A FUNDAMENTAL APPROACH TO TRANSITION ZONES ANALYSIS: FROM SHORT- TO LONG-TERM

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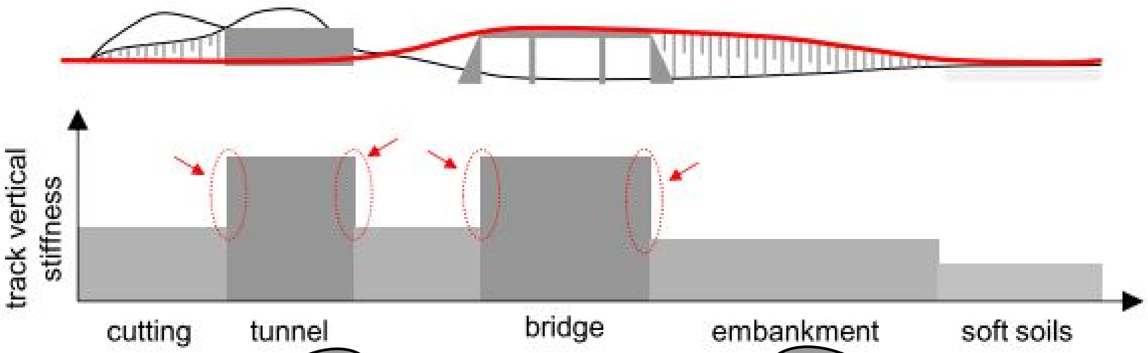
1. TRANSITION ZONES: DEFINITION

LOCATIONS WITH ABRUPT CHANGES IN:

TRACK SUPPORT: STIFFNESS/DAMPING

BRIDGES

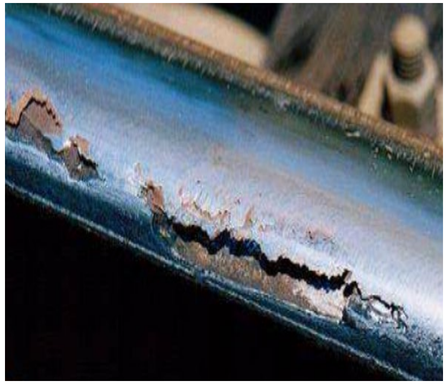


TRACK GEOMETRY:

SWITCHES & CROSSINGS

SUPERSTRUCTURE PROBLEMS

CRACKED SLEEPERS



RAIL DEFECTS

HIGHER MAINTENANCE COSTS

U.K. : 44% of the total track maintenance and renewal budget, but represent just 4% of the length [5]

SUBTRUCTURE PROBLEMS

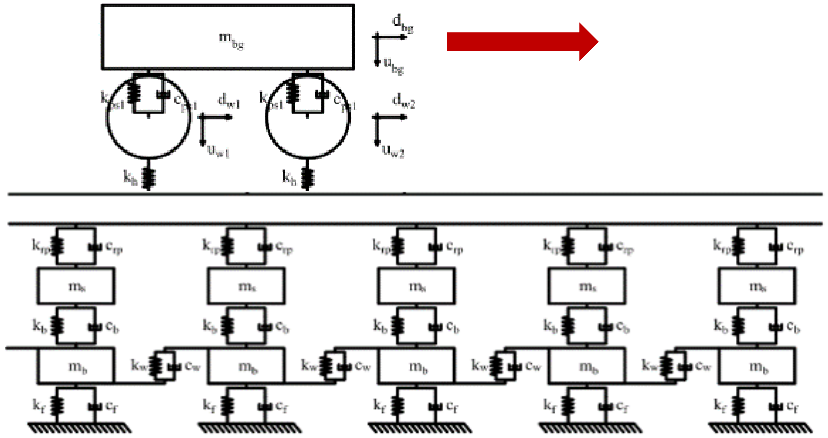
DIFFERENTIAL SETTLEMENT

BALLAST DEGRADATION

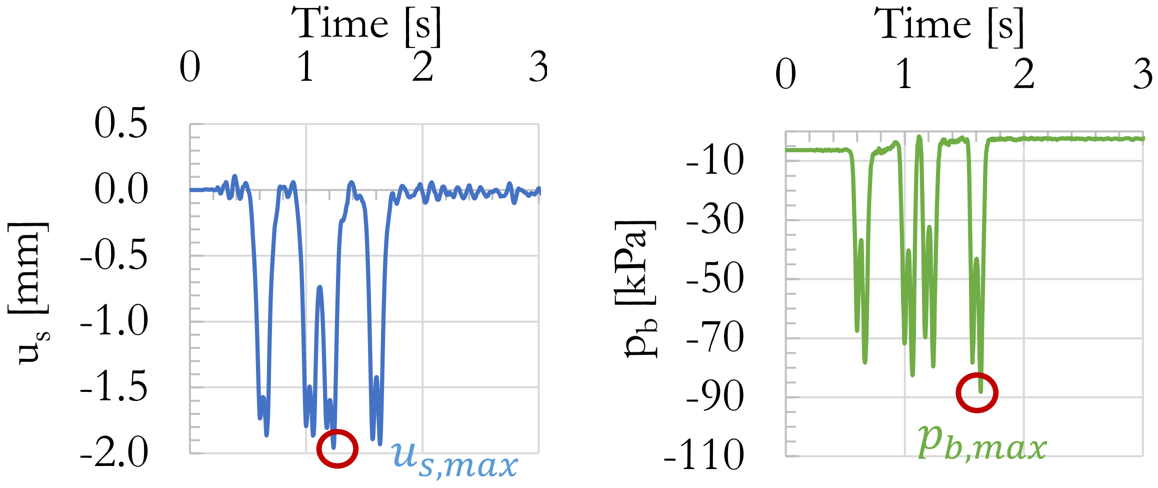
1. TRANSITION ZONES: LONG-TERM SIMULATIONS

UNDERSTAND DEGRADATION MECHANISMS ← **NUMERICAL MODELS** → **OPTIMISE (DESIGN AND MAINTEINANCE)**

1. VEHICLE-DYNAMIC SIMULATION



2. ANALYSIS OF DATA



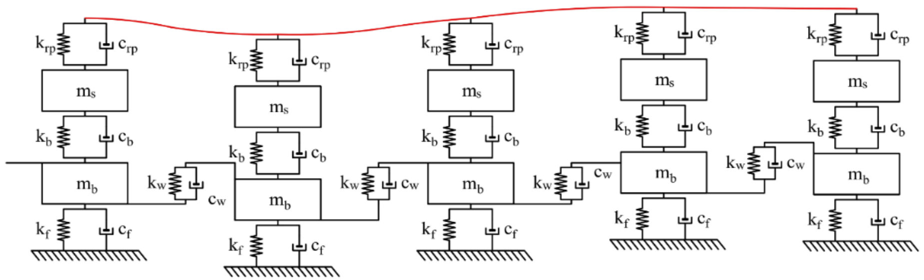
3. BALLAST SETTLEMENT CALCULATION

Typical approaches relate parameters such as **deflection** or **average stress** to settlement increment

$\Delta S_N = f\ (u_{s,max})$

$\Delta S_N = f\ (p_{b,max})$

4. UPDATE TRACK GEOMETRY



2. KNOWLEDGE GAPS, CHALLENGES AND AIM

KNOWLEDGE GAPS

- **Current** ballast **settlement models**: **pure empirical, do not account** usually the **stress and load-history dependency behaviour, no generally applicable**
- **What** is the **main cause of differential settlement**: abrupt **changes** in track **stiffness** or initial local track **geometry defects**?
- An **optimal solution** has **not** been **found** yet

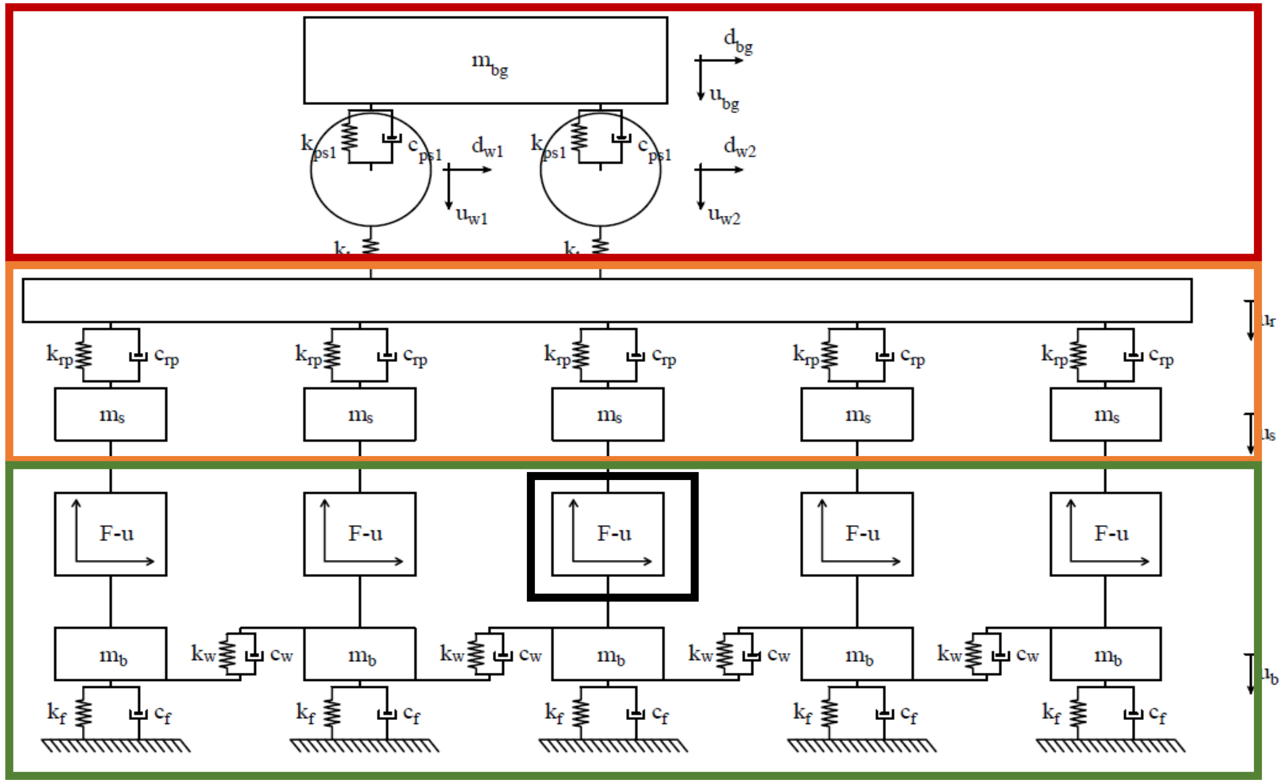
CHALLENGES

- **Lack of data:** few laboratory data and almost zero from the field
- **Long-term dynamic** analysis are **highly computational time demanding:** need a relative simple model!
- **Ballast** mechanical behaviour is **complex** and **erratic**

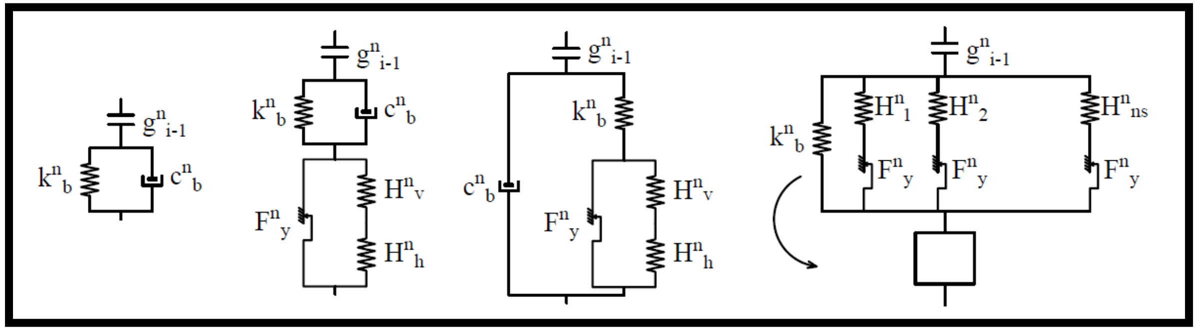
AIM: "Improve existing numerical models of transition zones and use them to understand the main degradation mechanisms and to diagnose and evaluate remediation."

3. SETTLEMENT MODEL: NEW VTI MODEL

Schematisation of the VTI model

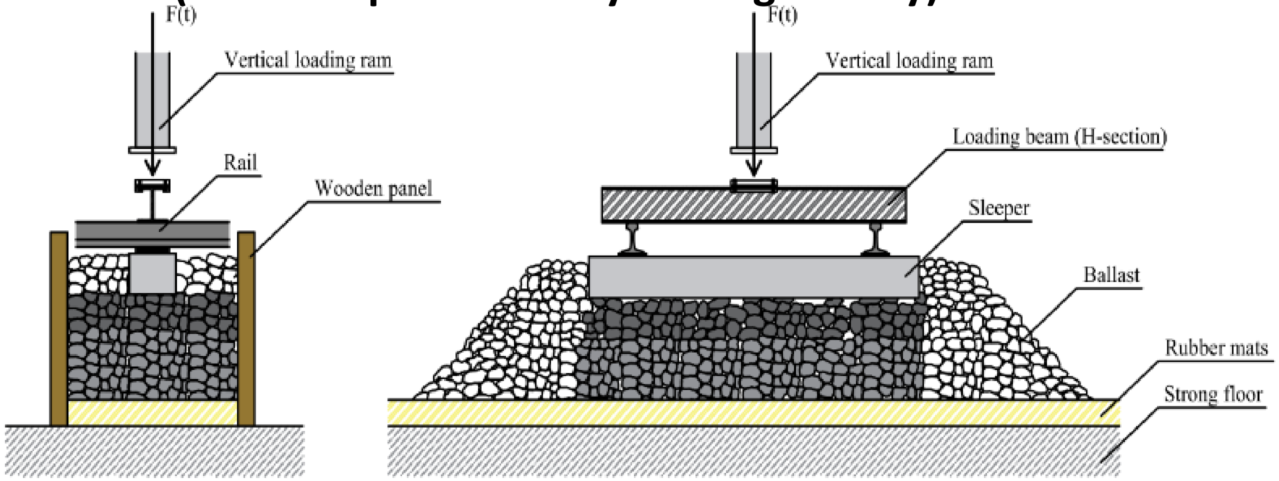


Schematisation of the ballast models



- It can idealised in **three layers**:
  - **Train**
  - **Superstructure** (rail, railpads, sleepers)
  - **Substructure** (ballast, subgrade)
- It is made of a **combination of fundamental mechanical elements**: springs, dashpots, masses
- The **ballast unit** can be seen as a **black—box** (input: deformation, output: force) which works depending on the model used. A new elasto-plastic cyclic model has been implemented and calibrated using laboratory data

SRTF (Southampton Railway Testing Facility)

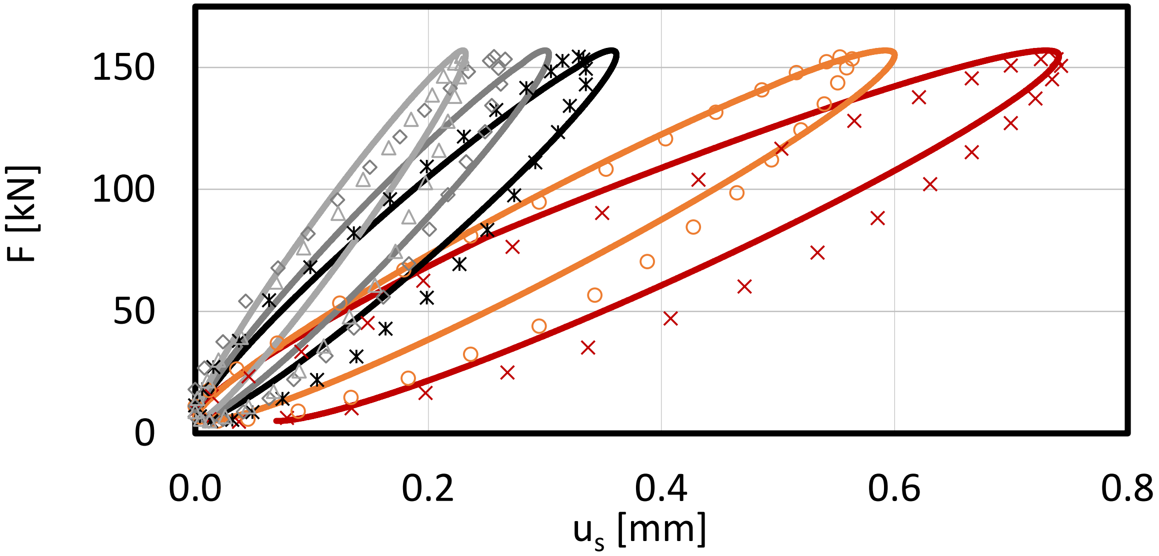


Input

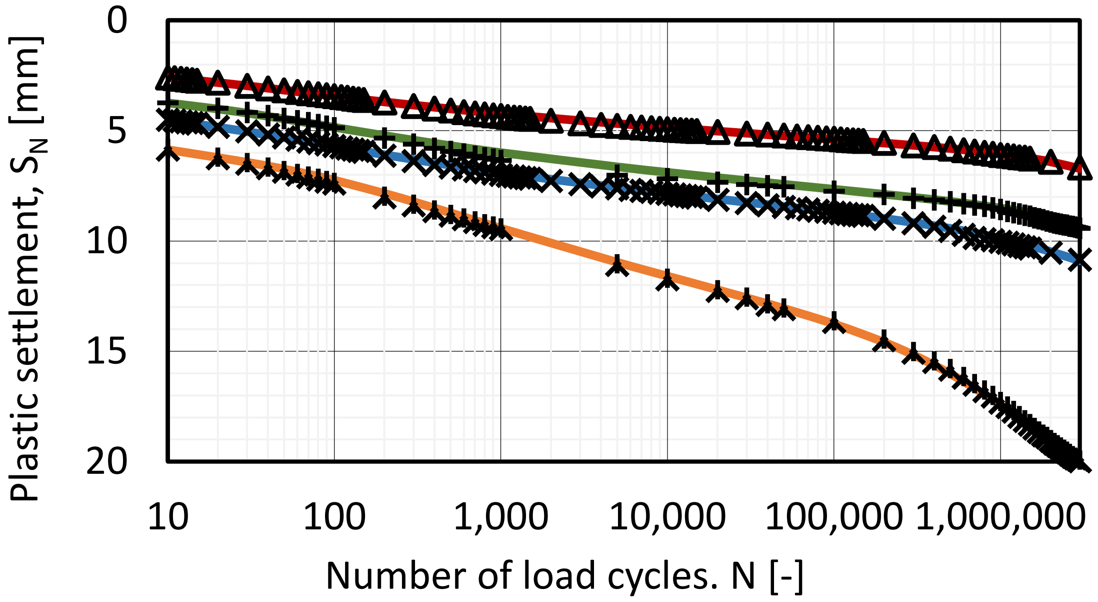
Cyclical sinusoidal force (actuator)

Output

Sleeper deflections over several points (LDVT)

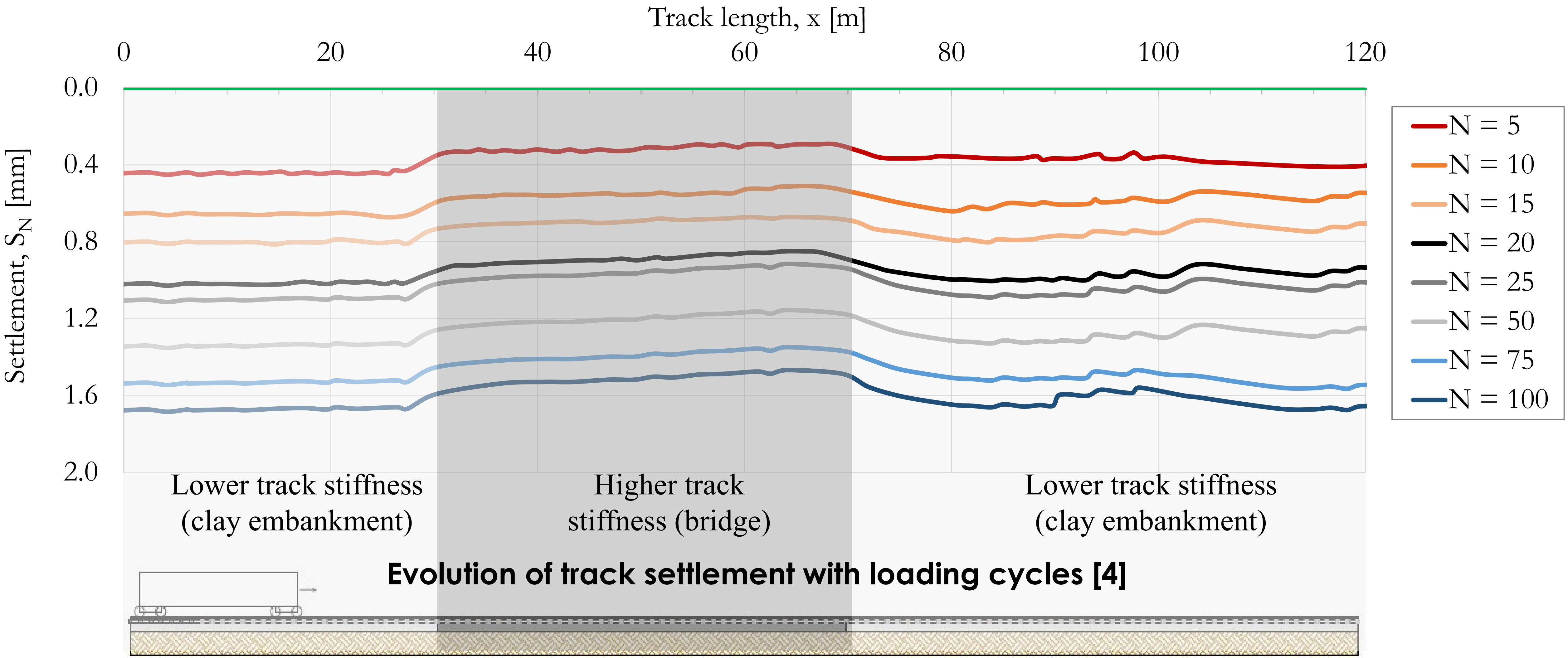


Measured sleeper deflection vs. Force actuator



Measured permanent settlement vs. cycles

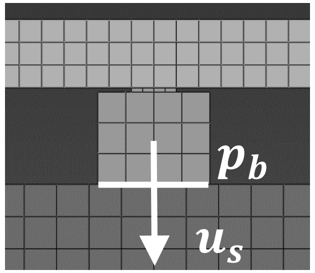
4. ANALYSIS: LONG-TERM ANALYSIS OF A BRIDGE-APPROACH



Evolution of track settlement with loading cycles [4]

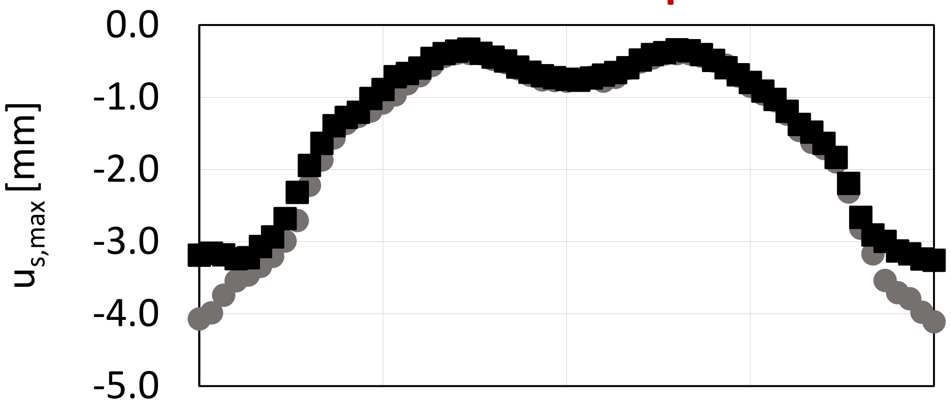
4. ANALYSIS: SHORT-TERM ABALYSIS OF A BRIDGE-APPROACH

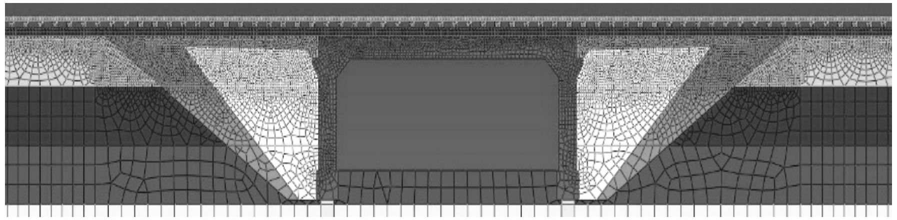
Maximum sleeper deflection [3]

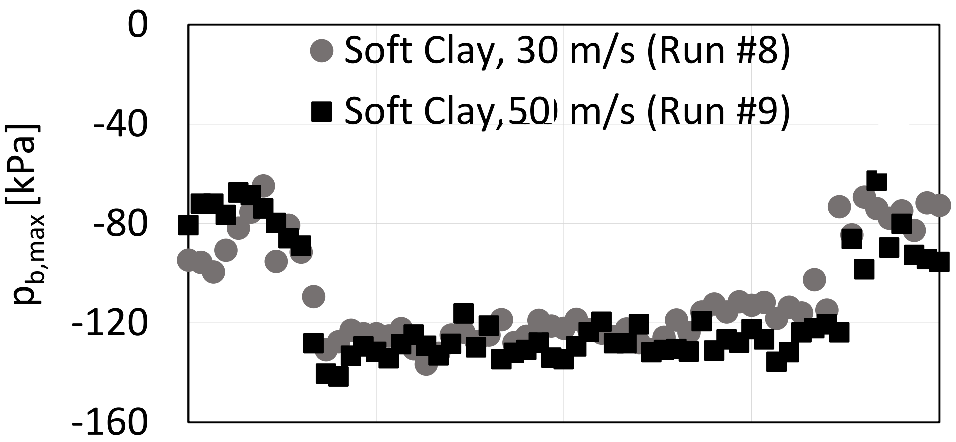


Maximum sleeper-ballast pressure [3]

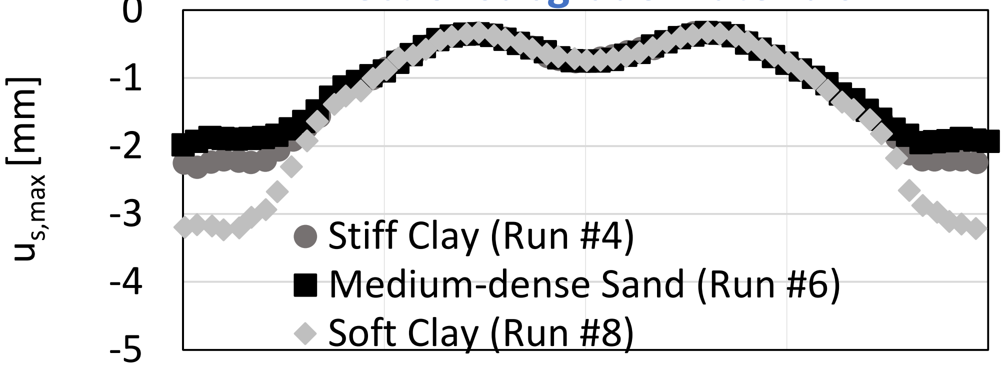
Effect of train speed

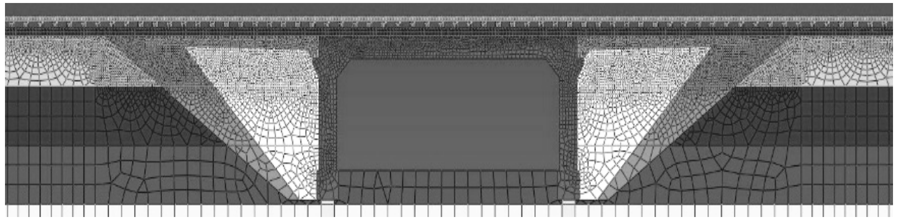


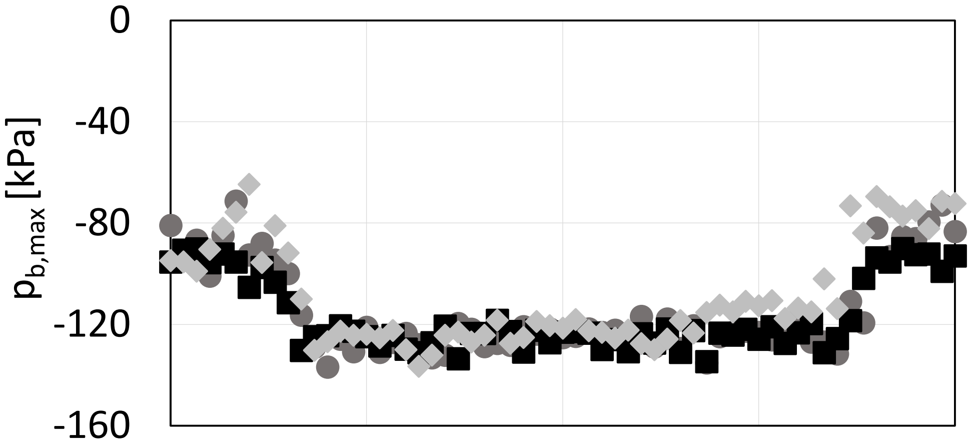




Effect of subgrade materials







5. CONCLUSIONS

FUTURE WORKS

- Implement an **acceleration algorithm** to be able to analyse **thousands/millions of cycles**
- **Validate** the model with reference of **field data** (available in **the literature** and from **historical track quality data**)

REFERENCES

[1] G. Ognibene et al. (2021) – An alternative approach to track settlement, *4th International Conference on Transportation Geotechnics*, Chicago, U.S.

[2] G. Ognibene et al. (2021) – Resilient and damping properties of ballast and their effect on the track performance, *5th international conference on railway technology: research, development and maintenance*, Mallorca, Spain.

[3] G. Ognibene et al. (2019) – Analysis of a bridge approach: long-term behaviour from short-term response, *15th international conference of railway engineering*, Edinburgh, U.K.

[4] G. Ognibene *et al*. (2021?) – A fundamental approach to transition zone analysis (on-going)

[5] M. Hamadache et al. (2019) – On the fault detection and diagnosis of railway switch and crossing systems: an overview, *Applied Sciences*, 9(23).

THANK YOU