Modified 3 Parameter Model Incorporating Particle Shape, Texture and Vibration to Predict Packing Density of Binary Particulate Mixtures

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Abstract

Particle packing density is one of the most important parameters in materials engineering. Ultra-high-performance concrete (UHPC), lightweight concrete, porous concrete, advanced ceramic materials, porous asphalt, filter materials are some of the major applications based on the packing density. Determination of packing density of a particulate mixture is a complicated and a laborious process. Hence, many researchers investigated the behaviour of particulate systems in a confined space in order to develop mathematical relationships to predict particle packing density. Several particle packing models have been developed so far such as Toufar model (Toufar, Born, & Klose, 1976), Compressible packing model (CPM) (Sedran & De Larrard, 1999) , 3-Parameter model (Kwan, Chan, & Wong, 2013), Linear packing density model (Stovall, De Larrard, & Buil, 1986) etc. However, due to the complexity of the particulate systems, many of these models are based on several basic assumptions; spherical shape, random loose packing method, smooth particles etc. A study carried out by Hettiarachchi and Mampearachchi (2017) revealed that the packing models can be effectively utilized to improve concrete mixtures for Interlocking concrete block pavers (ICBP). Nevertheless, the study also revealed that the packing models do not accurately predict the packing densities and 3-parameter model predictions are showing a close relationship with the actual packing densities.

Hence, the objective of this study was to modify the 3-parameter model incorporating particle shape, surface texture and vibration frequency. A vibration table and a vibration hammer were used to apply vibration to the particles. Spherical glass beads were quoted with sand dust of various sizes to achieve different surface textures. Aggregates of various shape factors were taken to investigate the effect of shape. Each effect was isolated, and the packing density of the mixtures were measured varying the large particle volumetric fraction. Effect of the size ratio was also investigated by varying the size of the two particle classes of the mixture.

The variation of packing density with vibration, shape and texture were analysed and the combined effect was modeled using regression analysis. The 3-parameter model was then modified using back calculation techniques to develop relationships with each effect. The modified 3-parameter model was validated using over 300 experimental data. The modified 3-parameter model found to be in correlation with the experimental data with a correlation coefficient of 0.95. In conclusion, the developed model will be able to predict the packing density of complex mixtures with high accuracy to provide more realistic outcomes which will benefit the materials engineering greatly.

Key words: Particle packing models, Packing density, Vibration, Shape, Surface texture, 3- parameter model

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