# Characterizing and modeling single particle crushing behavior of construction and demolition waste (CDW) by accurate shape quantification and peridynamics

W. Hua[1], Y. Xiao[1,2]

[1]Department of Geotechnical Engineering, School of Civil Engineering, Central South University, Changsha 410075, Hunan, China
[2]Ministry of Education (MOE) Key Laboratory of Engineering Structures of Heavy Haul Railway (Central South University), Changsha 410075, Hunan, China
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Presenting author email: wenjun.hua@csu.edu.cn

With the increasing production of construction and demolition wastes (CDWs), the use of non-traditional CDWs as road base/subbase materials has emerged as a sustainable, eco-friendly, and low-carbon-emission disposal alternative. However, the breakage-susceptible nature of CDW particles could potentially weaken the in-service performance of such materials and thus hinder its widespread use in road construction if no proper engineering countermeasures were taken. To address this technical challenge, the three-dimensional (3D) laser scanning technology was first employed to collect the surface point cloud data of nearly five hundred real particles of three major constituents of CDW materials (i.e., recycled aggregates, bricks, and mortars) with particle sizes ranging from 4.75 mm to 26.5 mm, from which the 3D models of those individual particles were then reconstructed by using digital image processing technique, respectively. A series of shape indices describing three independent aspects of particle shape (i.e., form, angularity, and surface texture/roughness) were calculated by a customized computer program. Laboratory uniaxial compression tests were then conducted on single CDW particles of representative sizes and morphological levels to investigate their crushing characteristics. The loading rate of the MTS® testing setup was kept at 0.01 mm/s during the tests. The Weibull distribution was used to fit the testing results of crushing strength of single particles with each size range. The establishment of linkages between single particle crushing characteristics and macroscopic behavior of CDW materials such as particle packing features, plastic yielding, deformation, and failure was attempted.

To further disclose the underlying micromechanical mechanisms of single particle crushing, the ordinary state-based peridynamics simulations of laboratory uniaxial compression tests were performed by a customized computer program to study the fracture and fragmentation of single particles with different combinations of material type, size range, and morphological level. The major advantages of peridynamics simulations include reduced computational time, more computationally friendly consideration of irregular particle shape, and the ease of calibrating micromechanical input parameters. The shape of individual fragments was characterized and quantified, and the relationships among fragment shape, single particle shape, and fragment size were analyzed by identifying each fragment produced from single particle crushing.

It can be found that the vast majority of CDW particles studied resemble spheroids and disks regardless of material types. There is no significant difference in the form and roundness of CDW particles among different particle size ranges. With the increase of particle size, the three different types of CDW particles tend to be more angular, and the surface roughness of recycled aggregate particles across all size ranges is significantly greater than that of brick and mortar particles. There is a noticeable size effect on the crushing strength of three different types of CDW particles. The single-particle crushing strength decreases with increasing particle size, and particle shape has a significant influence on such size effect of the crushing strength. The more irregular particle shape is, the smaller the Weibull modulus of single-particle crushing strength is, and the more obvious the size effect of single-particle crushing strength is. Despite the large differences in shape features of single particles studied, it is found that the cumulative distributions of the sizes and shape indices of the fragments produced from particle crushing can be well fitted by the Weibull function. The sensitivity of sphericity, aspect ratio, and convexity indices of fragments to particle shape gradually increases. The sphericity distribution of fragments of different sizes shows that the larger-sized fragments tend to be more angular. The findings of the study could offer insights into the behavior of single CDW particle crushing, which is useful for better understanding the mechanical behavior of CDWs recycled for use in road base/subbase layers.

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