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Risk and Reliability Based Probabilistic Structural Analysis of Railroad Subgrade Using Finite Element Analysis

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Abstract : Finite Element (FE) method coupled with ever-increasing computational powers has substantially advanced the reliability of deterministic three dimensional structural analyses of a structure with uniform material properties. However, railways trackbed is made up of diverse group of materials including steel, wood, rock and soil, while each material has its own varying levels of heterogeneity and imperfections. It is observed that the application of probabilistic methods for trackbed structural analysis while incorporating the material and geometric variabilities is deeply underworked. The authors developed and validated a 3-dimensional FE based numerical trackbed model and in this study, they investigated the influence of variability in Young modulus and thicknesses of granular layers (Ballast and Subgrade) on the reliability index (-index) of the subgrade layer. The influence of these factors is accounted for by changing their Coefficients of Variance (COV) while keeping their means constant. These variations are formulated using Gaussian Normal distribution. Two failure mechanisms in subgrade namely Progressive Shear Failure and Excessive Plastic Deformation are examined. Preliminary results of risk-based probabilistic analysis for Progressive Shear Failure revealed that the variations in Ballast depth are the most influential factor for vertical stress at the top of subgrade surface. Whereas, in case of Excessive Plastic Deformations in subgrade layer, the variations in its own depth and Young modulus proved to be most important while ballast properties remained almost indifferent. For both these failure moods, it is also observed that the reliability index for subgrade failure increases with the increase in COV of ballast depth and subgrade Young modulus. The findings of this work is of particular significance in studying the combined effect of construction imperfections and variations in ground conditions on the structural performance of railroad trackbed and evaluating the associated risk involved. In addition, it also provides an additional tool to supplement the deterministic analysis procedures and decision making for railroad maintenance.

Keywords : finite element analysis, numerical modeling, probabilistic methods, risk and reliability analysis, subgrade
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