Numerical prediction of track settlement in railway turnouts

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Contents

15 Existing knowledge within Trafikverket shows that the main reason behind the high maintenance costs for switches (turnouts) is the need to repair and replace crossings and switch blades. These components are not sufficiently stable in level and alignment (track geometry) over time. Trafikverket states that bad track geometry increases the degradation rate leading to higher dynamic forces. They induce larger stresses and raise the risk of crack development.

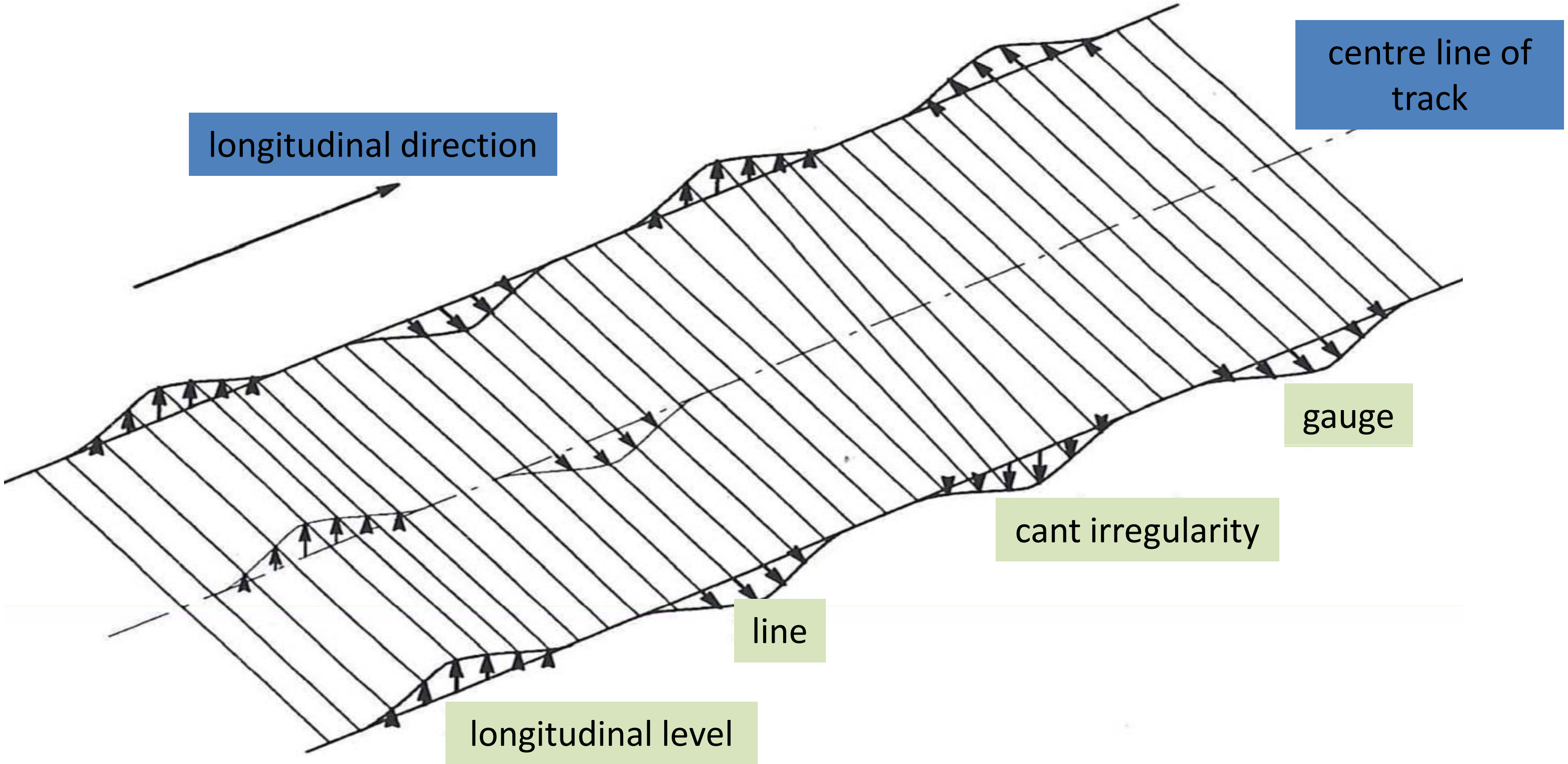
Xin Li, 01/10/2012

Objectives of CHARMEC TS15

- Focus on Switches and Crossings (S&C)
  - Reduce
    - traffic disturbances
    - need for maintenance & life cycle costs
  - Increase understanding of track geometry degradation
  - Develop an iterative model for prediction of track settlement
  - Optimize S&C design
  - Cooperate with parallel research project at LTU

Introduction

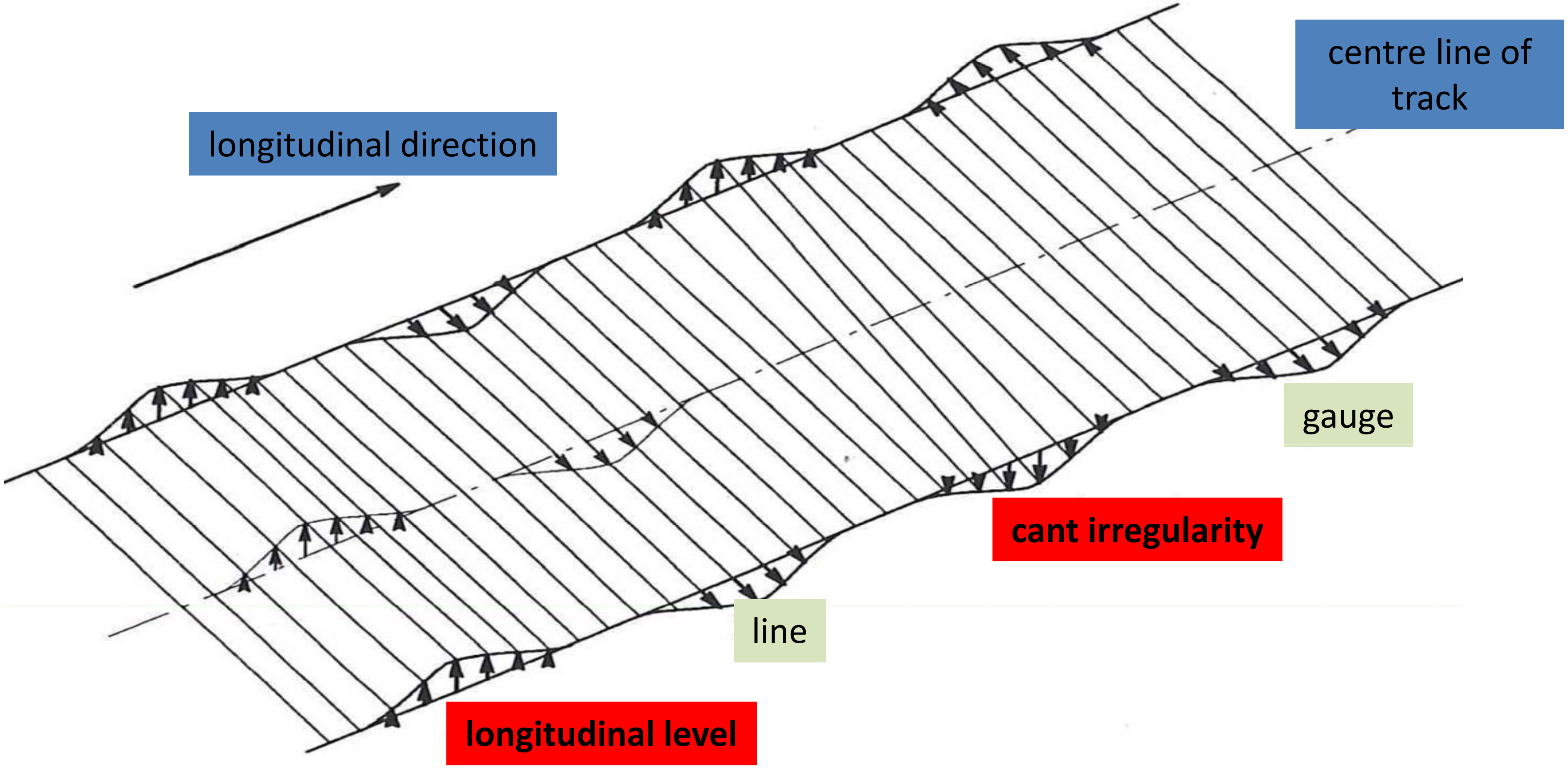
- Definition of track irregularities



Reference: Andersson, E., Berg, M. and Stichel, S. Rail Vehicle Dynamics

Introduction

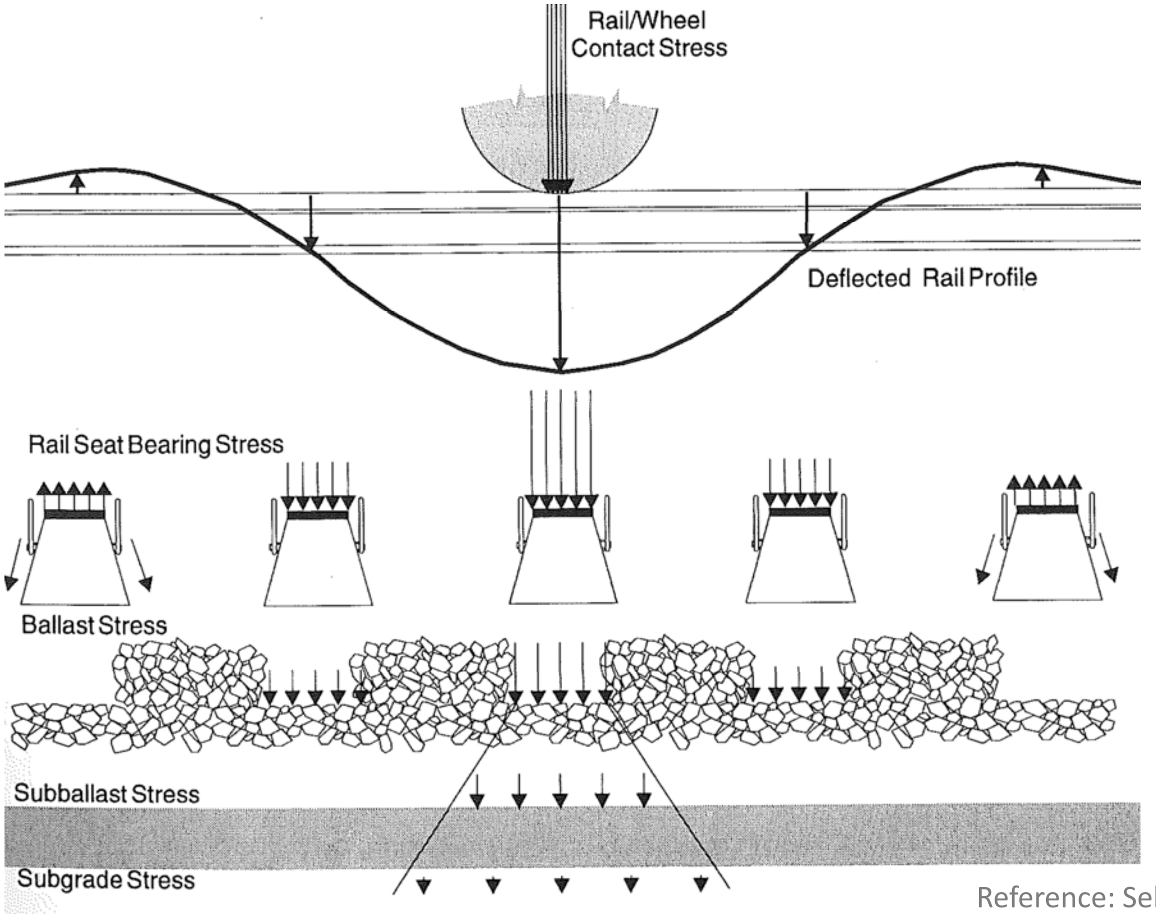
- Definition of track irregularities



Reference: Andersson, E., Berg, M. and Stichel, S. Rail Vehicle Dynamics

Introduction

- Load distribution



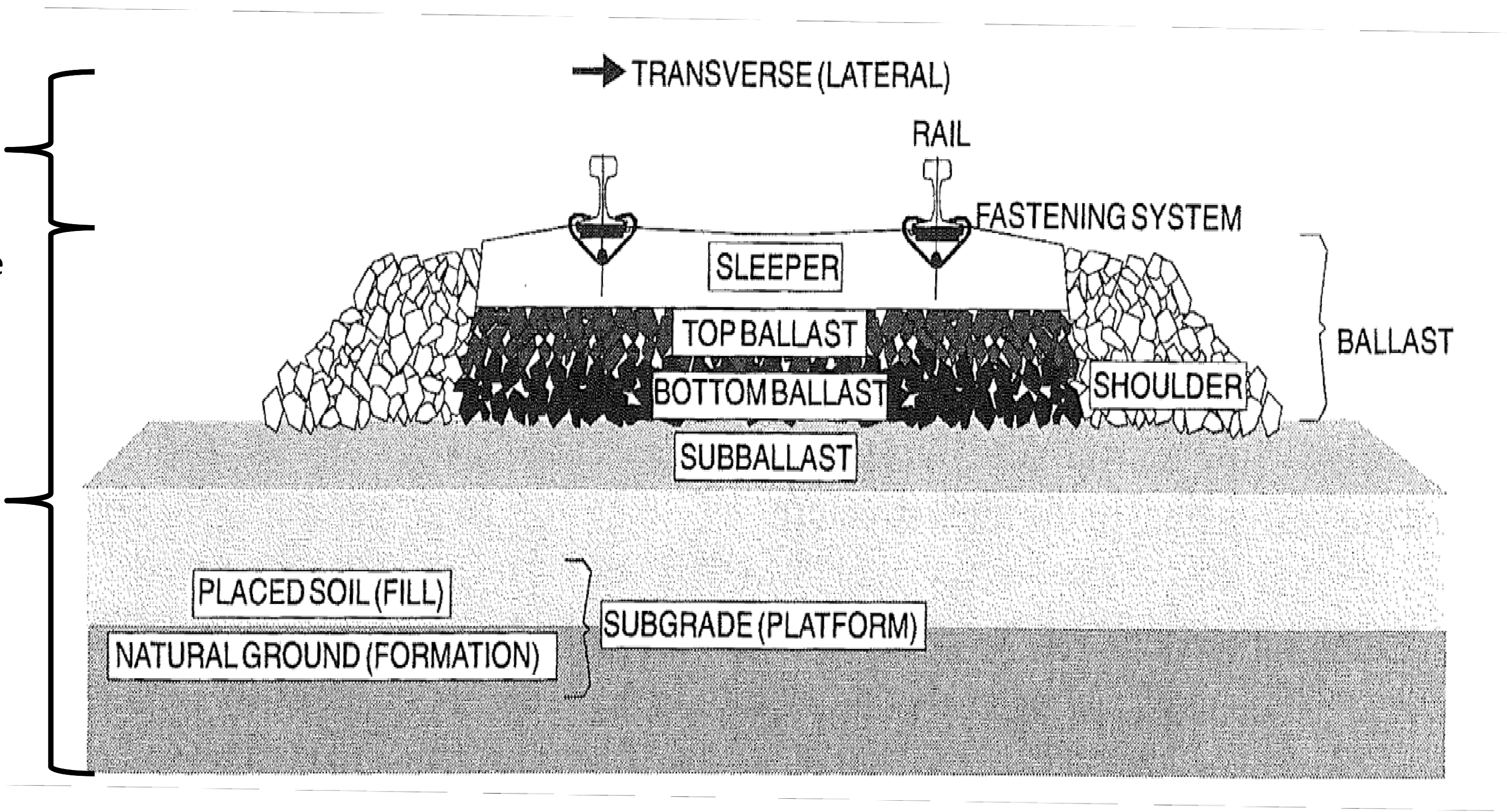
Reference: Selig, E.T. & Waters, J.M. (1994)

Introduction

- Definition of track substructure components

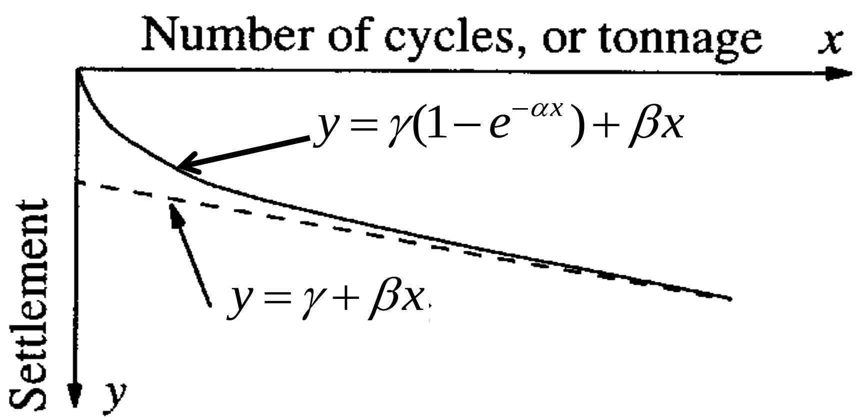
Track superstructure

Track substructure



Introduction

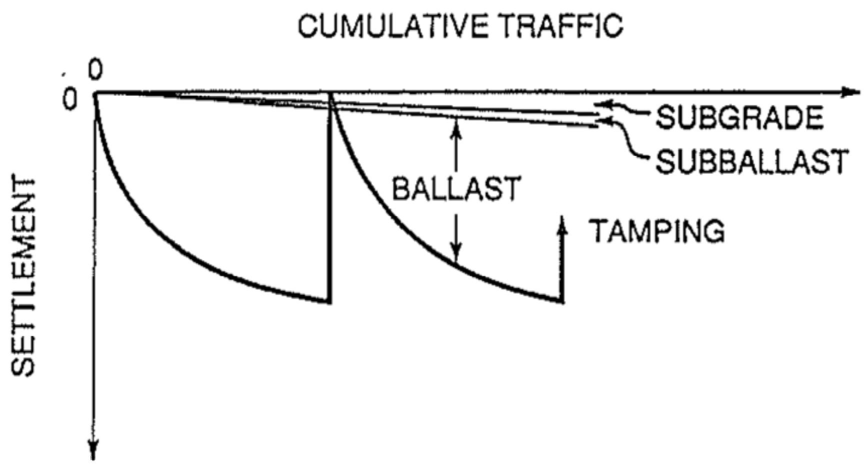
- Settlement characterisation :
  - Two phases of settlement
    1. Short term settlement: fast settlement directly after tamping
    2. Long term settlement: slower linear settlement against time (or load)



Reference: Dahlberg, T. (2001); Sato, Y. (1995)

Introduction

- Settlement sources
  - Sleeper movement and ballast migration
  - Volume reduction due to particle rearrangement
  - Particle breakage
  - Abrasive wear
  - Subballast or subgrade penetration
  - Inelastic recovery during unloading

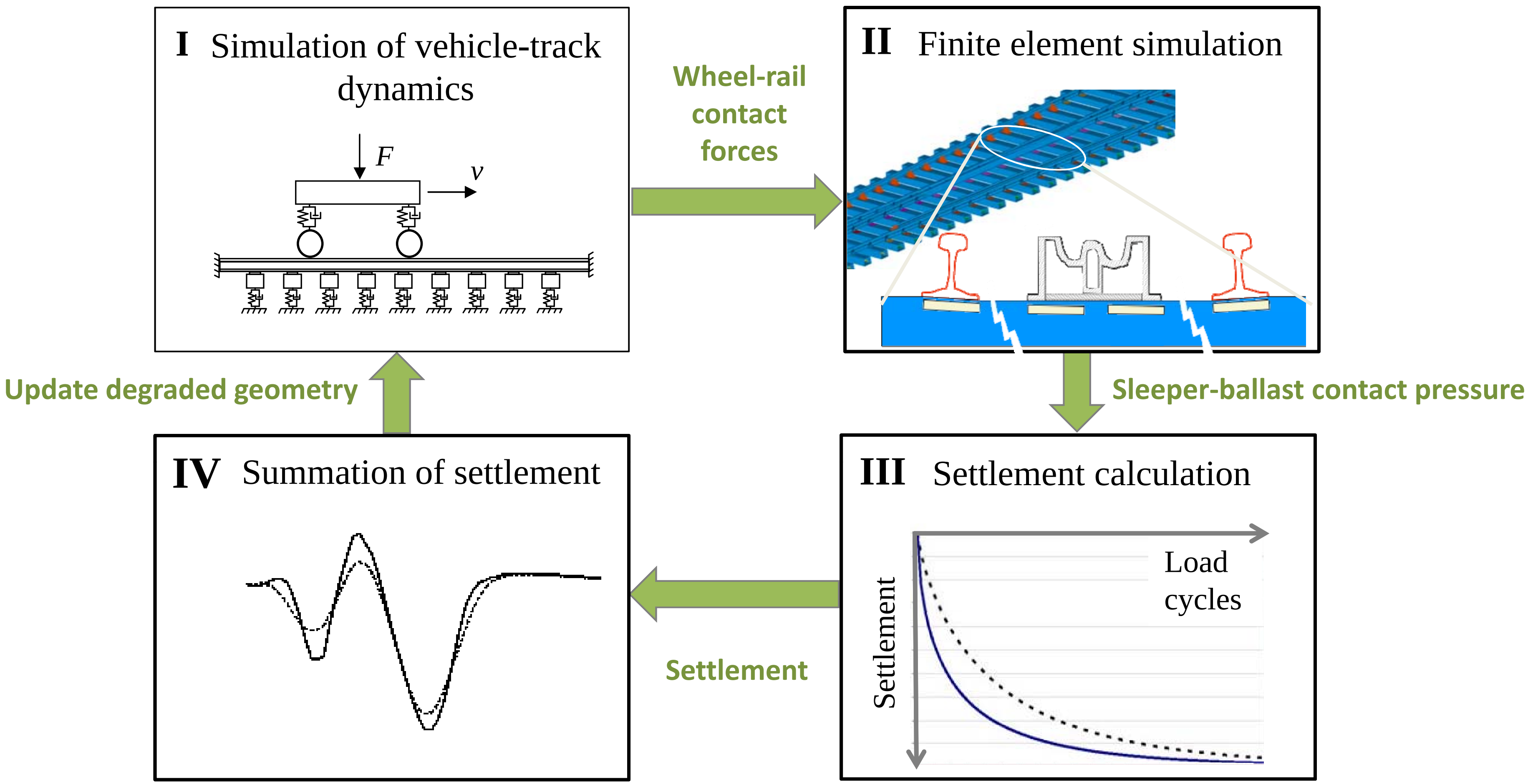


Reference: Selig, E.T. & Waters, J.M. (1994)

Introduction

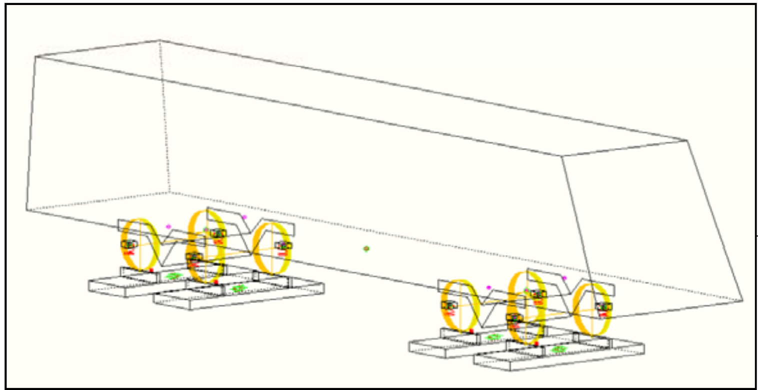
- Differential track settlement
  - Track stiffness variation
    - Transition zone
    - Rail joint
    - Turnout
    - Voided sleeper
    - Heterogeneity in track components
      - Sleeper spacing, sleeper properties (length, width, material)
      - Discrete nature of ballast particle
      - Subgrade change

Iteration scheme

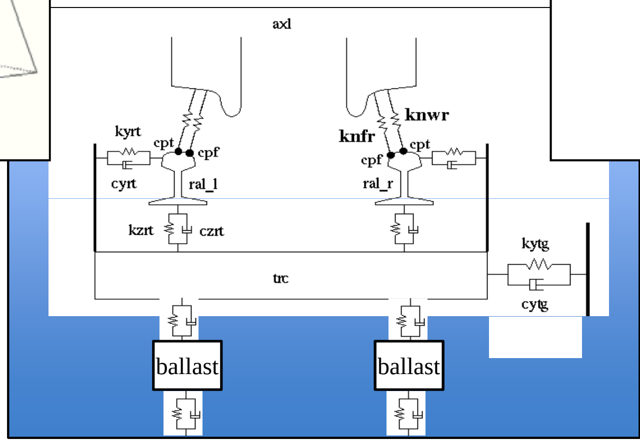


Simulation of vehicle-track dynamics

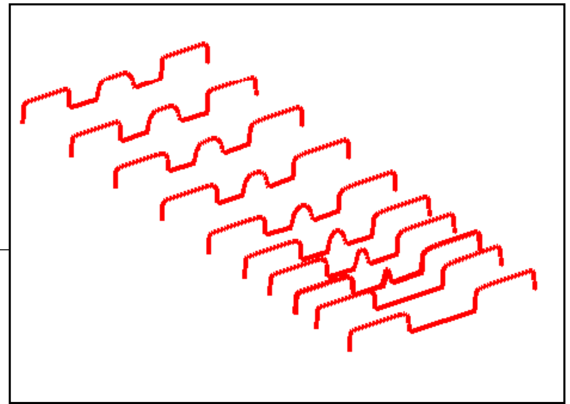
Train-turnout interaction is simulated in GENSYS



MBS-model
Freight train featuring Y25 bogies



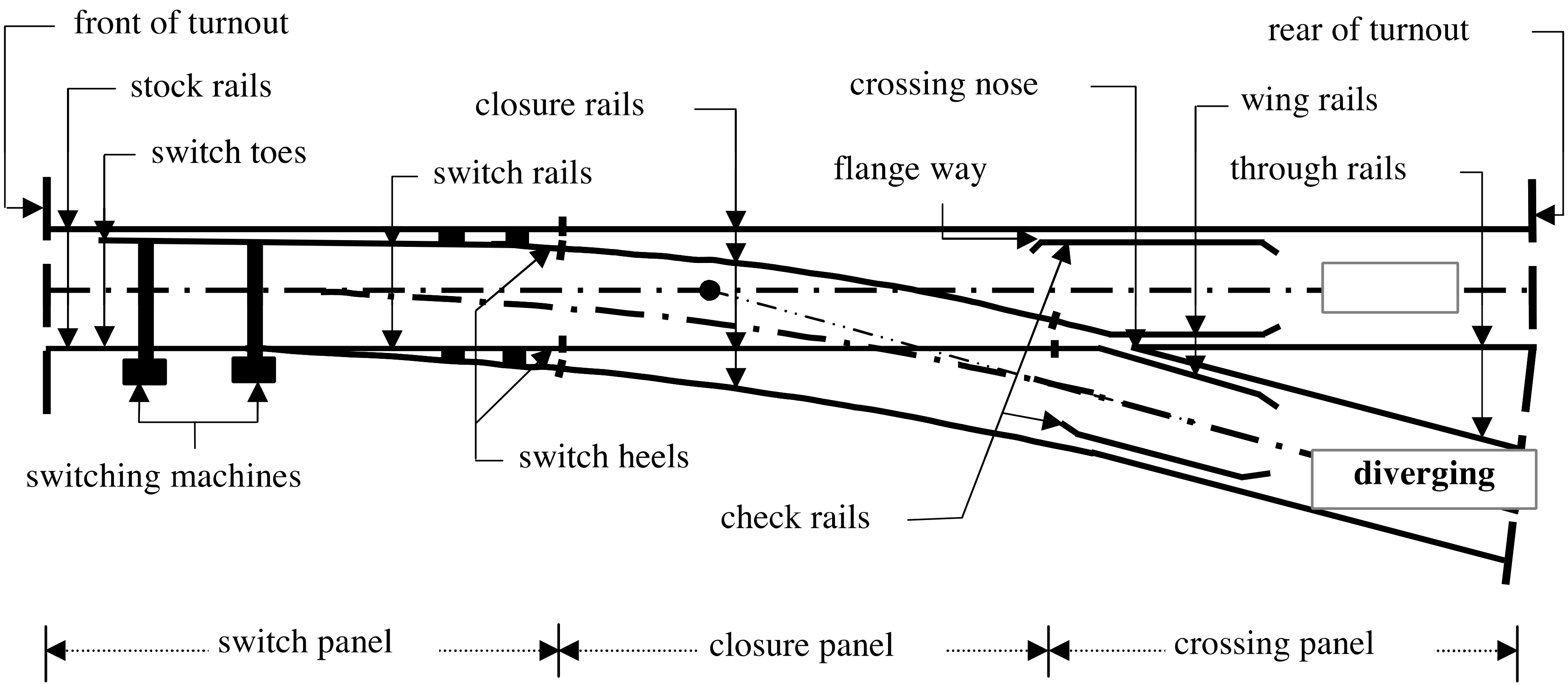
Co-following track model(s)



Discrete rail sections
60E1-760-1:15 turnout

Reference: Pålsson, B. CHARMEC

Finite element simulation



Reference: Kassa, E. (2007)

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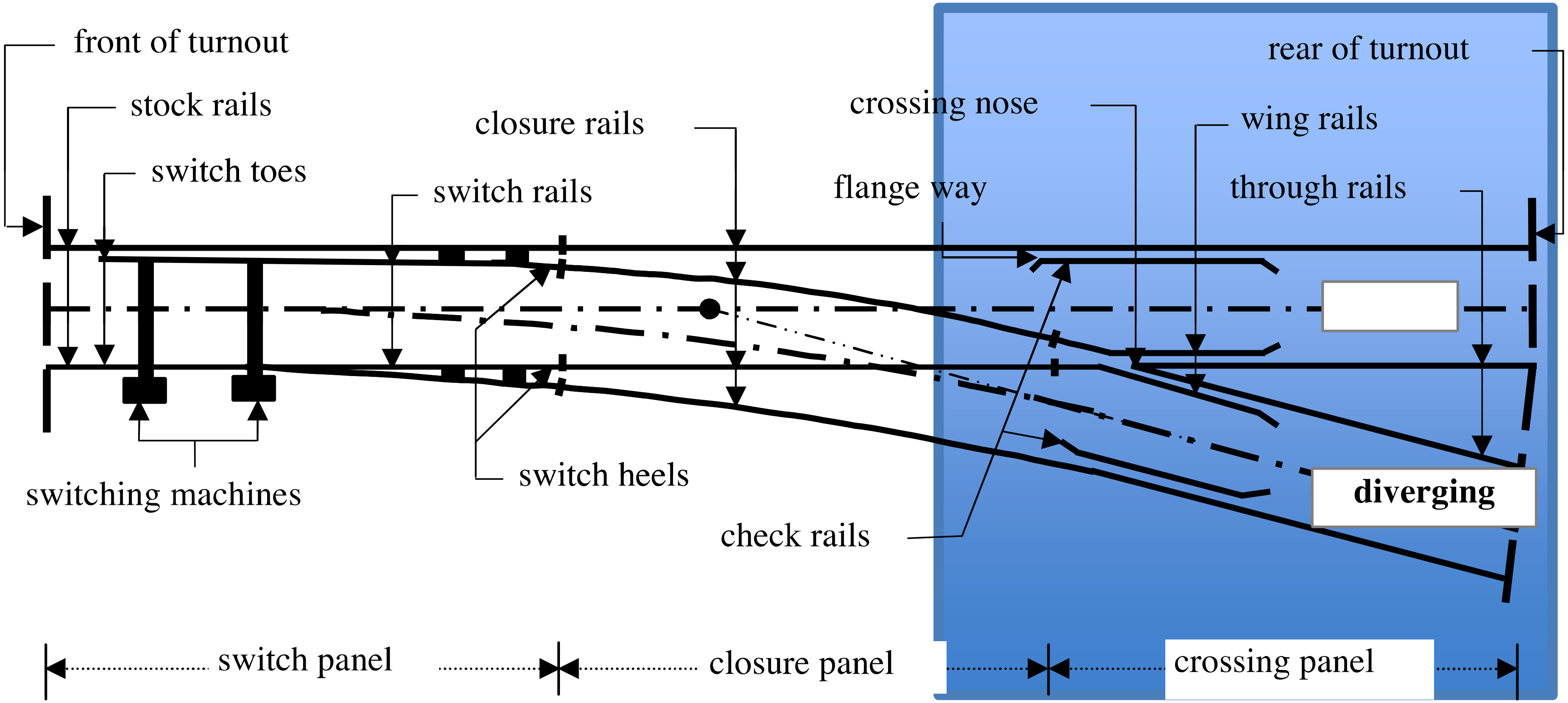
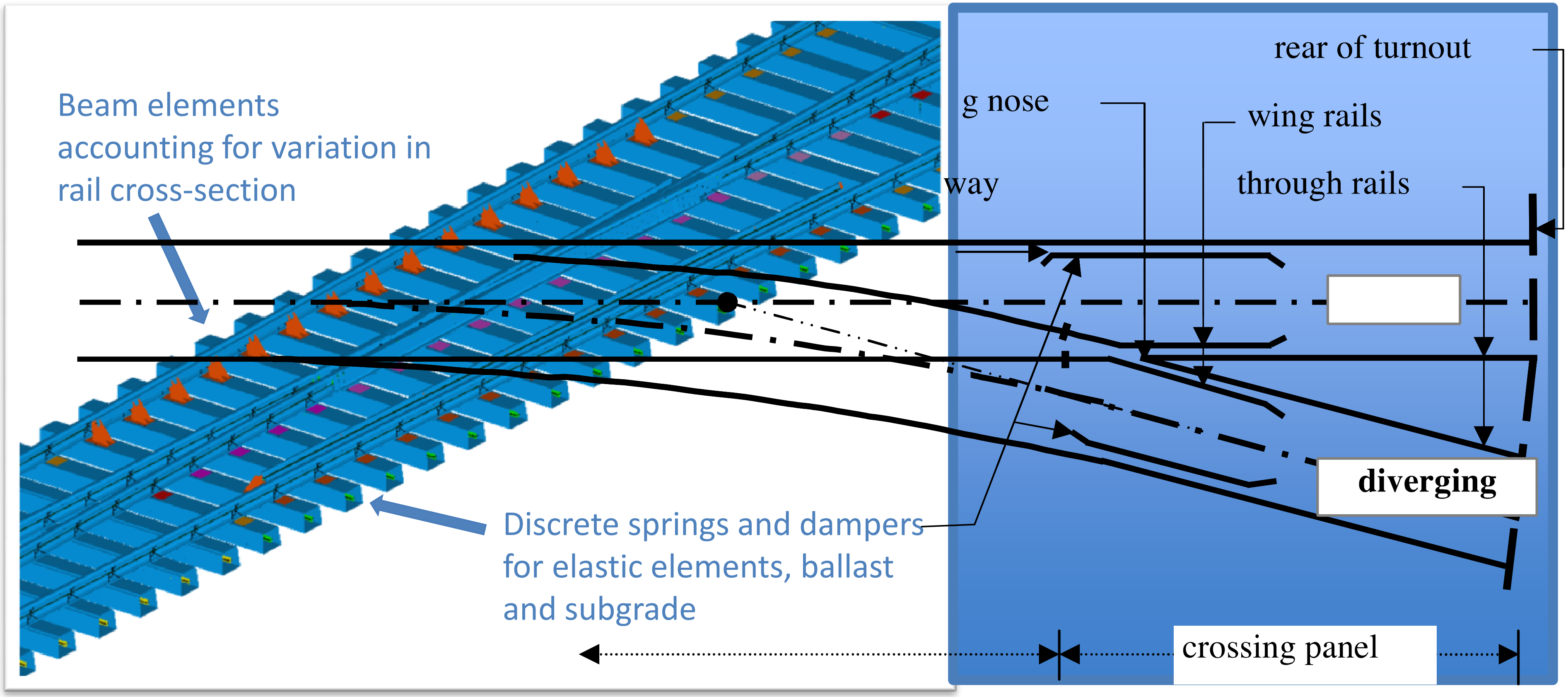
Finite element simulation



Reference: Kassa, E. (2007)

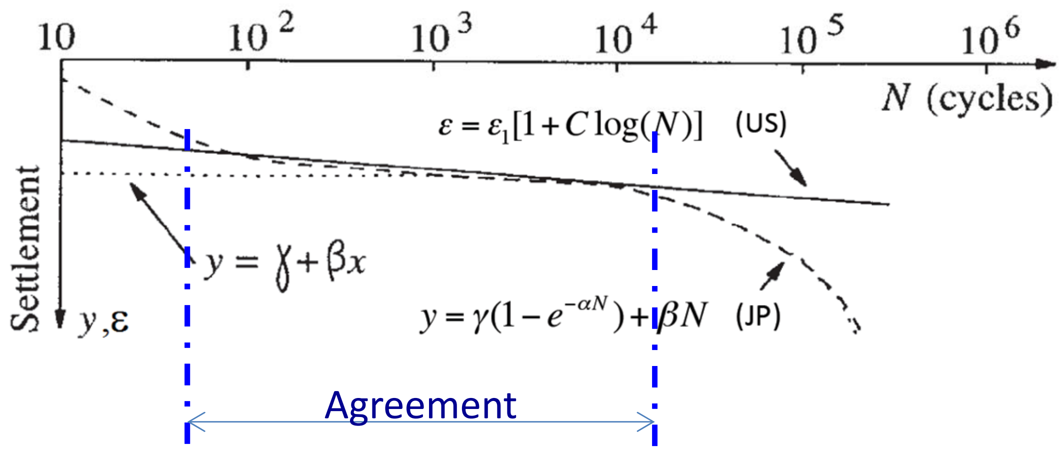
Finite element simulation



Reference: Bolmsvik, R., Nielsen, J., Kron, P., & Pålsson, B. (2010)

Modelling of track settlement

- Empirical models



- ε_1 is permanent strain after first cycle
- C controls deformation rate

- γ gives the severity (size) of the settlement
- α indicates how quickly the initial part of the settlement attenuates
- β determines the long-term settlement.

<u>US model</u>:

considers wheel load magnitude

Settlement does not happen if the load magnitude is below a threshold value

<u>JP model:</u>

capture initial short term settlement

Reference: Dahlberg, T. (2001)

17

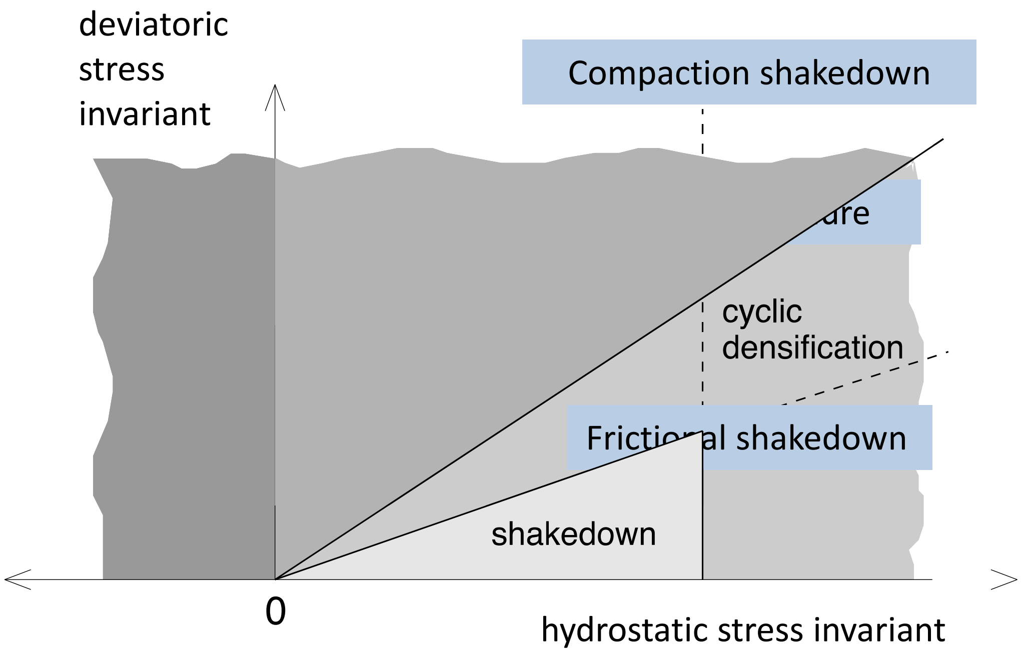
1. Crushed stones give a (much) lower value of â than gravel.
2. β is proportional to the square of the velocity of the repeated loading.
3. Soil contamination of the ballast may improve (if dry) or worsen (if wet) the settlement.
4. β is proportional to sleeper pressure.
5. β is proportional to ballast (vertical) acceleration.

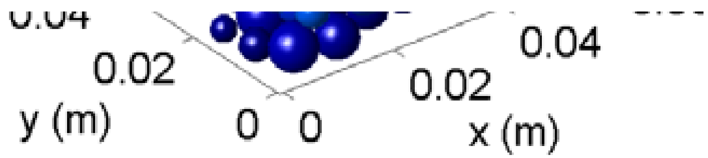
The two last items are of particular interest in this study, as they are
relatively easy to manipulate when building a new track or when renewing an old track.
The sleeper pressure may be lowered by making the sleepers wider or by installing them closer together in the track.
The sleeper pressure may also be changed by changing the pad stiffness and/or the rail bending stiffness and/or by using under-sleeper pad . The ballast acceleration is influenced by, for example, the speed of the train and the irregularities on the rail head and on the wheel tread.

Xin Li, 01/10/2012

Modelling of track settlement

- Constitutive models
  - Settlement envelop
  - Discrete Element Method





Reference: Suiker, A.S.J (2005); Karrech, A. (2007)

Outlook

- Document current literature survey
- Start dynamic simulation in GENSYS
- Implement empirical settlement model
- Perform iterative simulation scheme
- Compare the result from iterative scheme with data from literature and validate its functionality