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Analysis of dynamic stresses in ballasted railway track due to train passages at high speeds

Key words: Ballasted railway; Stress analysis; Track irregularity; Stress path; High speeds

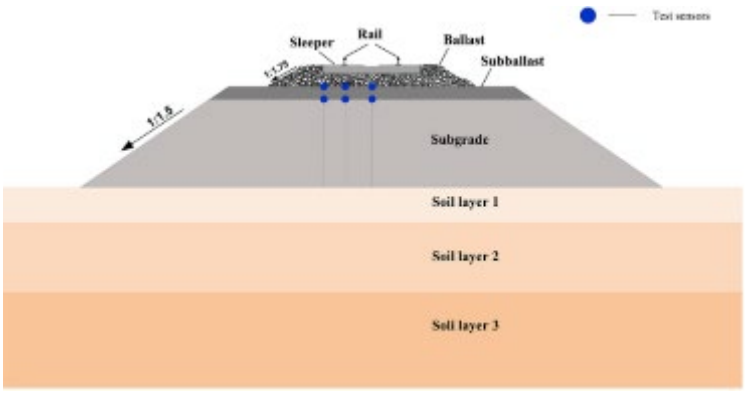
- Train loads are transmitted through the superstructure and distributed by the substructure into the natural ground below. With the substantial increase in train speeds and axle loads in ballasted railways, the substructure is often confronted with settlement problems because of the increasing superimposed stress transferred into the subgrade.

- The existed researches reveal the dramatic amplification effect on stresses when a train approaches or exceeds the critical speed.

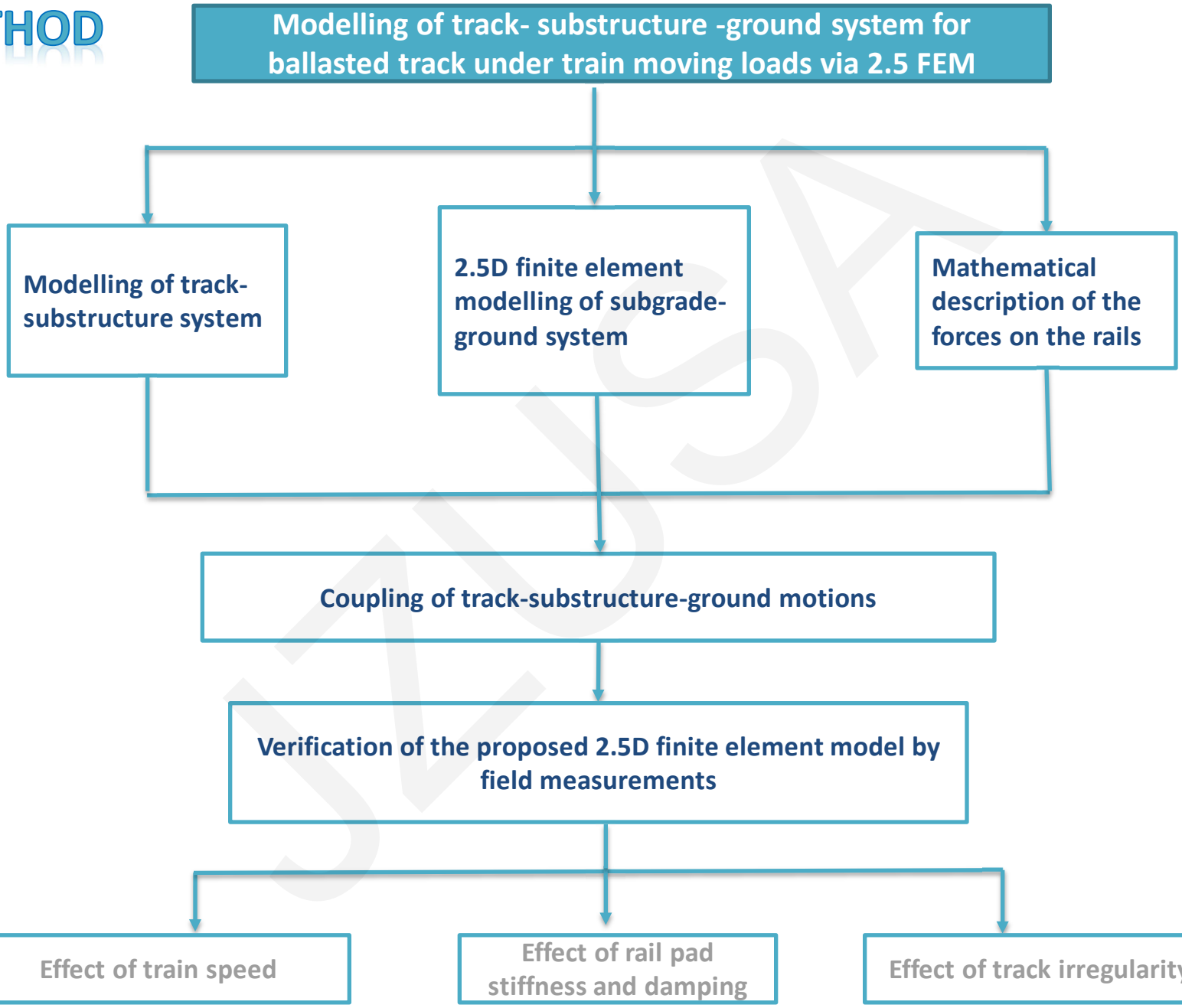
- Soil subjected to traffic loads usually undergoes cyclic principal stress rotation, which has a considerable effect on the deformation behavior of soil.

- However, the effect of track irregularity on stress and principal stress rotation under loading at high speeds has rarely been discussed.

- In this paper, a numerical model is proposed, based on the two and half dimensional finite element (2.5D FE) method. This incorporates a ballasted railway track, substructure and natural ground and allows the dynamic stress response of a high-speed ballasted railway track to be determined. The dynamic stress responses and principal stress rotation behavior of track substructures under train traffic loads at high speeds taking into account track irregularity are fully analyzed.



METHOD


Modelling of track- substructure -ground system for ballasted track under train moving loads via 2.5 FEM
Modelling of track-substructure system
2.5D finite element modelling of subgrade-ground system
Mathematical description of the forces on the rails
Coupling of track-substructure-ground motions
Verification of the proposed 2.5D finite element model by field measurements
Effect of train speed
Effect of rail pad stiffness and damping
Effect of track irregularity

RESULTS AND CONLUSIONS

- The Boussinesq approximation can't consider the effect of multi-layered substructures and train speeds in determining the vertical stress induced by the train traffic loads.

- At low speed (<100 km/h), the analysis model for assessing dynamic stress response under train moving loads can be based on the assumption of a smooth track and can give acceptable results. However, in the design and maintenance of high-speed railways, an empirical formulation considering only the effect of train speed is not accurate enough, and the dynamic amplification effect caused by track irregularity should also be taken into account.

- When the stiffness of the rail pad is reduced, an increase in the damping value can effectively decrease the dynamic stress transmitted to the subgrade.

- As the track irregularity develops, larger stress amplitudes will be induced by the moving train load, and significant stress levels will propagate deeper. Consequently, the soil will suffer from large stresses, which are more likely to cause soil deformation.

- The track irregularity can induce many principal stress rotations even under a simple single moving load. Increasing levels of longitudinal track irregularity will move the stress paths closer to the indicative failure line, increasing the likelihood of failure, especially at high speed.