TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Bauingenieurwesen
Institut für Geotechnik
Professur für Bodenmechanik und Grundbau

Influence of the grain shape and grain roughness on the soil behaviour – experimental investigation

(Einfluss der Kornform und –rauigkeit auf das Bodenverhalten – experimentelle Untersuchung)

Bashar Nseir

Introduction

The grain size distribution of a soil (D_{50} and C_u) determines the forces at the inter-particle level, the particle packing and the resulting soil macroscale behaviour. Therefore, the grain size distribution plays a central role in soil classification system. On the other hand, the influence of the particle shape and roughness on the strength and deformation properties of granular materials is being progressively realized .

The aim of this work is:

- First, to determine the grain shape and grain roughness of the tested materials.
- Second, to investigate the influence of the grain shape and grain roughness on the index and mechanical properties of the tested materials.

Tested materials

Three sands having almost identical grain size distribution were used. In this work, the sands are noted w5, w7 and w8 respectively. Smooth glass beads were also used as a reference material. The glass beads mixture was gathered, so that the grain size distibution of the sample is practically the same as the one of the sands.

Figure 1 shows the grain size distribution curves of the tested materials, while table 1 summarizes the mean size and coefficient of uniformity of the materials.

Material	w5	w7	w8	GB
D_{50} [mm]	0.54	0.6	0.58	0.6
C_u [-]	2.7	2.8	3.1	3.6

Table 1: Mean size and the coefficient of uniformity of the tested materials

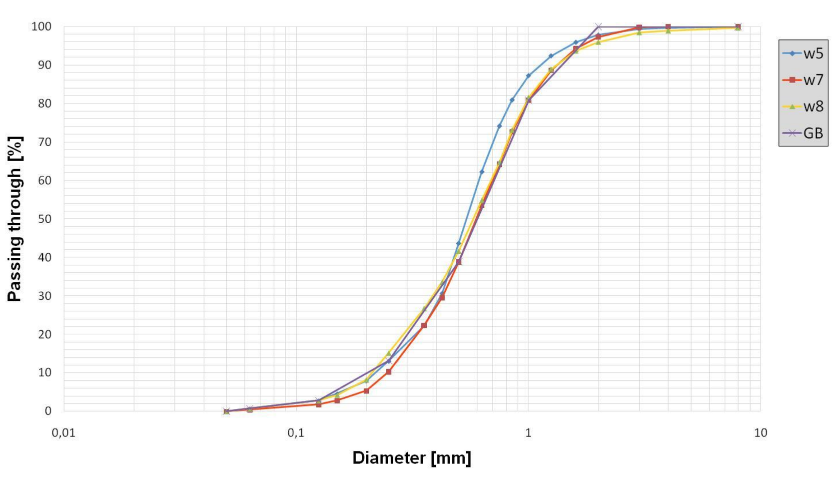

Fig. 1: Grain size distribution curves of the materials used in this study

Grain shape

The scanner method was used for the determintaion of the grain shape. In this method, the grains from different fractions of the materials are first scanned (Figure 2). The images produced from the scanner are transformed into binary (black and white) images and then processed with software *ImageJ*. The circularity and roundness of the materials are determined with *ImageJ*, but with defining the circularity as the width over the height of the smallest bounding rectangle of the grain instead of *ImageJ* definition.

The circularity and roundness values are summarized in Table 2.

Material	w5	w7	w8	GB
Circularity	0.85	0.85	0.88	0.97
Roundness	0.77	0.77	0.79	0.96

Table 2: Circularity and roundness of the tested materials

Table 2 shows that the three sands have the same circularity and roundness, while the glass beads have values very close to 1.

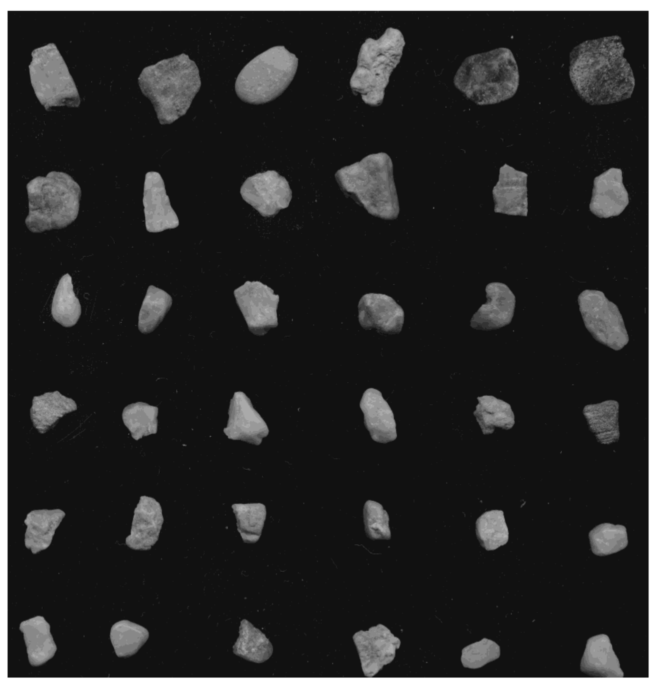

Fig. 2: Scan of w5 sand with a 47 pixels/mm resolution

Grain roughness

For the determination of the grain roughness, a high-resolution microscope was used for scanning the grains.
A new approach is used, in which the outline of each grain is searched for anomalies (marked with red ellipses in Figure 3). The term irregularity is used instead of roughness and it is defined as the ratio of the sum of the length of all anomalies over the length of the perimeter of the grain.
The grain is then described as:
- Smooth if the value of the irregularity is smaller than 0.33
- Rough if the value of the irregularity is between 0.33 and 0.66
- Very rough if the value of the irregularity is bigger than 0.66

The irregularity values of the sands are summarized in Table 3 and they show that both w5 and w8 sands can be described as smooth, while w7 can be described as rough.

Material	w5	w7	w8
Irregularity	0.2	0.36	0.15

Table 3: Irregularity values of the sands

Fig. 3: Determination of the irregularity of a grain from w7 sand (220 pixels/mm resolution)

Index and mechanical tests

Maximum and minimum void ratios

The maximum and minimum void ratios are plotted against circularity and roundness in Figure 4. Figure 4 shows that by having lower circularity and roundness, the sands obtained higher vlaues of e_{max} and e_{min} and higher void ratio difference $I_e = e_{max} – e_{min}$ than the glass beads.

Having lower circularity and roundness will hinder the grains mobility and their ability to attain a dense packing configuration which corresponds well with the results in Figure 4.

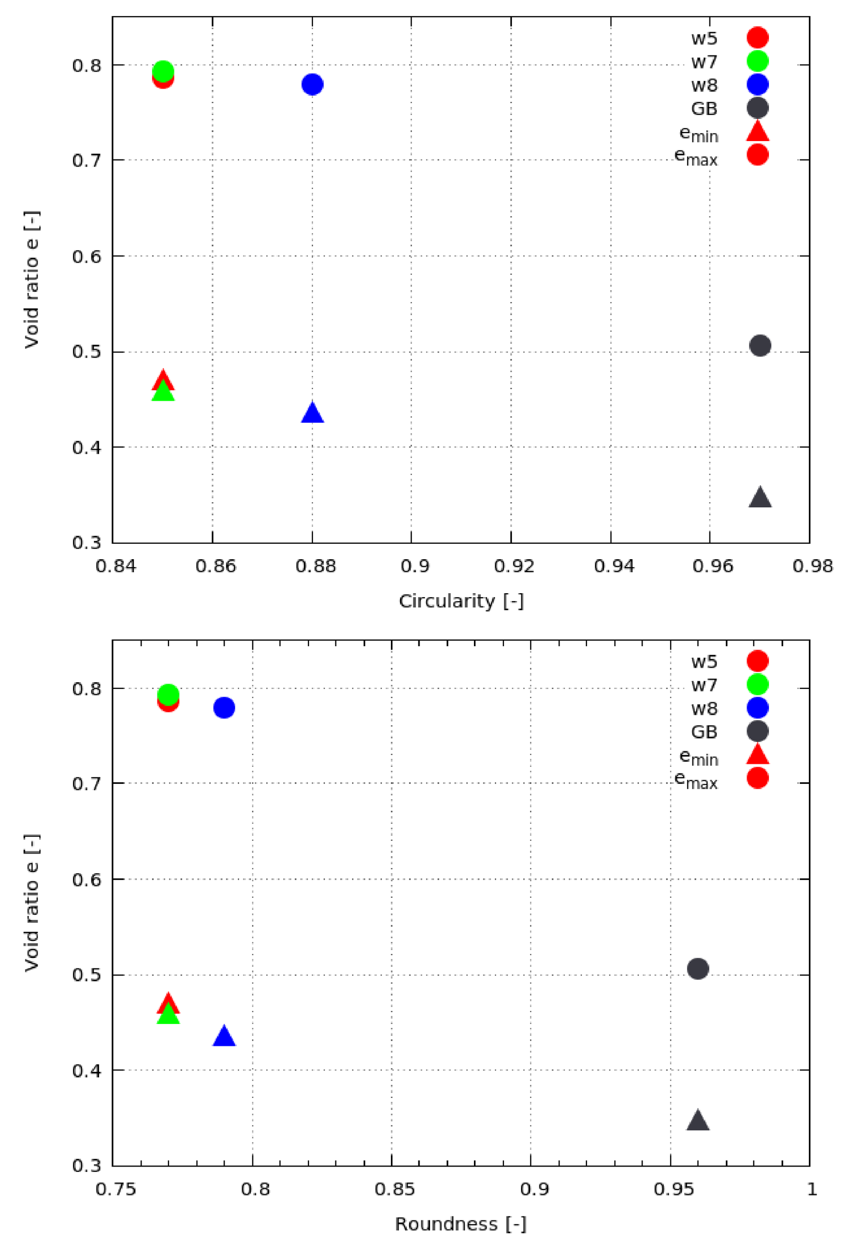

Fig. 4: Influence of circularity (top) and roundness (bottom) on the maximum and minimum void ratios

Oedometer

The compressibility index values are plotted against circularity and roundness in Figure 5. Figure 5 shows that by having lower circularity and roundness, the sands obtained higher vlaues of Cc than the glass beads.

Having lower circularity and roundness will increase the deformation at the contacts between the grains and will also hinder the contact slippage, which will lead to higher values of Cc. This corresponds well with the results in Figure 5.

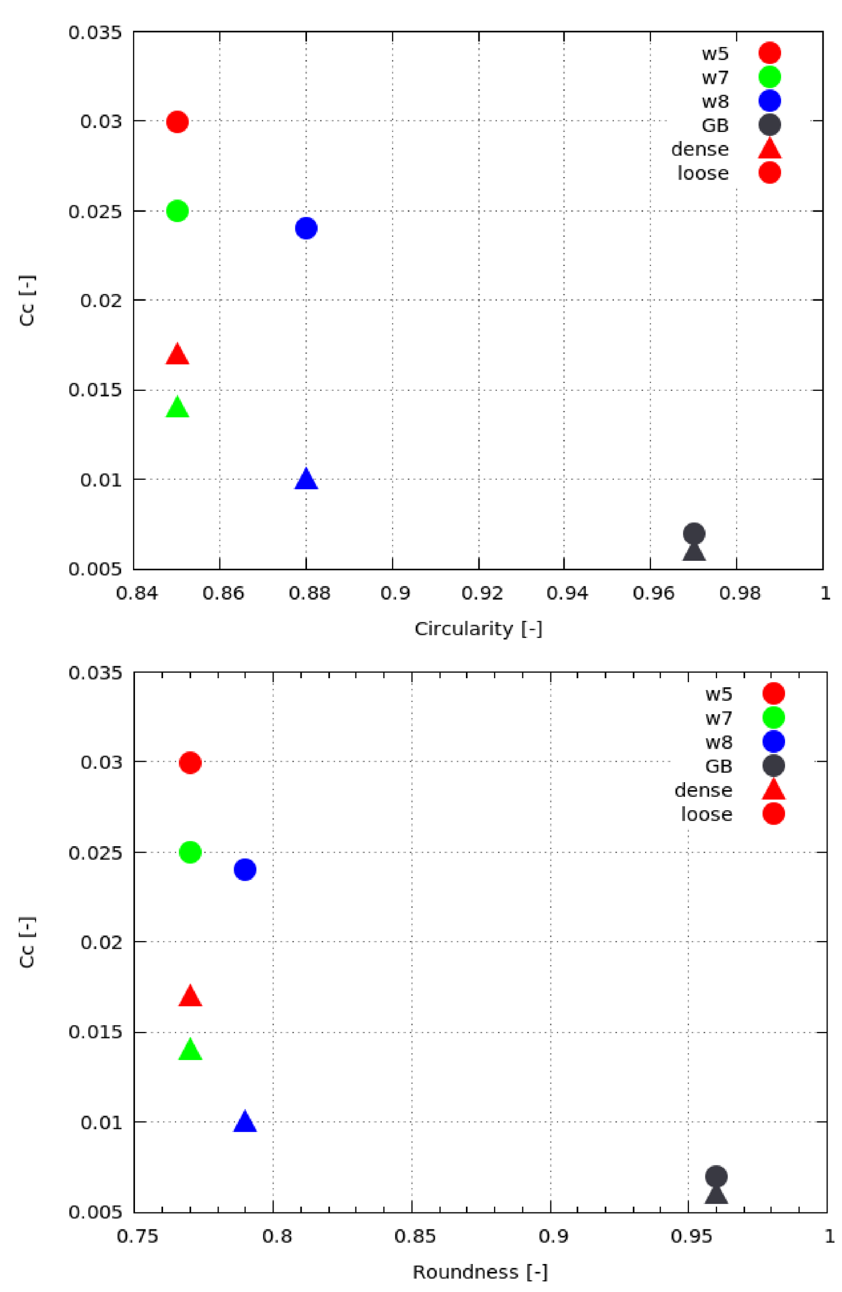

Fig. 5: Influence of circularity (top) and roundness (bottom) on the values of Cc

Direct shear

The values of critical and peak friction angles of the materials are plotted against roundness and irregularity in Figure 6. Figure 6 shows that the sands have close values of both critical and peak friction angles. w8 has the highest critical friction angle, while w7 has the highest peak friction angle and the highest dilatancy. The glass beads have lower values of the critical and peak friction angles than the sands. This corresponds well with the glass beads being smooth and round.
Having higher angularity will add difficulty to the grain rotation, while having higher irregularity will hinder the slippage between the grains, which will yield higher dilatancy and peak friction angle. This correspond well with the results in Figure 6.

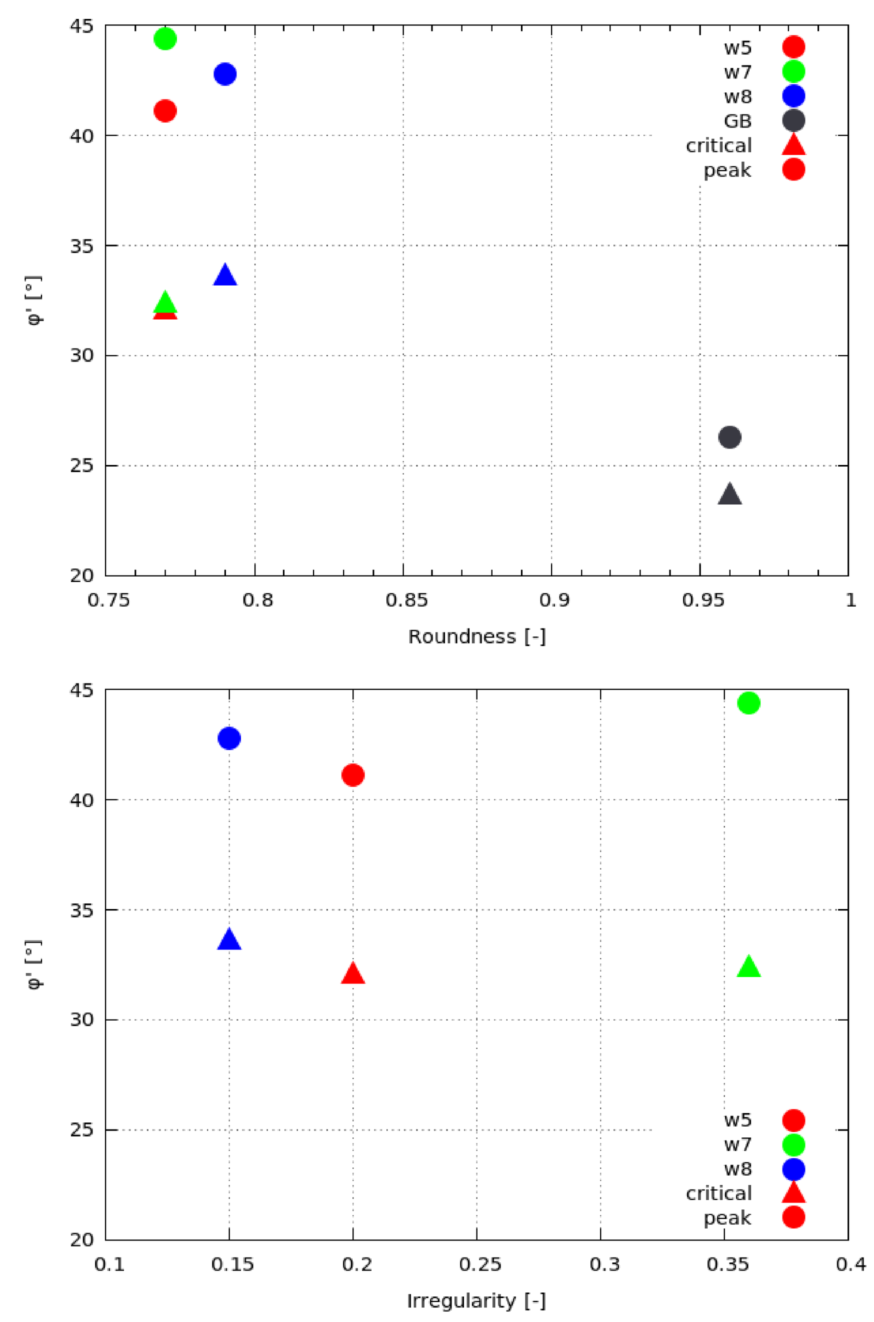

Fig. 6: Influence of roundness (top) and irregularity (bottom) on the critical and peak friction angles

Summary

In this work, the influence of the grain shape and grain roughness on the soil behaviour was investigated.
The processed scanned images of the materials showed that the sands have the same circularity and roundness, while w7 has higher irregularity than the other two sands.
The index tests results showed that having lower circularity and roundness allow the sand to obtain higher values of e_{max} and e_{min} and higher void ratio difference $I_e = e_{max} – e_{min}$.
The oedometer results showed that higher circularity and roundness yield lower values of Cc.
Finally, the direct shear results showed that lower roundness and higher irregularity yield higher peak friction angle and higher dilatancy.

Project
Master thesis

Responsible professor
Univ.-Prof. Dr.-Ing. habil. Ivo Herle, TU Dresden

Scientific mentors
M.Sc. Bozana Bacic

Submission
October 2019