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Characterization of the shape of aggregates using image analysis and machine learning classification tools

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ABSTRACT

Engineering applications including pervious concrete require effective packing of aggregates to optimize strength. Size and shape distribution of aggregates significantly affect the performance. Computational methods numerically represent shape of aggregates, from image analysis, the effectiveness of has not been compared and verified. This study aims to analyse the representability of shape aspects of aggregates by different computational methods. Crushed aggregates were grouped into 5 clusters, and each group was milled in a Los Angeles machine for different degrees (0–2000) to induce morphological changes on the aggregates. Aggregates ranging from 5 to 30mm in diameter were obtained (7191 in total). imageJTM, was used to compute dimensions and shape factors of aggregates from 14 computational methods. Statistical tests, Pearson's Correlations and Principal Components Analysis and machine learning classification tools, Decision-tree, Random-Forest, Naïve-Bayes, Support-Vector-Machines, K-Nearest-Neighbours and Perceptron were employed to assess. In conclusion, no shape factor could be singularly used to numerically represent the morphological changes on aggregate particles but a combination of shape factors is required. Data matrix had three primary dimensions. Combination of Circularity, Kumbrein-Solidity and Barksdale-Shape-Factor yield best representation of aggregate shape. Regression Tree classification method had the highest accuracy (0.9) in classifying milled and unmilled aggregates.

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KEYWORDS
Aggregates; shape factor; morphology; shape distribution; aggregate surface texture

1. Introduction

Aggregate properties define the applicability of aggregate in civil engineering applications in transportation, geotechnical and construction industries. The aggregates would often be arranged and packed in applications, to give a rigid skeleton matrix that in turn contribute to strength in the applications, such as subbase in highways, ballast in railway tracks and in concrete in the construction industry (Evangelista and de Brito 2007, Bhutta *et al.* 2013, Ćosić *et al.* 2015). An aggregate is defined by properties including specific gravity, particle size distribution (conformity and uniformity coefficients), aggregate impact value, aggregate crushing value, Los Angeles Abrasion Value, elongation index and flakiness index (Akçaoğlu, Tokyay *et al.* 2004, Al-Rousan *et al.* 2005, Arasan *et al.* 2011).

Packing of aggregate particles is affected by size and the shape of particles while they are usually assumed as of a single representative size in applications (mono-size particles) and that they are in the shape of a sphere (spherical particles) (Dinger and Funk 2013, Chan and Kwan 2014). Several studies in contemporary literature have attempted to mathematically optimise packing model using dual-size particles, yet, remain highly limited in applications (de Larrard and Sedran 1994, Gan *et al.* 2010, Das *et al.* 2011, Chang and Deng 2020). Naturally, aggregates come in different sizes and are represented by particle size distribution curve, and are numerically represented by the uniformity coefficient, conformity coefficient and at times together with effective diameter which corresponds to D_{10} (where 90% of the particles are bigger than the effective diameter). Although these numerical quotients are used mostly in soil classification as classifying parameters, the efficacy of these numerical values representing the size distribution of particle size distribution in mathematical models remains debatable. Developing a packing optimisation model for a lump of particles with a distribution of sizes may need emphatic numerical representation, perhaps as a single or number of coefficients (Mueller 2010, Ng *et al.* 2016, Pouranian and Haddock 2018, Shen *et al.* 2019).

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