Dear Referee #2

First of all, authors would like to say thank you very much for your careful review and precious comments to our first manuscript. Authors revised the first manuscript based on the referee #1 and #2. We submitted below files:

1. Revised manuscript with tracking change
2. Revised manuscript without tracking change
3. Letter to referees (this file)

In fact, we submitted texts, figures and tables separately in the first submission. But the revision manuscript has included all in one file in this revision process. Since authors decided to omit some figures based on referee's comment and so we imagined how referee reviewed second manuscript. We thought that it is probably better for both referees to be able to see the figures and tables and recognize which figure was omitted and modified in one file. Hence, the second manuscript includes many revisions and looks complicated. In order to clarify which figures were omitted and how figures were modified to both referees, we left detail revision history. Please accept this approach. Then, we put color maker at the part which referee pointed out in the first review for each referee's comment. We think it is not difficult for referee to find who authors revised in the manuscript. In below, authors put our comment for each referee's comment and we divided some for each revision. In the last, we listed the omitted references and newly added references.

Actually, authors provide two supplement results in this revision. Both referees pointed that the previous manuscript had too many figures so that authors omitted some figures based on the referee's comment. However, authors decided that it might be good to prepare supplement results to explain the contents to both referees. If referee agree with the use of supplement results, we will revise the number of figures in the next manuscript.

Reviewer's comments to the paper:

X-ray CT analysis of pore structure in sand
by Toshifumi Mukunoki et al.

This paper nicely fits the scope of this special issue of Solid Earth. I think that overall it is a welcome addition to the technical literature in the field, and its scientific content is quite good. However, in my opinion the current version of this paper requires some major revision, both in terms of the structure and most importantly in terms of the English, the quality of which is at times so poor that the reader doesn't understand the meaning of what the Authors are writing.

In the reviewer's opinion, the contribution under review cannot be published in its present form. The Authors should be encouraged to revise and resubmit their paper, but this will clearly require substantial modifications to the present version, and a new referee review.

Comments to referee#2

Again, authors would like to say thank you very much for your careful review and precious comments. We will reply you for each comment as below.

General remarks

1) Quality of the English: besides many typos and errors (too many to be listed herein: I'll just mention the word "retentively" often – but not always - used instead of "retention"), some statements are really hard to understand, e.g.,

- ✧ "*This behavior indicates that mean pose size caused a capillary pressure head of 30-40 cm is mainly distributed. This behavior should be caused by sands with a value less than the uniform coefficient*"
- ✧ "*Figure 24 concluded that a reasonable WRC can be obtained from saturation degree and distribution of pore diameter concerned the percolation property*"
- ✧ "*it was possible for the porosity and surface area to evaluate the relative standard deviation less than 1%*")
- ✧ "*… requires that the water/oil flow in the soil quantitatively understand the pore structure*"

I strongly suggest to the Authors to ask the help of a native English speaker.

Comments to referee#2

Next revision had included native check so English quality would be improved. Because of native check, some parts are grammatically revised except for referee's points so that the meaning of contents does not change, of course.

2) Figures: they are far too many (24!), and some of them are in fact quite useless – e.g., Fig. 1. Some other figures might be combined in one single figure.

Comments to referee#2

Authors agreed with referee's comment so we omitted some figures from previous manuscript as follows: Figures 1, 2, 3, 7, 10, 12, 13 and 22 as previous figure number. Figures 4, 8, 9 and 18 as previous figure number are revised and current figure numbers are Figure 6 in page 21, Figure 4 in page 17, Figure 5 in page 19 and Figure 11 in page 29.

2) References: they are often cited in large groups, and it is not clear what is the criterion for citing those references rather than others. It would be better to cite fewer references, while making clear(er) what was studied/presented in each of them.

Comment to referee #2

Authors revised them for each corresponding part.

Line 3-14 and line 17-21 in page 2

Line 10-14 in page 4 to line 18 in page 4 to line 12 in page 5; and,

Line 8 in page 30 to line 17 in page 31

3) Sections and subsections: they are far too many. The structure of the paper might be simpler, with fewer subsections.

Comment to referee #2

Authors agree with referee's comments so some figures are omitted and combined; hence, some sentences were also deleted.

More specific remarks

4) It is stated in the introduction that "*In this paper, authors distinguish pore from pore structure*" (page 3, line 12). Yet, I haven't been able to find in the paper any clear definition neither of the former nor of the latter.

Comments to referee #2

Authors agree with referee's comment so we made text on line 17-24 in page 13.

> Note that the labelled number is given to each circular element and its number is corresponding to the radius of circular element. Besides the location of each circular element is also recoded; hence, the spatial distribution of the overlapping circular element can be visualized as shown in Figure 2. The GIA is very useful technique because the pore size can be evaluated without measuring the individual pores. However, it should be recognized that the diameter of the circular element is not strictly equal to the pore diameter. The authors suggest a diameter for the spherical elements fitting the pore space as the pore size in sand; this will be discussed later in Section 4.

5) At the end of the introduction, the Authors write that "*the evaluation of sand will be treated in this paper because it is natural material and has a uniform grain shape*". This is just not true: Toyoura sand grains have not a "uniform" grain shape – whatever this means.

Comments to referee#2

Authors agree with referee's comment so we omitted the last sentence "Toyoura sand grains have not a "uniform" grain shape."

6) Image segmentation (section 3.1): The very first step of image binarization is not discussed at all, which is weird – this is a crucial step in the analysis, because it affects all subsequent

steps. They have used the image segmentation method developed by Otsu (1979). Are they aware that there are many other segmentation methods? The Authors simply inform the reader that "… *the Toyoura sand tested showed two distinct peaks in this study*", but they don't show any histogram of greylevel for a typical tomographic image – in my opinion they really should, this is mandatory.

Comments to referee#2

Authors agree with referee's comments so we prepared the histogram as supplement figure in page 9. Because both referees suggest us to reduce the number of figures. So, in this moment, we provide Figure S1 as shown in page 9 and if referee judged we should show this results, we will give the actual figure number to Figure S1. Then, authors added some related references Kato et al. (2014) and Mukunoki et al. (2014) on line 1 in page 9.

7) The explanation of the granulometric method (section 3.1.2, figure 5) is not very clear to me. I must confess I got lost – and yet I know a bit of image analysis…

Comments to referee#2

Figure 5 explained the shape of sphere element visually for readers in the previous manuscript. In fact, the size of sphere element become large based on the equation (2) which we explained section 3.1.2. As long as the equation was used to create sphere element, the diameter of sphere element should be odd number. This indicates that the pore space with even number of voxel is evaluated as one less size of sphere element. For example, the minimum sphere element is one voxel and this voxel can fill entire pore space. Next size of pore space should 2 voxels. But our algorithm does not prepare the sphere element with the diameter of 2 voxel so next size of sphere element is 3 as shown in Fig. 5 (b). Therefore, sphere element which the number of voxel for diameter is 3 scan the entire pore space but this cannot detect the pore space with 2 voxel. This is a feature of granulometric image analysis (GIA). Already we have 24 figures and both referees suggest us to reduce the number of Figure. Referee 1 suggests omitting Fig. 5 because this is very fundamental. We provide supplement results as Figure S2 in page 10-11.

8) Also section 3.2 is rather obscure to me, I find Fig. 6 really not clear. The Authors are encouraged to substantially improve this section (and this figure), because this is an important part of their paper.

Comment to referee #2

Authors appreciate kind encouragement in the comment. Authors also believe section 3.2 is important section. We explain Figure 2 more detail on line 1-7 in page 12.

9) In Fig. 9 (grain size distribution of Toyoura sand), the measured data are only two points.

How is it possible?

Comment to referee#2

Authors performed additional sieving test using different specification from the specification in Japanese geotechnical engineering; actually, we used the specification Japanese concrete engineering so we could add three more plots as shown in Figure 6 (previous number is Figure 9). As for the mineralogy of Toyoura sand, authors added more information in the text and two more references lines 12 to 14 in page 7.

Toyoura sand has been widely used as benchmark sand for civil engineering in Japan and it is a quartz dominative sand (Miura et al., 1989 and Oluwapelumi et al. 2012).

10) When commenting Fig. 23, the Authors state that "*the AIM had an overestimation of between0.03 and 0.055 mm* …". The figure might in fact also indicate that VPM underestimates pore size in that range…

Comments to referee#2

Authors appreciate referee's comments so we added more discussion on line 12-18 in page 32.

The AIM by Uno et al. (1998) supposes that the pore space in sand exists in a tubular form. Since air wants to intrude a large pore space, it is thought that the evaluation of the pore size by the AIM has a high precision; however, the precision decreases for the evaluation of pore space with a small size, where air does not smoothly intrude. On the other hand, the VPM can easily evaluate the size of a complicated pore space regardless of the physical interaction and does not assume that the complicated pore is a straight tube.

Conclusions:

11) Conclusion #1 is incorrect: the Authors cannot write that "*The size of a voxel affected the results of image analysis*", simply because they have studied only one voxel size. Of course I see what do they mean, and it is of course true that voxel size affects the results of image analysis. Affects, not affected: here is one of the numerous examples where a bad English can be misleading.

Comments to referee#2

Authors appreciate referee#2's comments. Native check was conducted to section of conclusions.

12) in conclusion #3, the statement "*This issue revealed that the pore diameter obtained from AIM was not Poiseuille*" deserves more explanations, I believe.

Comments to referee#2

Authors appreciate referee's comments so we added more discussion on line 12-18 in page 32.

The AIM by Uno et al. (1998) supposes that the pore space in sand exists in a tubular form. Since air wants to intrude a large pore space, it is thought that the evaluation of the pore size by the AIM has a high precision; however, the precision decreases for the evaluation of pore space with a small size, where air does not smoothly intrude. On the other hand, the VPM can easily evaluate the size of a complicated pore space regardless of the physical interaction and does not assume that the complicated pore is a straight tube.

13) conclusion #4: that "…the VPM was the better image analysis method distribution" should be explained better.

Comments to referee#2

Authors revised the conclusion at corresponding location on line 22-28 in page 35.

the VPM can easily evaluate the size of a complicated pore space regardless of the physical interaction and does not assume that the complicated pore is a straight tube. Then, the capillary pressure head can be deduced on the basis of the Young–Laplace equation as long as precise image data of the pores in sand were obtained by a microfocused X-ray CT scanner.

Further general remarks

14) On how many experiments is the paper based? Just one?

Response to referees.

We added one more WRC test result in Fig.13 (previous figure number is 20). In fact, the capillary pressures less than saturation degree (Sr) of 0.3 show the different curve from VPM results. It is not so easy to regulate the elevation head around low saturation degree so the accuracy less than Sr of 0.3 may be suspicious. But, we cannot evaluate the accuracy of this test method any more so authors hope that it is enough to add one more test result in Figure 13 in page 30.

15) The Authors are right when stating – at the very end of the paper – that "in future work, it will be necessary to verify the appropriate dimension (i.e. REV) for several kinds of grains". This is a very crucial issue: to what extent the results obtained in this study can be generalized to other granular materials and other resoultions/images? I believe the Authors should further comment on this.

Response to referees.

We added some words after the pointed sentence like below on line 33 in page 35 to line 3 in page 36.

In future work, it will be necessary to verify the appropriate dimensions (i.e., the REV) for several types of grains with round and angular shapes and wide range of grain sizes. These features will further clarify the issue of pore connectivity with respect to the aspect ratio, which affects the results of the WRC.

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Newly added reference list

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