Shape characterization of railway ballast stones for discrete element calculations

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ABSTRACT

Railway ballast is a layer of granular material that resists to vertical and horizontal loads, produced by the passing train over the rail. The calculation of this kind of complex geomechanic problems has been traditionally addressed using refined constitutive models, based in continuum assumptions. Although these models may be suitable in the evaluation of the critical state of soils [1], or in the calculation of bulk material masses flowing [2], they are not appropriate to represent the local discontinuities of granular materials, which induce special features such as anisotropy or instabilities.

The Discrete Element Method (DEM) is an alternative approach that considers the discontinuous nature of granular materials, which has proven to be a very useful tool to obtain complete qualitative information on calculations of groups of particles [3]. However, the computational cost of contact evaluation between Discrete Elements (DEs) is high and limits the calculation capability. In this regard, it should be noted that particle shape greatly affects contact calculation computational cost, being spherical DEs the less computational demanding type of particles.

From the point of view of micro-scale analysis, it is essential to represent the exact geometry of the grains. By contrast, if the interest lies in the behaviour of the granular material as a whole, particles geometry is not a determining factor. Therefore, for efficiency purposes, a trade-off between particle shape accuracy and computational cost needs to be achieved.

In this work, different approaches to represent ballast stones are assessed: spheres with rolling friction, sphere clusters, polyhedrons and superquadrics. The first two were chosen for further analysis.

Rolling friction allows avoiding excessive rotation when irregular shaped materials are simulated as spherical particles. This work presents a new insight for its application called the Bounded Rolling Friction model [4].

Regarding sphere clusters, there is a key point in the friction between elements. As they reproduce irregular particles using clumps of spheres rigidly joined, the cavities between those spheres introduce interlocks that increase friction. To overcome this drawback, a new contact model is proposed.

Finally, results of the application of both approaches are displayed, and conclusions are drawn as regards the convenience of using more accurate and computational demanding geometries.

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