Real grain shape analysis: characterization and generation of representative virtual grains. Application to the railway ballast.

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Abstract

The railway ballast is a granular layer formed by irregular rock grains of a centimetric size extracted from hard stone (granite, diorite…) quarries by crushing. It is a crucial element of railway track that ensures the load transmission from the superstructure (rails and sleepers) to the geotechnical structure (platform), and despite its simplicity, its functions are numerous and of great importance for the good performance of the track: Absorbing the mechanical and acoustic vibrations, containing lateral loads and longitudinal loads of the track through shear strength , draining rainwater, etc. Hence, in order to fully perform these functions, the ballast should meet many quality criteria that could be evaluated through its mechanical performances. For SNCF, as a modern railways asset manager, improving the mechanical performances of the ballast while reducing the maintenance needs is a goal to achieve in order to reach a better economical balance. This is one of the motivations of this study.

On the other hand, mechanical performances of the ballast depend strongly on the shape, the size and the mineralogy of its components. While the particle size has been empirically but carefully chosen, particle's shape remains a poorly specified property probably due to both the lack of control on the industrial crushing process and to the difficulty to well characterize the ballast particle shape The main objective of this study is then to both characterize and study the impact of the shape of the ballast on its mechanical performances, by means of numerical simulations using the Discrete Elements Method (DEM) which has been proved to be successful to tackle this question [1,2]. The numerical analysis will be performed using the Contact Dynamics (CD) method on LMGC90 software, with ballast grains represented as irregular polyhedra. The idea is to study the shape influence on some fundamental mechanical properties, such as internal friction, and dilatancy (difference between maximum and critical solid fractions), etc. Yet, a first and interesting challenge remains to generate virtual grains that are representative of real ones. This is the purpose of this paper, by presenting a new method to generate an infinite set of virtual grains morphologically representative of a real sample of grains.

The proposed approach consists of building a stochastic model of the ballast grain shape based on a population of real grains. The first step is to scan ballast such that each one is represented by a point cloud describing the surface grain. After a suitable pre processing, we identify, by means of Proper Orthogonal Decomposition (POD), the optimal hierarchy of shape functions that fully describe the grain sample. This approach has two main advantages: 1) Reducing the number of needed shape functions to represent the grain shape with a quantitative controlled approximation (error based), such that we reduce the parametric space to the most optimal one 2) Allowing to generate as many equivalent virtual grains as wanted to perform a statistical analysis of the mechanical properties of granular packings. In this communication, we will detail these two advantages as well as the complete process of generation, and the first mechanical results for small samples of some simple systems.

REFERENCES

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