Stress distribution in trimodal samples

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The particle size distribution (PSD), i.e. the cumulative distribution by particle mass (volume) of particle sizes (diameters), is one of the most basic ways to characterize a soil in both geotechnical research and practice. Soils are described as uniformly graded, broadly graded or gap-graded depending on the shape of the particle size distribution. While the PSD shape is understood to influence the engineering behaviour of soil, the fundamental mechanics of the influence of PSD shape on behaviour are poorly understood.

Restricting consideration to non-plastic, cohesionless soils, it is clear that there have been a large number of experimental studies looking at gap-graded soil. In most cases a finer grained sand was mixed with a coarser grained sand or fines were added to a host sand so that the resulting mixtures in both cases were almost bimodal. The proportion of the overall mass taken up by the finer grains (typically representing silts and clays) is then termed the fines content (FC). Zuo and Baudet (2015) give a review of the relevant literature, focussing on the idea of a transitional FC, where the material behaviour transitions from being dominated by the coarse grains to become dominated by the finer grains. Developing on ideas put forward by Skempton and Brogan (1994), Shire et al. (2014) carried out a series of DEM simulations on gap-graded samples of spheres. They calculated the average stress in the finer grains normalized by the overall applied stress, this approximates to the proportion of stress transmitted by the finer grains. Shire's data showed that the extent to which the fines participate in stress transmission depends on the fines content and on the ratio between the coarse and finer grain sizes. The data do not support the concept of a single transitional FC, rather a more gradual transition between coarse- and fines-dominated behaviour.

Natural geological deposits of purely bimodal material are rare and so a comprehensive and relevant understanding of stress distribution in materials needs to consider more complex particle size distributions. More robust analyses of the effect of PSD shape on the mechanical behaviour of soil mixtures may therefore require varying PSDs in a more systematic way, from uniformly graded to well graded PSDs. In a first step to develop this broader perspective, this study considers trimodal materials, with fine, coarse and medium-sized grains. Rather than considering the stresses in the particles, the sample is partitioned into six classes: stress transmitted via (i) coarse-coarse particle contacts, (ii) coarse-medium contacts, (iii) medium-medium contacts, (iv) medium-fine contacts, (v) coarse-fine contacts and (vi) fine-fine contacts. DEM samples are compressed from an initial non-contacting cloud of grains to an isotropic stress of 500 kPa. Initially a purely bimodal material containing 25% fines is considered and the proportion of the medium-sized grains is then systematically increased.

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3. L. Zuo, B.A. Baudet (2015) Determination of the transitional fines content of sand-non plastic fines mixtures. Soils Found 55:213–219.