EFFECT OF GRANULAR PARTICLE MORPHOLOGY ON MECHANICAL RESPONSES UNDER CONSISTENT TAPPING METHOD

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1. INTRODUCTION

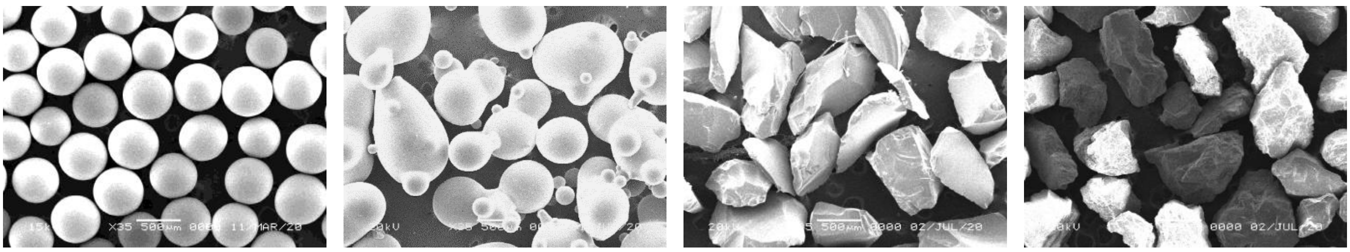
Soil behaviours are widely influenced by soil particle characteristics such as particle size and its distribution. Another influential factor is particle morphology (*e.g.* particle shape and surface roughness). Cho et al. (2006) and Altuhafi et al. (2016) have collected an enormous database and found that particle shape and surface roughness have a significant impact on mechanical responses of soils from small strains to critical states. The present study considers a series of triaxial tests performed in the dry and drained conditions. Three types of glass beads with different shapes and surface roughness and one type of natural sand were used. Unlike the typical approach by maintaining the similar initial void ratio (e_0) or relative density (D_{r0}), this study controlled the tapping energy during the sample preparation process to be equivalent.

2. MATERIAL DESCRIPTION

Three types of glass beads are spherical glass beads (SGB), clumped glass beads (CGB) and angular glass beads (AGB) In order to make the surface rougher, one portion of tested material and two portions of silica sand No.8 (D_{50}=0.1mm) were mixed in a milling machine and rolled for 48 hours. To differentiate materials as supplied and after roughened process, 'S' denotes smooth case while 'R' denotes rough case for glass beads. In addition, one natural sand (*i.e.* silica sand No.5 (SS5)) was also tested. To quantify particle shape and surface roughness, shape parameters were measured and calculated using QICPIC following Yang and Luo (2015) and the root mean of surface roughness (S_q) was estimated following Li et al. (2021). and Table 1 summarises the material properties and Fig. 1 presents the SEM images of the tested materials. In Table 1, *OR* stands for overall regularity, which quantifies the mean of sphericity, convexity and aspect ratio in Altuhafi et al. (2016). *OR*=1 means the particle is a perfect sphere, and the shape is more angular with the decreasing of *OR*.

Table 1 Material properties of materials

	SSGB	RSGB	SCGB	RCGB	SAGB	RAGB	SS5
G_s			2.5				2.64
D_{50} (mm)	0.496		0.903		0.746		0.525
OR	0.963		0.794		0.792		0.838
S_q (mm)	67.6	173.5	127.7	246.6	127.2	224.7	580



(a) (b) (c) (d)

Fig. 1 SEM images of tested materials (a) SGB (b) CGB (C) AGB (d) SS5

3. TESTING PROCEDURE

Soil samples were prepared on a standard triaxial apparatus with a diameter of 75 mm and a height of 150 mm. To ensure the uniformity of samples, materials were divided into five approximately equal portions. A funnel with a long shaft was used to deposit materials layer by layer, during which the bottom of the shaft was just touching the interface of deposited materials to ensure a zero-hight drop technique. After one portion was gently poured into the mould, side tapping was given around at four diagonal positions with a certain number of tapping. For each of the materials, the number of tapping was controlled to be almost the same, namely similar tapping energy. During the sample preparation process, the densification capacity is different due to particle shape and surface roughness, so the amount of material for the subsequent layers was slightly adjusted according to the level reached by the last portion. After sample preparation, the samples were isotropically consolidated with a confining pressure of 50 kPa, and then monotonically sheared in drained and dry conditions with a constant strain rate of 0.0006 %/sec.

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4. RESULTS AND DISCUSSIONS

Fig. 2 demonstrates the variations of deviator stress (q) with axial strain (ε_a) of tested materials during triaxial compression. The initial void ratios (e_0) and relative densities (D_{r0}) annotated in the figure were measured after isotropic consolidation to characterise the packing conditions of each case. Particle shapes can affect the packing density under similar external tapping energy. SGB has the lowest e_0 while AGB gives the greatest e_0. In addition, e_0 values for rough cases (*i.e.* RSGB, RCGB and RAGB) are greater than their smooth equivalent cases (*i.e.* SSGB, SCGB and SAGB), indicating that more angular particle shape and rougher surface prevent materials from densifying. The stress response is also affected by surface roughness, a greater value of q is observed for RSGB and RAGB, where the stick-slip happening with SSGB is also suppressed. An exception is identified for RCGB, giving a lower stress level than SCGB, which might be attributed to the looser packing concerning both e_0 and D_{r0}. Categorised by materials with different shapes, SGB exhibits the lowest q value, SS5 gives a medium value whereas CGB and AGB show the highest stress level. Among four, medium dense CGB displays significant soil softening behaviours at the post-peak stage while AGB gives a much later peak for the rough case but no significant peak for the smooth case. Consequently, compared with surface roughness that only promotes the shear strength, particle shape has a more profound impact on the stress responses as it cannot only affect the shear resistance but also the overall soil behaviour such as the onset of peak stress and the degree of stress softening.

To quantify the effect of particle shape, the deviator stresses at peak and steady states (q_{peak} and q_{ss}) were obtained from stress-strain responses to plot with overall regularity (OR). Note that q_{ss} is consistently retrieved from the value at ε_a=15% as not all cases have reached their steady states. In Fig. 3, both q_{peak} and q_{ss} decrease with the increase of OR. This reveals that more angular materials can attain a higher degree of shear strength, which can be compared under the equivalent tapping energy, although e_0 or D_{r0} was not maintained similar as a normal way to eliminate the effect of packing density.

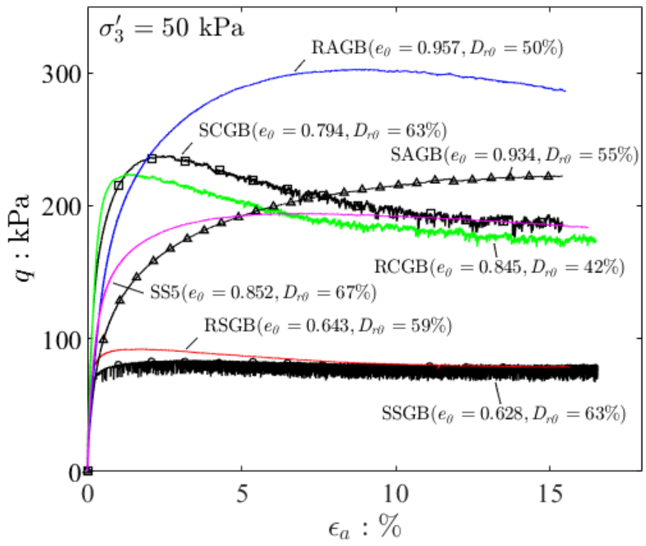

Fig. 2 Variations of deviator stress (q) with axial strain (ε_a) during triaxial compression prepared under similar tapping energy

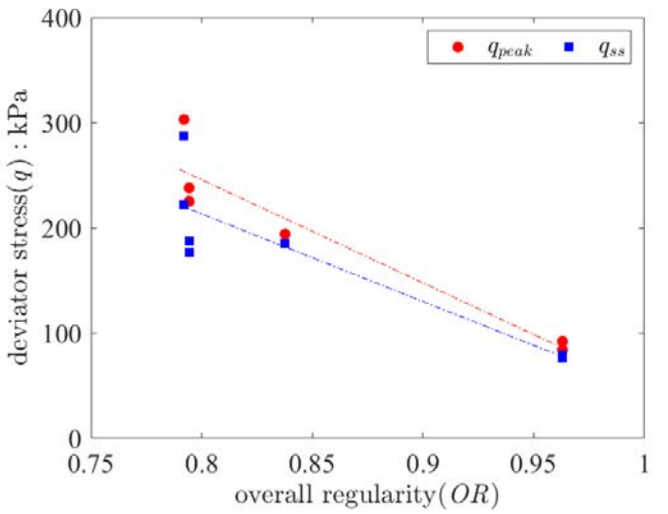

Fig. 3 Variation of deviator stresses at peak and steady states (q_{peak} and q_{ss}) with overall regularity (OR)

5. CONCLUSIONS

This study has considered the effect of particle morphology on the stress responses of granular materials using triaxial tests. Samples were prepared under similar tapping energy during sample preparation, then consolidated with an isotropic confinement of 50 kPa and monotonically sheared in a dry and drained condition. Main conclusions are drawn:

- More angular particle shape and rougher surface tend to cause looser packings when similar tapping energy is applied.
- Particle shapes significantly influence the stress responses including the appearance of peak stress and stress softening.
- Peak and steady state deviator stresses (q_{peak} and q_{ss}) are well corrected by shape parameter overall regularity (OR).
- Surface roughness also promotes a higher shear resistance, while its impact is less significant than that of particle shape.

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