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Modelling transition zones in railway tracks

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Introduction

Transition zones are locations of discontinuity in the support, such as stiffness transition zones in the ballasted track (close to bridges, culverts and tunnels). These zones necessitate special attention, mainly because they:

- Require frequent and expensive maintenance activities.
- Cause delays due to unexpected maintenance.

Model A

1D model of an infinite Euler-Bernoulli beam on viscoelastic Winkler foundation subjected to a constant moving load.

Main characteristics

- Infinite extent of the beam-foundation system.
- Inhomogeneous foundation stiffness and damping.
- Nonlinear foundation-stiffness constitutive law.

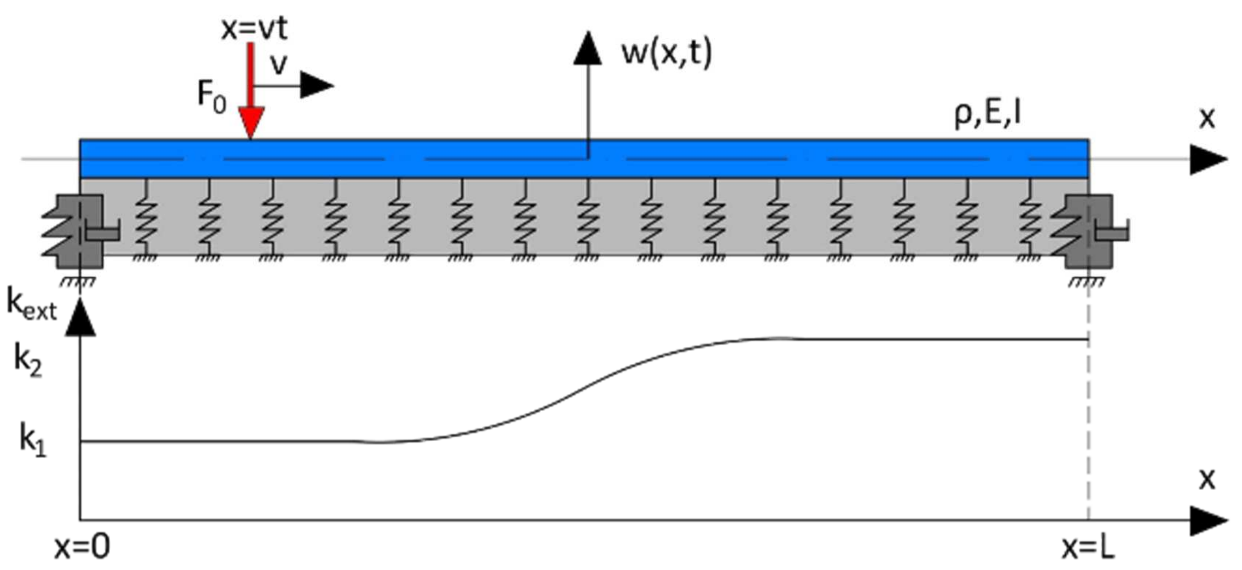

Figure 1: Schematics of Model A

Solution method

The nonlinear problem is solved using the Mixed Time-Frequency Method. Assuming that the system behaves linearly in the beginning, the forward Laplace transform is performed over time. Then, the Finite Difference Method is used to approximate the 4th order spatial derivative. The solution in the Laplace-domain reads:

$$\hat{w}_j = \left(K_{i,j} + \rho s^2 I_{i,j} + c_i s I_{i,j} + k_i I_{i,j}\right)^{-1}\left[F_{ML,i} + F_{IC,i} + F_{b,i}\right]$$

In the time-domain we search for the first nonlinear event. Then, we make a new system with updated stiffness profile and solve it assuming linear behaviour until the next nonlinear event occurs. The next solution in the Laplace-domain reads:

$$\hat{w}_{2,j} = \left(K_{i,j} + \rho s^2 I_{i,j} + c_i s I_{i,j} + k_{2,i} I_{i,j}\right)^{-1}[F_{ML2,i} + F_{NL2,i} + F_{IC2,i} + F_{b2,i}]$$

The procedure is repeated until the whole solution is obtained.

Graphical Results

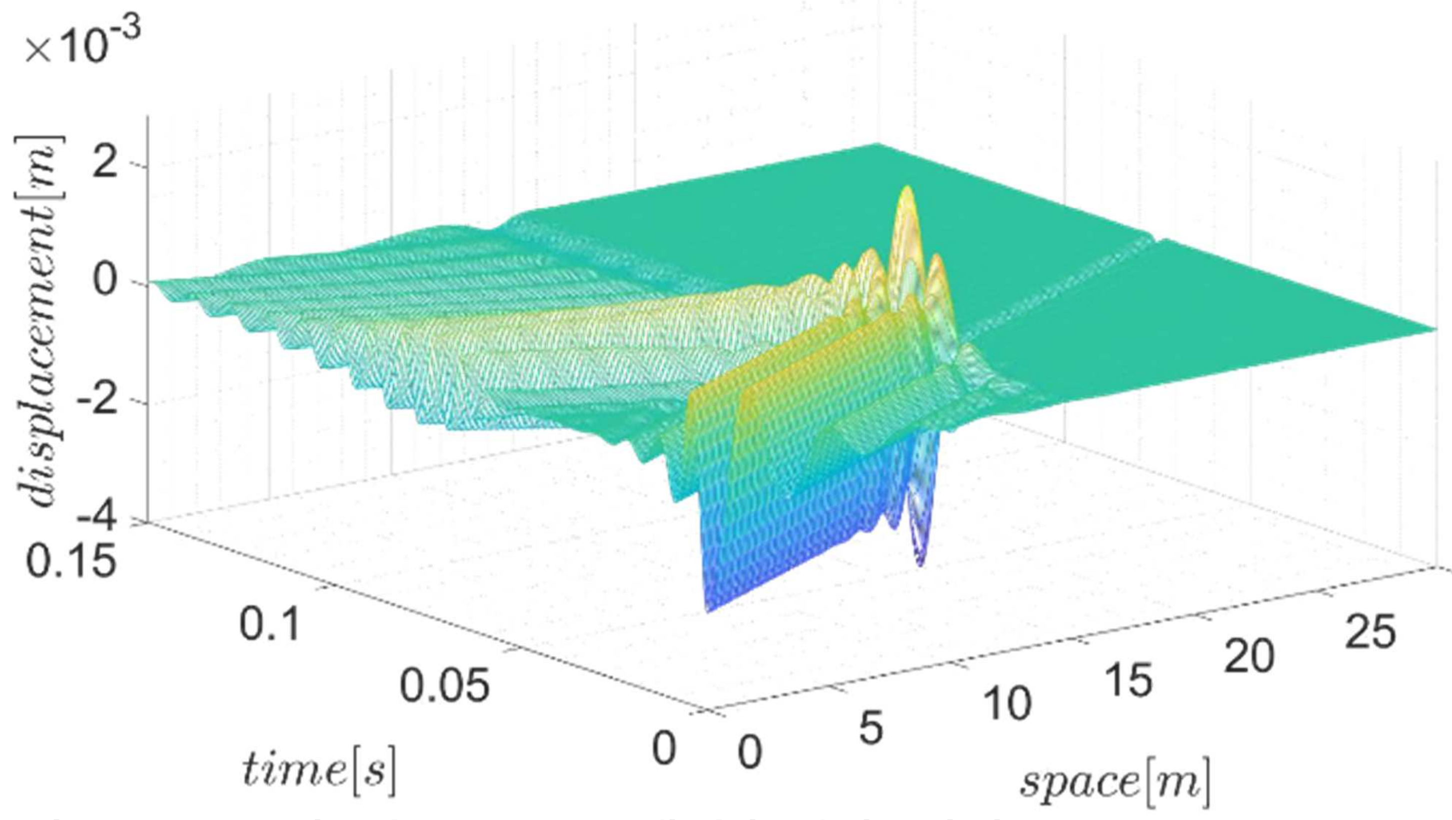

Figure 2: Displacement field of the inhomogeneous and nonlinear system

Model B

1D model of an infinite Euler-Bernoulli beam on viscoelastic Winkler foundation subjected to a mass-spring oscillator.

Main characteristics

- Infinite extent of the beam-foundation system.
- Inhomogeneous foundation stiffness and damping.
- Nonlinear contact stiffness (Hertzian contact model).

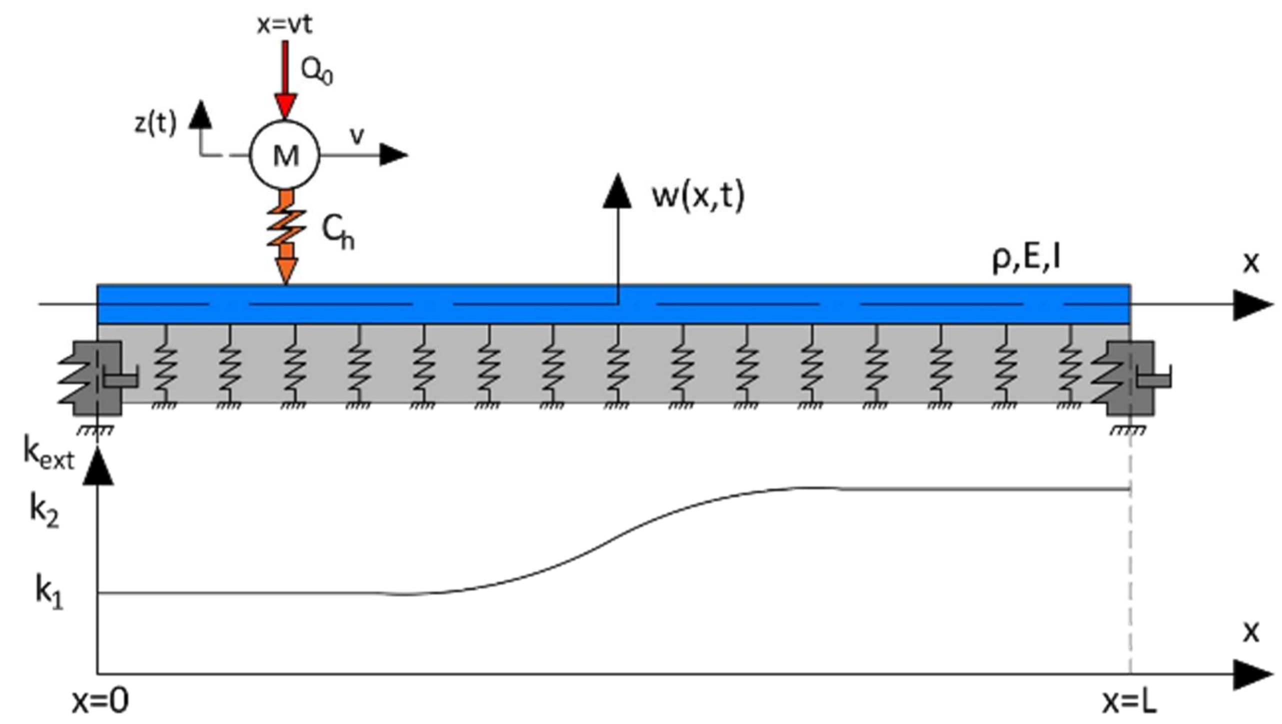

Figure 3: Schematics of Model B

Solution method

The interaction between the mass and the beam-foundation system is solved using the Green's Function Method. Firstly, the beam-foundation system Green's functions are computed:

$$\hat{g}_j = \left(K_{i,j} + \rho s^2 I_{i,j} + c_i s I_{i,j} + k_i I_{i,j}\right)^{-1}\hat{F}_{impuls,i}$$

Secondly, the Green's function of the mass is derived analytically. Finally, the Green's functions of the two subsystems are combined using the following contact relation:

$$\left(\frac{Q(t)}{C_H}\right)^{\frac{2}{3}} = \left[z(t) - w(0,t)\right]H\left[z(t) - w(0,t)\right]$$

The nonlinear equation is solved iteratively for the contact force.

Graphical Results

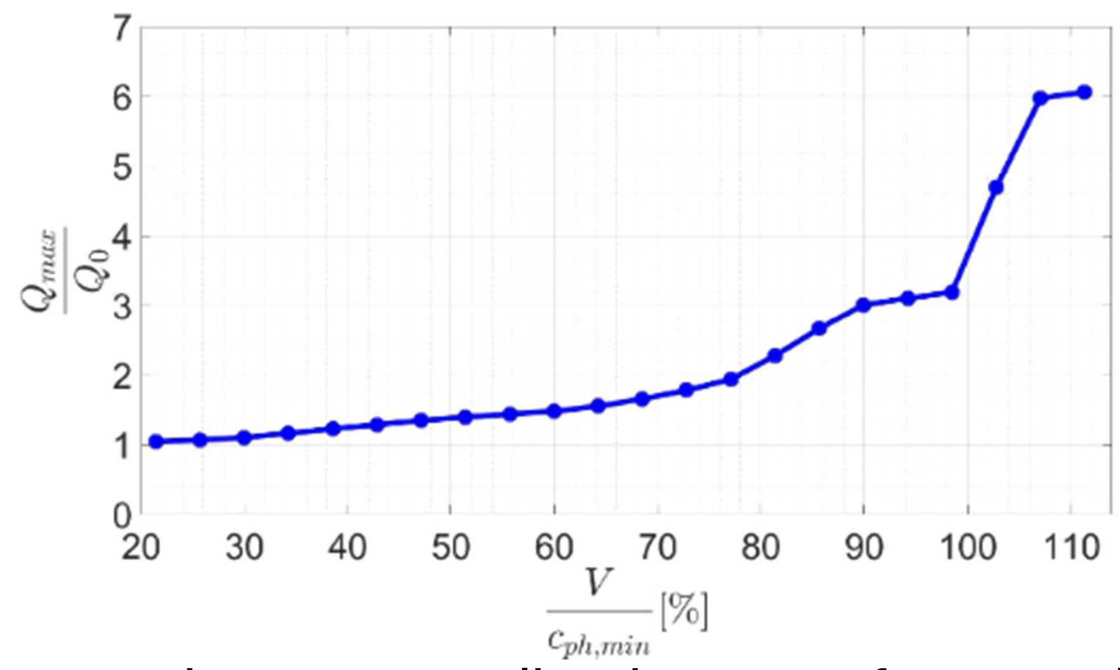

Figure 4: Maximum normalized contact force vs. load velocity

Conclusions

The models presented here can be used for preliminary designs of transition zones in railway tracks. Given the stiffness dissimilarity and the initial plastic deformation, the optimum length of the transition zone can be obtained to minimize the damage in the railway track.

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PhD progress

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