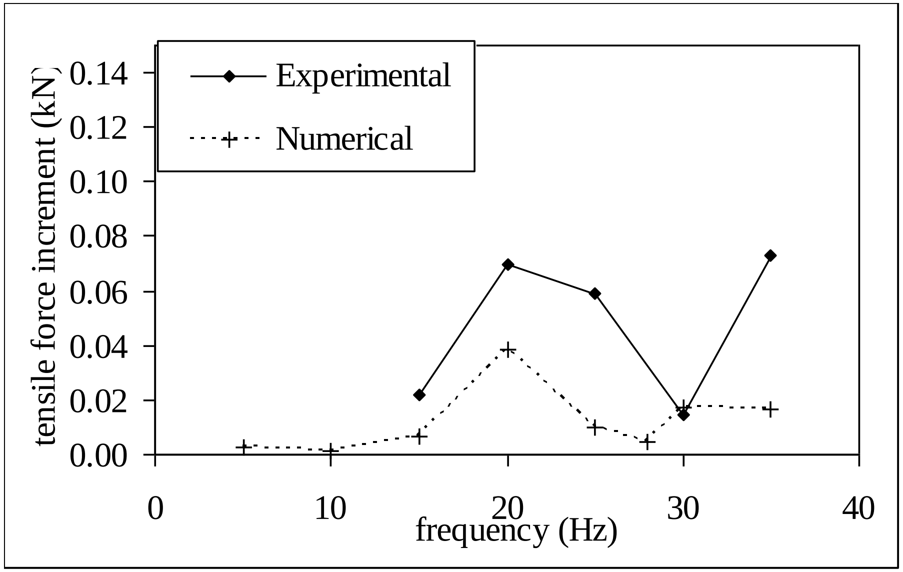
# Results : vertical stresses

- Incremental vertical stress at the backfill/sublayer interface

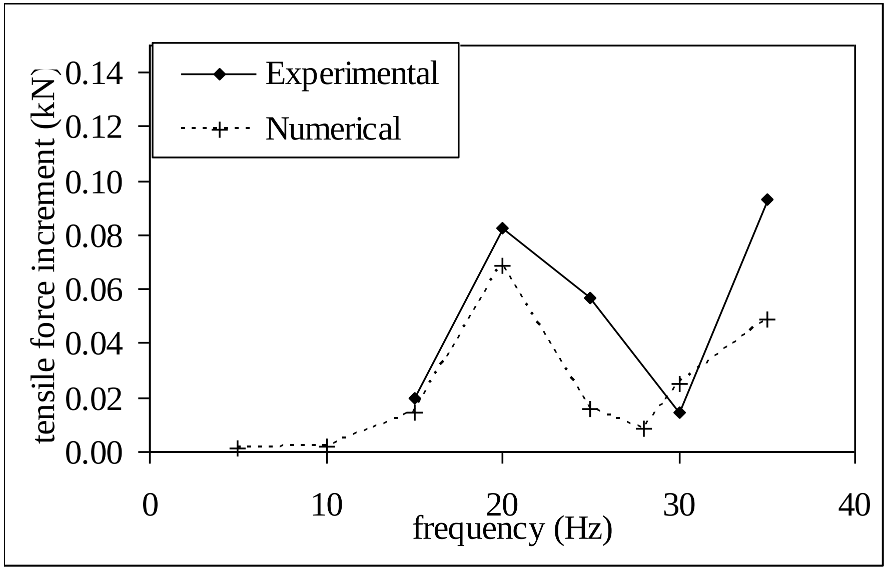


# Results: tensile forces

- Top layer reinforcement, at 10 cm from facing

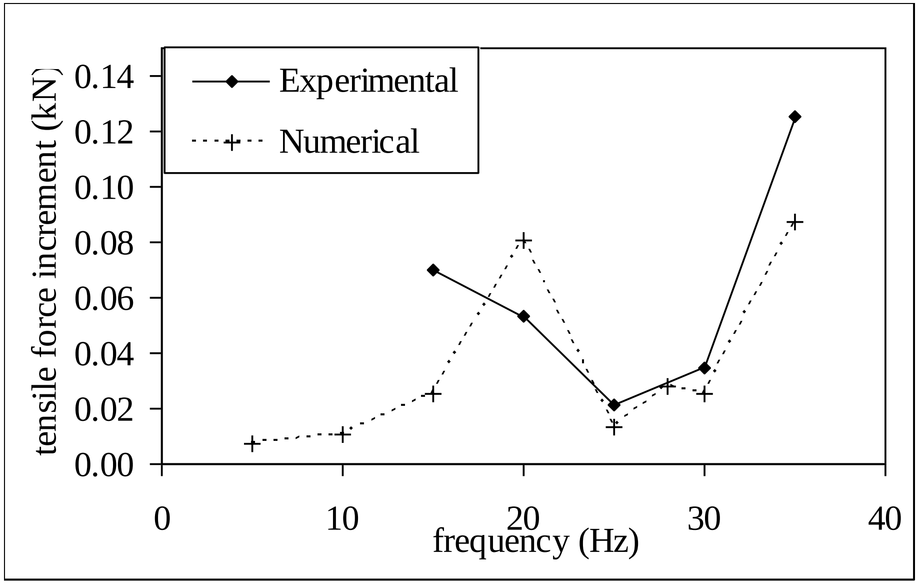



- Top layer reinforcement, at 30 cm from facing

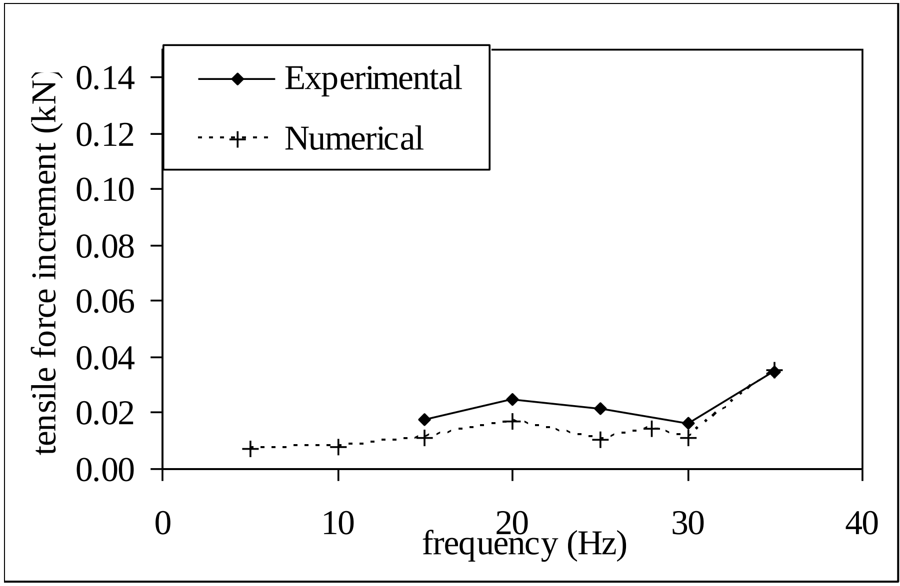


# Results: tensile forces

- Top layer reinforcement, at 1.4 m from facing




- Top layer reinforcement, at 3.35 m from facing



# Conclusion on the numerical model

- Numerical model validated
- Will be used to investigate dynamic behavior more accurately.

# Apparent coefficient of friction

- Focus on local reinforcement-ground interface behavior
- Tensile force in a point x of the reinforcement: $dN = 2.b.\tau(x,t).dx$
- From a static point of view, one often defines a friction coefficient μ, so that:

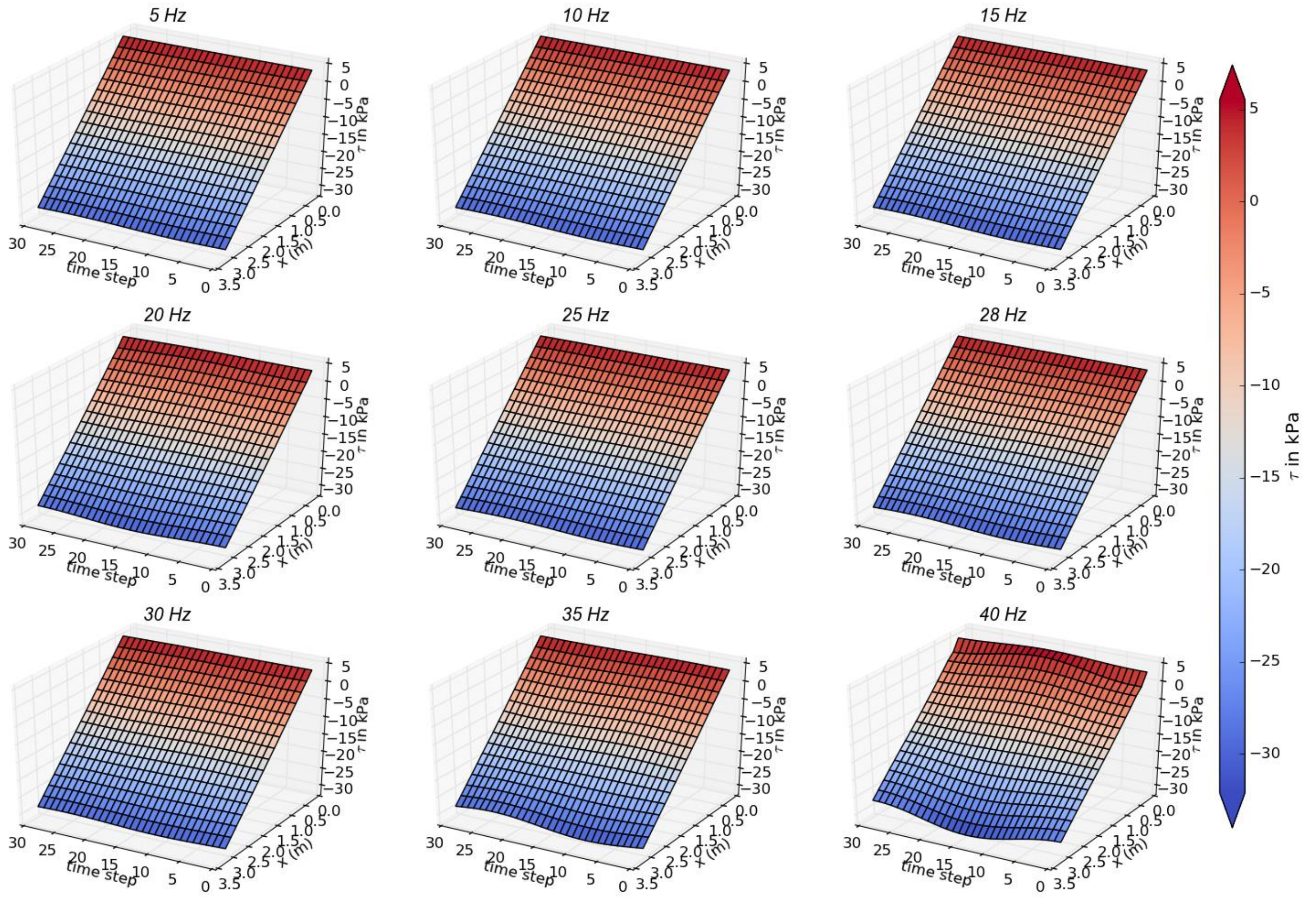
$$\tau(x) = \mu.\sigma_v(x)$$

# Apparent coefficient of friction

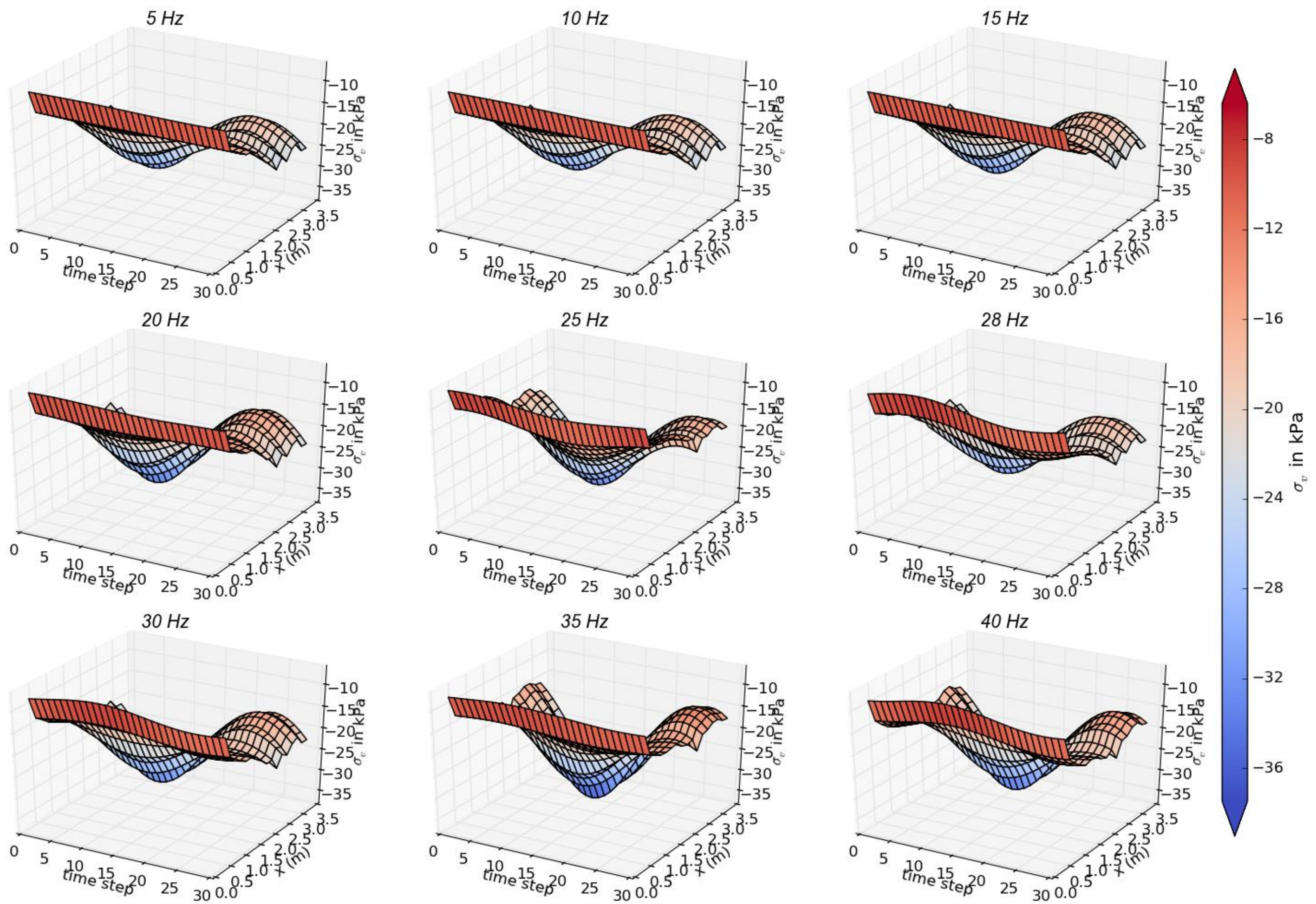
- μ is often used in design to estimate the maximal value of the mean friction coefficient along a reinforcement strip, at failure (pull-out tests)
- μ takes into account the effect on restrained dilatancy on low confining pressure
- $\mu < \mu^*$ with $\mu^*$ given by the norm

- **In dynamic loading??**
- $\mu_{dynamic\_loading}$ defined by total shear stress and total vertical stress acting along the strip

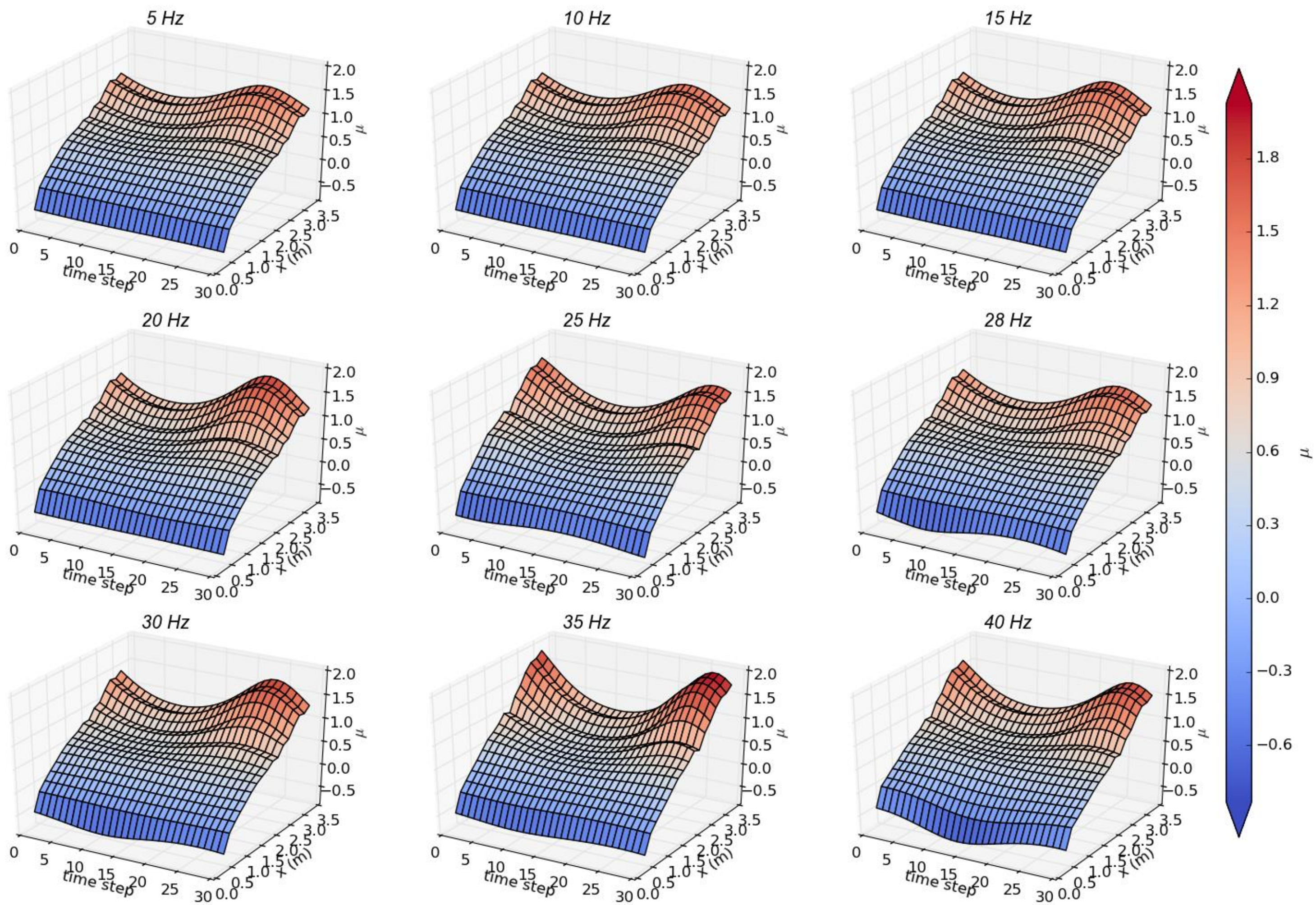
# Total shear stress along a first layer reinforcement (1/2b dN/dx)



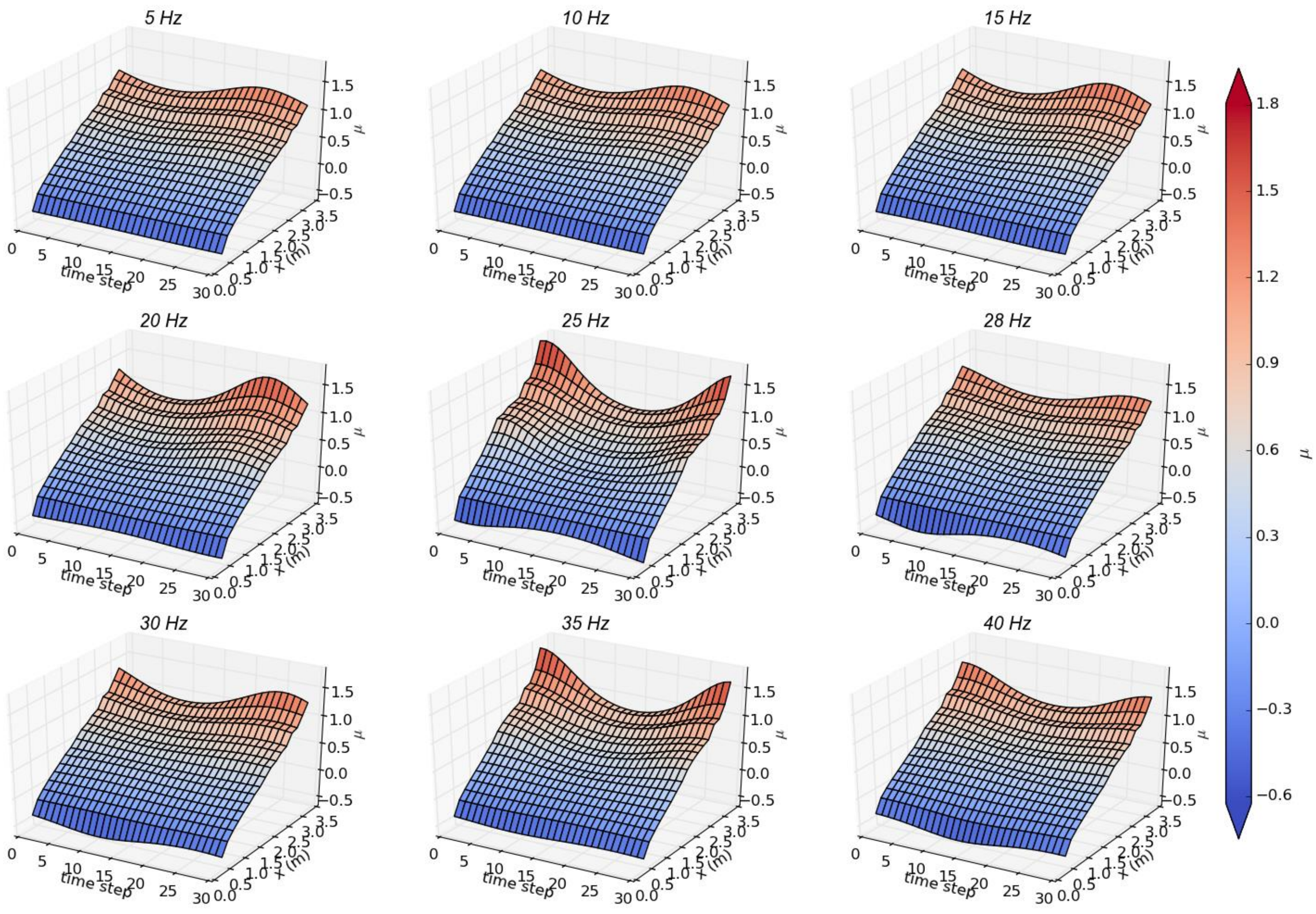
# Total vertical stress along a first layer reinforcement



# Apparent coefficient of friction along a 1st layer reinforcement

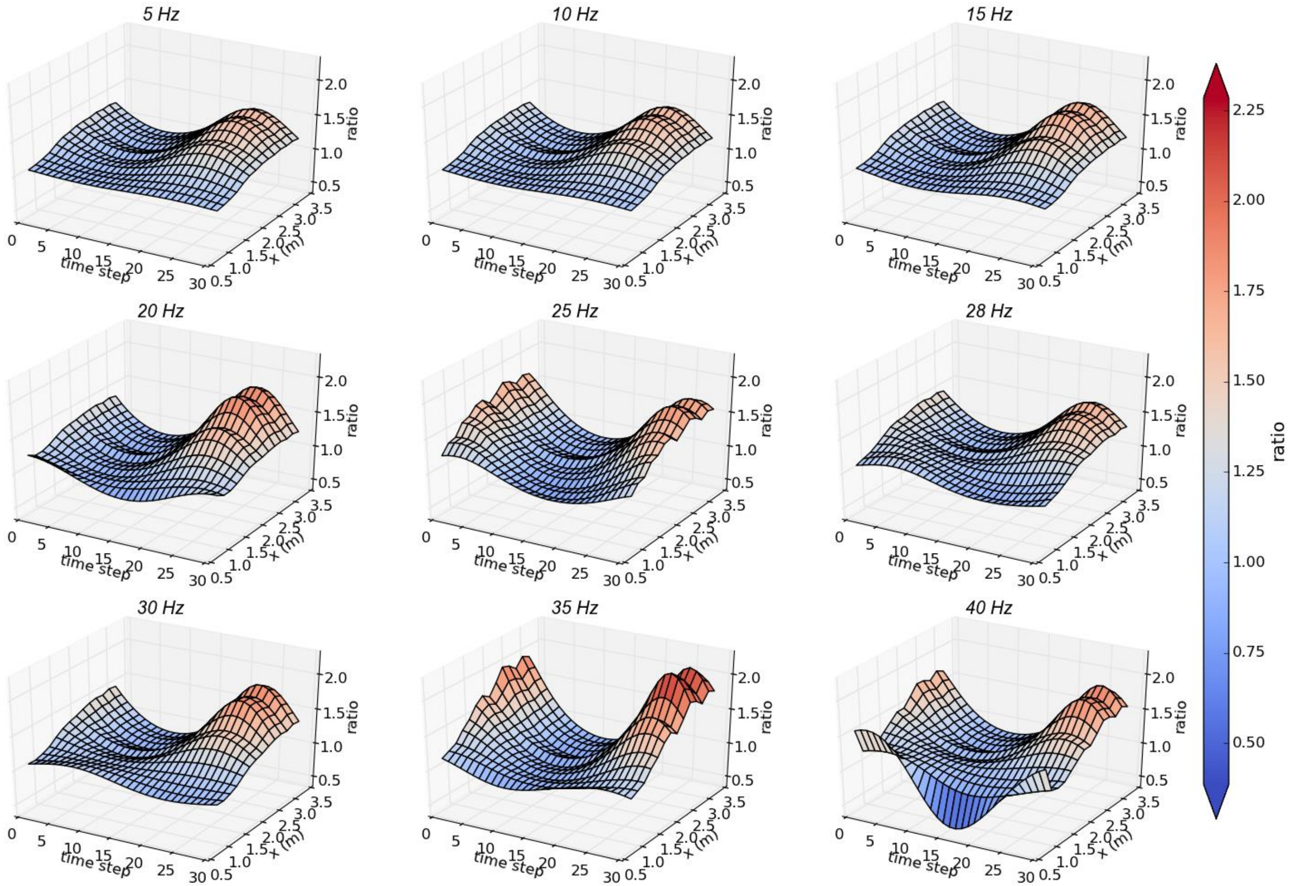


# Apparent coefficient of friction along a 2nd layer reinforcement



# Comparison with a static load with same amplitude

- Plot the ratio $\mu_{dynamic\_loading}/\mu_{static}$



# Apparent friction coefficient

- Conclusions
  - Behavior of the interface different than in static case
  - $\mu_{dynamic}$ variations depends on $\sigma_{v,incremental}$
  - $\mu_{dynamic}$ can reach values up to 2.2 times greater than in static case (for 35 Hz), but not in each point of the strip nor at each time of a period.
  - Dynamic behavior not critical for a design point of view, for a time scale corresponding to a single HST passing.

# Perspectives

- Computations:
  - Actual HST loading
  - Real structure
  - Long term studies (interface fatigue)

- Numerical developments:
  - Development of a interface-fatigue constitutive model

# Thank you for your attention!