Numerical analysis of a reinforced backfill under dynamic loading

Jean-Baptiste PAYEUR 3rd year PhD student
Alain CORFDIR (laboratoire Navier, Cermes)
Emmanuel BOURGEOIS (IFSTTAR)
Outline

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

![Graph showing rail deflection for a HST at 300km/h](image)
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.

![Graph showing variation with frequency]

- Dynamic loading on RS
- Dynamic loading on CE
- Static loading on RS
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)

DefMax=0.257mm  w=-0.257mm
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: \( dN = 2b\tau(x,t).dx \)
- From a static point of view, one often defines a friction coefficient \( \mu \), so that:
  \[ \tau(x) = \mu.\sigma_v(x) \]
Apparent coefficient of friction

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

- **In dynamic loading??**
  - $\mu_{\text{dynamic\_loading}}$ 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 $\mu_{\text{dynamic\_loading}}/\mu_{\text{static}}$
Apparent friction coefficient

Conclusions

- Behavior of the interface different than in static case
- $\mu_{\text{dynamic}}$ variations depends on $\sigma_{v,\text{incremental}}$
- $\mu_{\text{dynamic}}$ 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!