Review History for "A simple method for the determination of sensitivity to density changes in sand liquefaction"

Bozana Bacic & Ivo Herle ***2020***

Summary

This paper was sent to two reviewers: Dr. Junghee Park, King Abdullah University of Science and Technology (Reviewer 1) and Dr. Jorge Macedo, Georgia Institute of Technology (Reviewer 2). The two reviewers remained anonymous during the entire review process. After the reviewing process was complete, both reviewers agreed to disclose their identity.

In Review Round 1, both reviewers provided a series of comments for the authors. Reviewer 1 recommended that revisions were required while Reviewer 2 recommended that the authors rework the manuscript and resubmit it for review.

In Review Round 2, Reviewer 1 recommended the manuscript for publication with no reservations. Reviewer 2 recommended revisions required. On the basis of the author responses to Review Round 1 and the clarifications those provided, the managing Editor decided to accept the revised version of the manuscript for publication with the caveat that sentences addressing the remaining concerns of Reviewer 2 be addressed during the manuscript copyediting process.

Review Round 1

Reviewer 1 (Junghee Park)

The authors propose a simple method for the sensitivity to density changes in sand liquefaction. They analyze their experimental results in terms of initial relative density and soil fabric. Specifically, soil fabric appears to be critical in the liquefaction resistance. In general, this paper is well written, and may attract the attention of the readers. However, this reviewer encourage the authors to address the following comments for the possible publication in *Open Geomechanics*.

Page No.	**Detail**	**Comments**
Page. 3	Figure 1	Please insert (laser distance sensor) followed by “7 – measurement of the horizontal displacement” in Figure 1 capture.
	Figure 2	I am not convinced of a constant confining effective stress u_o throughout experiments. The use of suction for confining stress under undrained conditions is not effective. After applying suction for confinement, have you ever checked that the suction value (u_o = 40 kPa) was constant for one hour without applying cyclic loading? I am not sure that this result is true soil behavior or because of losing suction.
	Figures 2 & 7 - drained or undrained?	Saturated sand specimens subjected to cyclic loads require a determination of drained or undrained loading conditions in terms of time-scales. The time for loading tload should be smaller than the time for pressure diffusion tdiff for undrained conditions in this study (i.e., tload << tdiff); clearly, undrained loading conditions prevail. If we consider f = 1 Hz, how long does it take to reach 90% of consolidation for Sands 1, 2 and 3?
	Axis title	Please add axes titles for all figures.
	N50	Could you address the reason why the number of cycles N_{50} corresponding to $\Delta u = 0.5u_o$ represents the sensitivity to liquefaction?
	Soil Fabric	The authors define “soil fabric” in page 6. However, the definition is not clear for me. Could you redefine the term and address earlier in the manuscript?
	Figure 3	Could you change the x-axis scale i.e., 0.01, 0.1, 1, 10? Furthermore, please put a boundary line for grain diameter d = 0.075 mm.
	Table 1	Particle shape is missing in the Table although shape plays a critical role in prediction of soil response, packing density, and critical state soil behavior. Could you analyze your data from the particle shape point of view? It will strengthen this article.
Page. 4	Table 2	What does A = 2.5 cm ±2% indicate? Please define all symbols throughout the manuscript.
Page. 5	Figure 7	Even dense sands tend to contract in the beginning of shear loading. It will generate positive pore water pressure. It is ok. However, based on the results in this figure, phase transformation point seems to vary with sand type. Could you discuss this observation?
	Figure 7	Furthermore, is it meaningful to involve the test results for sand specimens with D_{ro} > 0.65 to investigate the sensitivity to density changes in liquefaction? If we exclude the results for sand specimens with D_{ro} > 0.65, the regression coefficient k_{cs} for Sand 2 seems to be very similar with k_{cs} for Sand 3.
	Figure 7	Sand specimens with D_{ro} < 0.50 seem to experience 20 kPa positive pore water pressure when subjected to one single cyclic loading event. Is it true?
Page. 6	Table 3	You may miss putting the data for Sand 1 as in this table 3 into Figure 7. If we add this data for Sand 1 – D_{ro} = 0.428 and N_{50} = 36 in Figure 7 and exclude the results above D_{ro} = 0.7, Sand 1 may exhibit the greatest k_{cs} coefficient.
Page. 6	Role of soil fabric and Figure 12	I am not convinced of the two statements and do not agree with them: • “Therefore, it is reasonable to assume that all specimens have the same soil fabric in the initial state” • “Thus, the same soil fabric is controlling the build-up of the pore water pressure more than (different) the relative density” There seems to be many other factors that lead to similar N_{50} values rather than soil fabric (e.g., low C_u? particle shape?, or very sensitive relative density values for three sands within error range?). Furthermore, how can authors distinguish the effect of soil fabrics and relative density on N_{50}? Once again, please check whether pore water pressure is constant or not for one hour without applying cyclic loading.

Reviewer 2 (Jorge Macedo)

The authors present a procedure for a rapid determination of sensitivity to density changes in sand liquefaction. This reviewer considers that the experimental procedure should be much more detailed (or referenced). Using only the current information in the manuscript, this reviewer feels there is not enough information to have an opinion on the value of the proposed procedure. The authors show comparisons of their procedure using results from 3 sets of cyclic triaxial tests. This reviewer considers that this is not a proper validation of a procedure, 3 sets of cyclic triaxial tests are not sufficient. In addition, it is not clear what the influence on boundary conditions, loading mode, and loading frequency on the presented comparisons is. Finally, the conclusions about the fabric influence using only relative density seem not to be conclusive. See the attached document for specific comments.

Author Response

Response to Reviewer 1 (Junghee Park)

Figure 1:
Please insert (laser distance sensor) followed by ”7 – measurement of the horizontal displacement” in Figure 1 capture.

Authors: We inserted it.

Figure 3:
I am not convinced of a constant confining effective stress u_0 throughout experiments. The use of suction for confining stress under undrained conditions is not effective. After applying suction for confinement, have you ever checked that the suction value (u_0 = 40 kPa) was constant for one hour without applying cyclic loading? I am not sure that this result is true soil behavior or because of losing suction.

Authors: The authors agree with the reviewer that this issue may be of importance. The suction value was checked in case of Sand 1 for longer than one one hour. However, for the tests in this study only first 30 to 40 seconds (30 to 40 cycles since f = 1 Hz) are relevant, because this is the duration of the tests with the lowest initial relative densities in case of the three sands (see Table 3 and Figure 13) where the reduction of the suction is the highest. The results have shown that this reduction lies under 1 kPa for 40 s (see Figure 2) and the authors consider its influence on the final results as negligible. The same can be assumed for Sand 2 and Sand 3. A short clarification has been added to the manuscript.

Figures 3 & 8:
Saturated sand specimens subjected to cyclic loads require a determination of drained or undrained loading conditions in terms of time-scales. The time for loading tload should be smaller than the time for pressure diffusion t_{diff} for undrained conditions in this study (i.e., $t_{load} << t_{diff}$); clearly, undrained loading conditions prevail. If we consider f = 1 Hz, how long does it take to reach 90 % of consolidation for Sands 1, 2 and 3?

Authors: The specimen is globally in undrained conditions. There is no possibility for external drainage. Analogously to numerous undrained cyclic shear tests published by other authors elsewhere, one representative PWP for the whole specimen is assumed. This explanation has been added to the manuscript.

Axis title:
Please add axes titles for all figures.

Authors: We added them.

N50:
Could you address the reason why the number of cycles N_{50} corresponding to $\Delta u = 0.5 u_o$ represents the sensitivity to liquefaction?

Authors: In the presented paper the k_{cs} is representing the sensitivity to liquefaction and not N_{50}. With N_{50}, the rate of increase of pore water pressure during cyclic loading is covered. The authors are convinced that the change to another reference number, *e.g.* N_{60}, would not change the statements based on these tests.

Soil Fabric:
The authors define “soil fabric” in page 6. However, the definition is not clear for me. Could you redefine the term and address earlier in the manuscript?

Authors: We redefined the term and addressed it in the introduction part.

Fabric:
Could you change the x-axis scale i.e., 0.01, 0.1, 1, 10? Furthermore, please put a boundary line for grain diameter d = 0.075 mm.

Authors: The authors do not understand the requirement. They prefer the representation of the grain size distribution curve as common in soil mechanics, since it helps to clasify the soil visually. The reason for the boundary d = 0.075 mm is not clear for the authors.

Table 1:
Particle shape is missing in the Table although shape plays a critical role in prediction of soil response, packing density, and critical state soil behavior. Could you analyze your data from the particle shape point of view? It will strengthen this article.

Authors: It is not possible for the authors to analyze the particle shape in detail at the present stage. However, by visual inspection the particle shape is similar for all three tested sands. This additional information has been added to the manuscript.

Table 2:
What does A = 2.5 cm ±2 % indicate? Please define all symbols throughout the manuscript.

Authors: A indicates the loading displacement. We have defined all symbols in the corresponding figure and text.

Figure 8:
Even dense sands tend to contract in the beginning of shear loading. It will generate positive pore water pressure. It is ok. However, based on the results in this figure, phase transformation point seems to vary with sand type. Could you discuss this observation?

Authors: The tested sands generate only positive pore water pressures. In Figure 8 each point represents one test. We did not observe any negative pore water pressure change within one cycle. Thus, we cannot discuss the phase transformation point on the basis of our tests.

Figure 8:
Furthermore, is it meaningful to involve the test results for sand specimens with $Dr_0 > 0.65$ to investigate the sensitivity to density changes in liquefaction? If we exclude the results for sand specimens with $Dr_0 > 0.65$, the regression coefficient k_{cs} for Sand 2 seems to be very similar with k_{cs} for Sand 3.

Authors: The authors are convinced, that it is scientifically non-ethical to exclude experimental data.

Figure 8:
Sand specimens with $Dr_0 < 0.50$ seem to experience 20 kPa positive pore water pressure when subjected to one single cyclic loading event. Is it true?

Authors: No, this is not true. See *e.g.* Figure 3.

Table 3:
You may miss putting the data for Sand 1 as in this table 3 into Figure 8. If we add this data for Sand 1 – $Dr_0 = 0.428$ and $N_{50} = 36$ in Figure 8 and exclude the results above $Dr_0 = 0.7$, Sand 1 may exhibit the greatest k_{cs} coefficient.

Authors: We have added the data for Sand 1 from Table 3 to Figure 8. The additional point does not influence the results very much. k_{cs} values have been adjusted accordingly. However, we do not want to exclude any measured data since this would contradict a good scientific practice.

Figure 12: I am not convinced of the two statements and do not agree with them:

- “Therefore, it is reasonable to assume that all specimens have the same soil fabric in the initial state”

- “Thus, the same soil fabric is controlling the build-up of the pore water pressure more than (different) the relative density”

There seems to be many other factors that lead to similar N_{50} values rather than soil fabric (e.g., low C_u? particle shape?, or very sensitive relative density values for three sands within error range?).

Authors: The authors agree that there are many factors influencing the tendency of soil to the build-up of pore water pressure. Nevertheless, the assumption of the same fabric follows from the same installation procedure for all specimens regardless of the sand. This assumption is common in soil mechanics if the grain shape is not significantly different. As the authors have stated, the particle shape is visually similar for all three sands. The experiments show that all three sands have similar N_{50} values although the relative density is significantly different in case of Sand 2. The differences in the relative density are not surprising since there is a distinctly different Cu value for Sand 2 compared to Sand 1 and Sand 3. Thus, logically, the same installation procedure (fabric) is responsible for the similar N_{50} values. (In other words, the authors want to point out to the fact that the common empirical criteria for the liquefaction based on relative density may be misleading.) The sensitivity of relative density values has been determined from the repeatability tests and included in the manuscript: The uncertainties in Dr0 values (derived from the repeatability tests) lie in range of ±2 %.

Furthermore, how can authors distinguish the effect of soil fabrics and relative density on N_{50}? Once again, please check whether pore water pressure is constant or not for one hour without applying cyclic loading.

Authors: The relative density can be measured and its effect can be directly quantified. Concerning the soil fabric, all specimens are prepared with the same installation procedure, see our last answer above. It is commonly accepted that specimens create a similar fabric in that case, if the grains are not dramatically different. The issue of pore water pressure decrease has been discussed at the beginning of our responses to the reviewer.

Response to Reviewer 2 (Jorge Macedo)

Since the reviewer 2 made comments directly in the pdf file, their comments and questions will here be related to the marked part of the text.

Marked text: factors for SPT or CPT penetration resistance were made [Youd and Idriss, 2001].
There is much modern literature that the authors should mention. The authors are focusing only on empirical-based procedures but the liquefaction research has also considered mechanistic- based approaches and it was been gradually moving to evaluating the consequences of liquefaction and not only the triggering (the empirical procedure only addresses the triggering).
Authors: We have included additional references. Nevertheless, this paper doesn’t intent to provide a review of the methods for liquefaction analyses.

Marked text: This can be useful especially in regions with a high variability in the soil properties, like flooded man-made landfills as products of the open pit mining. Could please the authors clarify the example they are offering.
Authors: We have offered an example from Lusatia, Germany.

Marked text: The role of relative density and fabric for soil liquefaction is indisputable [Ishihara, 1993]
A better descriptor than relative density is the state. The authors could consider any of the available definitions of state (i.e. the state parameter). Density along even for a fixed fabric may not control the potential to liquefaction.
Authors: The authors agree with the reviewer. However, since all tests in the manuscript are related to the same initial pressure, the state parameter is not of major importance here.

Marked text: the cylindrical specimen
What is the cylindrical specimen the authors are referring to? It was not previously introduced.
Authors: We have corrected the sentence: A fast installation of a cylindrical specimen is possible and the test provides results in a short time.

Marked text: A very high initial saturation ($Sr \approx 99\%$) of the soil is achieved in this way.
How saturation is controlled?
Authors: The following explanation has been added to the manuscript: Saturation is controlled by mixing of sand with water under vacuum prior to the installation of the specimen. Degree of saturation is determined by measuring the mass of water

in the specimen at the end of the test. These measurements yielded fluctuations up to ±2 %.

Marked text: specimen, the PWP and the effective stress are equal to zero (neglecting the self-weight stresses).
Could the authors clarify this sentence.
Authors: The sentence has been modified in the manuscript: After installing the specimen into the installation mold, the PWP and the effective stress are equal to zero corresponding to the atmospheric pressure (neglecting the self-weight stresses coming from the very small height of the specimen).

Marked text: It remains unchanged and equal to zero during the entire test.
Please clarify if this stress actually remains equal to zero.
Authors: The following explanation has been added to the manuscript: The total stress corresponds to the relative air pressure (atmospheric pressure) acting on the rubber membrane from outside (2). Small oscillations of the relative air pressure during the test can be considered negligible. It remains unchanged and equal to zero during the entire test.

Marked text: u0 is applied to the bottom of the specimen (3).
How the level of suction/pore pressures is controlled
Authors: The sentence has been extended in the manuscript: In order to consolidate the specimen, a negative PWP u0 is applied to the bottom of the specimen (3) using a volume pressure controller.

Marked text: cyclic horizontal displacement of the top cap of the specimen (5). This induces a deformation mode similar to cyclic simple shear (combined with a slight bending of the soil specimen). The displacement amplitude and frequency are kept constant during the entire test.
What is the influence of boundary conditions, system rigidity, loading frequency, etc. in the setup that the authors propose. The authors should put this in the context of other "well known" tests.
Authors: We have added an explanation to the manuscript. It is not possible for the authors to analyze all the details mentioned by the reviewer at this stage of the research. It is important to emphasize that all depicted results were obtained under the same conditions. Thus the influence of the effects mentioned by the reviewer is the same in all tests.

Marked text: During the test, the air pressure around the specimen and the excess PWP u within the soil are measured and registered.
How this is accomplished?
Authors: The following explanation has been added to the manuscript: During the test, the air pressure around the specimen and the excess PWP u within the soil are measured using two independent pore pressure transducers.

Marked text: certain value, e.g. 50 % of its initial value u_0.
Is this the initial suction?
Authors: No, this is the value of the pore water pressure in the specimen after the test is terminated, as stated in the sentence in the manuscript.

Marked text: 'disturbed' soil state (fabric, stress level) is always the same although different than in situ. The initial relative density depends on the granulometric properties of the tested soil. Such methodology enables a comparison of the results for different sands and can be understood as an analogy to the conventional index tests, e.g. determination of ρ_{min} and ρ_{max}.
How stress, is controlled during the test. For example If a test under 100 kPa is desired and then another test under 200 kPa is also desired; is there flexibility to do this with the author's setup?
Authors: The stress is controlled by a volume pressure controller, as stated above. A certain flexibility is possible up to the stress level of 100 kPa.

Marked text: All specimens were prepared with the same procedure
Please detail the preparation procedure
Authors: The procedure is explained in detail in Section 2.1. The following modification has been made in the manuscript: All specimens were prepared with the same procedure (described in 2.1) resulting in similar values of the initial relative density.

Marked text: dilatancy
Show dilatancy
Authors: Due to the undrained conditions, the volume of the specimen remains constant. Dilatancy is therefore not possible, only a tendency to it is reflected in the pore water pressure.

Marked text: Figure 6
Why P starts at 40 and then decreases?
Authors: P starts at 40 because all specimens were consolidated up to 40 kPa (see Table 2) at the beginning of the test. It decreases due to the pore water pressure increase during the applied cyclic loading.

Marked text: It is defined as the cyclic stress ratio (CSR) causing failure of the soil specimen in Nf = 10 cycles.
Please reference this definition
Authors: We have referenced it: It is defined as the cyclic stress ratio (CSR) causing failure of the soil specimen in N f = 10 cycles [Wichtmann et al., 2019].

Marked text: the cyclic shear tests
What are the cyclic shear tests the authors are referring to? Are the tests in this study?. This could be confusing since cyclic shear tests are well known in practice and they represent a different condition.
Authors: Yes, the referred cyclic shear tests are the tests from this study. The following modification has been made: Using a conventional description, the states of the triaxial specimens vary between loose and medium dense, while the specimens of the cyclic shear tests from this study are all in the medium dense state.

Marked text: specimen installation
Only installation?
Authors: Yes, we refer here only to the initial state after the specimen installation.

Marked text: factor Nc
What is Nc representing?
Authors: Nc is a scaling factor. It has been explained in the paper: In order to make a basis for a quantitative comparison of the results, the N50-values were divided by a scaling factor Nc.

Marked text: Many studies have demonstrated a strong influence of the soil fabric on the tendency to liquefaction.
Please reference these studies
Authors: We have added references to the manuscript.

Marked text: Table 3: 0.428
What is the uncertainty in these initial relative densities?, What would happen for larger densities? I think the authors should make this comparisons in terms of the soil's state (e.g. state parameter), it is not clear if the uncertainties associated with Dr, could be influencing the comparisons. In addition, what is maximum relative density for which the consistency in the pore pressure curves hold?
Authors: The uncertainty in initial relative densities (2 %) has been calculated from the repeatability tests and included in the paper. The soil state is defined mainly by the density since the con- fining pressure is the same in all tests. Within the submitted manuscript, the authors focus on the response of different sands installed by the same procedure and not on the role of higher densities.

Review Round 2

Reviewer 1 (Junghee Park)

This reviewer would like to thank the authors for the revisions and detailed responses. The authors have adequately addressed my review comments and now I have no reservation on this manuscript being published in Open Geomechanics.

Reviewer 2 (Jorge Macedo)

The authors addressed most of the questions proposed by this reviewer. However, there are some additional remaining doubts that I recommend to clarify.

1. It is not clear how the proposed experimental setup will be beneficial in environments with marked soil variability, the authors should make this clear if they consider there are important advantages of their procedures for these cases.

Environments with large soil variability tend to have important fine contents, and I consider this would impose challenges on the proposed procedure.

2. I do not agree with the author's statement: "…the state is not of major importance here..", I understand that density is capturing the state because the confinement was constant, but this is not consistent with saying that the state is not important.
3. The authors should include a section that describes the limitations of their proposed procedure. For example, it seems that it can be applied up to 100kPa, but not beyond, are there other limitations, etc?

Author Response

Additional responses other than those noted below in the Editor Decision were not requested from the Authors. Great, please publish it.

Editorial Decision

At the end of Review Round 2, the managing Editor has decided to accept the revised version of the manuscript for publication with the caveat that sentences addressing the remaining concerns of Reviewer 2 be addressed during the manuscript copyediting process since they do not change the technical content of the manuscript but rather clarify the limits of applicability of the proposed method. The applicability of the method could be expanded in the future pending additional tests and analysis on different soils.