Ballast Condition Analysis and Evaluation of Angularity

Dávid Danko and Ferdinand Pospischil

Institute of Railway Infrastructure Design

This project aims to create an effective method for evaluating the condition of ballast stones using numerical methods and subsequent experiments. The research specifically addresses the angularity and surface roughness of the ballast. This summary serves as an overview of the project and its direction. The final goal is to develop an approach for measuring the current state of ballast in service.

Introduction

Railway infrastructure plays a crucial role in ensuring efficient and reliable transportation. Among the essential components of this infrastructure, ballast stones contribute significantly to track stability and longevity. Monitoring the condition of ballast is important for maintaining a safe and operational railway network. The search for an effective approach to measure the current state of ballast in service is motivated by the need to enhance maintenance practices, prolong the lifespan of railway tracks, and ensure the overall safety and efficiency of rail transportation.

The quality of ballast utilized in track construction can presently only be assessed using the test methods outlined in ÖNORM EN 13450. However, there are additional factors influencing load transfer within the ballast bed. Given that only approximately every 10th ballast stone bears a load, the interlocking, angularity, and roughness of the ballast grains become essential for effective load distribution. To date, there are no established values or standards in the literature describing angularity and roughness or defining limit values.

Approach and methods

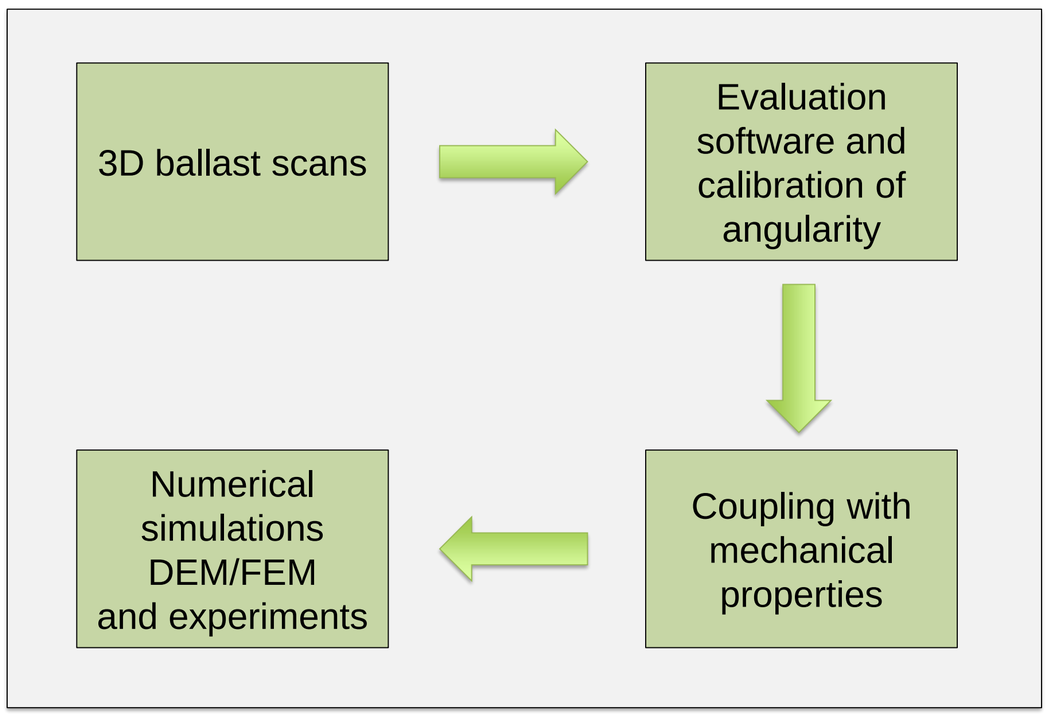

Fig.1: Procedure of ballast evaluation

The method is based on the determination of angularity and roughness through the analysis of individual ballast stones. The scheme of the procedure is shown in Fig. 1. By utilizing 3D scans of samples[1], an effective approach is developed to distinguish between fresh (angular) and fouled (round) ballast. To achieve this, a custom tool for automated evaluation and sorting of ballast was necessary. Once capable of categorizing ballast based on specific angularity indices or shapes, it is then possible to link these values to mechanical properties. This transition involves moving from the analysis of individual stones to the macroblock examination of ballast, which consists of a larger quantity of different stones, observing their properties as a whole. Parameters of interest include friction coefficient, acquired stress values, deformations in selected experiments, and load distribution.

Current stage and future projections

The current phase involves addressing the most suitable method for the evaluation and categorization of individual stones using a developed script in the Python environment with the assistance of the PyMeshLab library. The program operates with the 3D geometry of objects, focusing on one of its key features - the computation of curvature at every node of the mesh (Fig. 2). The ongoing effort aims to optimize the script's functionality to ensure accurate and efficient processing of ballast stone geometry, particularly utilizing the curvature values in various forms[2] for angularity characterization.

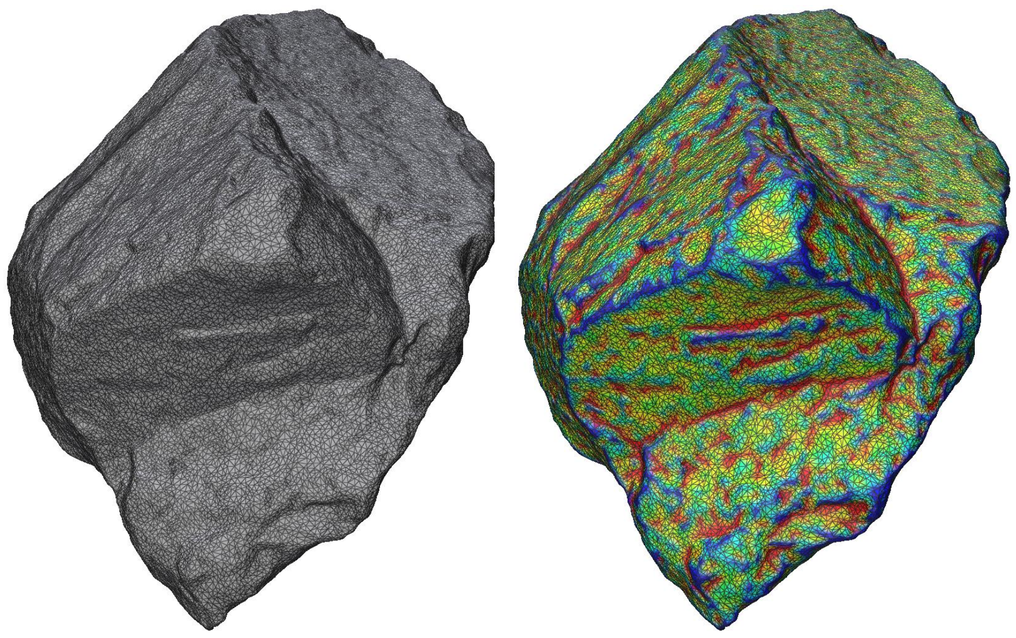

Fig.2: Edge detection and angularity evaluation of ballast scans

After having a stable sorting method, it will be possible to make a transition to numerical simulations using Discrete Element Method (DEM) and Finite Element Method (FEM) for ballast samples with varying mechanical properties based on their current state of angularity and roughness (Fig. 3). The goal will be to analyze how fouled stones behave differently from fresh stones and to devise a method for correlating measured mechanical properties backwards to angularity and roughness indices, determining current state of ballast in an unknown condition.

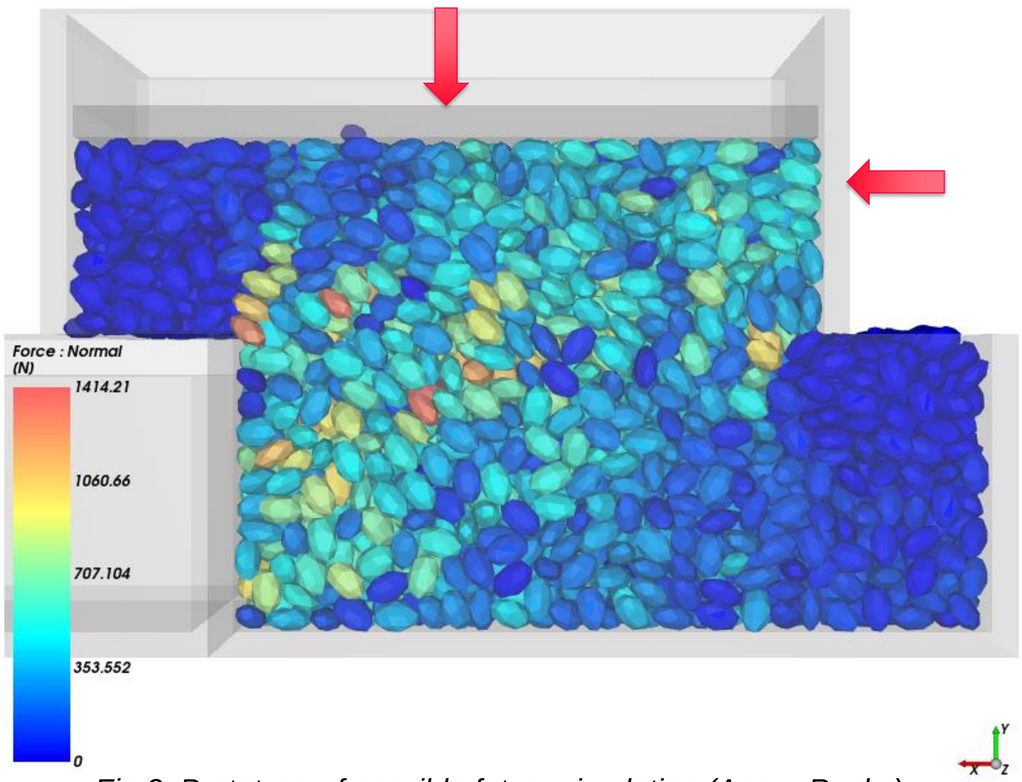

Fig.3: Prototype of possible future simulation (Ansys Rocky)

References

[1] Broekman, André & van Niekerk, Jacobus & Gräbe, Hannes. (2020). HRSBallast: A high-resolution dataset featuring scanned angular, semi-angular and rounded railway ballast. Data in Brief. 33. 106471. 10.1016/j.dib.2020.106471.

[2] Suhr, Bettina & Skipper, Will & Lewis, Roger & Six, Klaus. (2020). Shape analysis of railway ballast stones : curvature-based calculation of particle angularity. Scientific Reports. 10. 10.1038/s41598-020-62827-w.

January 2024

TU Graz – *Institute of Railway Infrastructure Design*
8010 Graz, Inffeldgasse 25/II, Austria, Tel.: +43 316 873-35081
rid@tugraz.at, rid.tugraz.at