Review History for "Comparative performance of some constitutive models in stress rotation"

Fabian Schranz, Wolfgang Fellin, Dimitrios Kolymbas *2019*

Review Round 1

Reviewer 1 (David Mašín)

The authors compare various so-called constitutive models in their performance with respect to stress rotations in less-standard laboratory tests (1gamma2epsilon and hollow cylinder). First, the selected models are briefly described, then mechanics of continua relevant for these tests is summarised and subsequently predictions of stress-controlled cyclic tests in the two apparatuses are shown. Merits and shortcomings of various models are identified.

I find the paper to be clearly and carefully written and technically sound. I recommend few relatively minor modifications:

- Graphs in Figs. 10, 11 and 12 are for some reason half-width of a column. I recommend to enlarge them for full-width for clarity. Also, it might be better to use the same vertical scales, so that differences between the models can be better identified.
- For 1gamma2epsilon simulations, please include also epsilon_V with respect to number of cycles and gamma with respect to number of cycles graphs.
- I do not find quite relevant comment "No simulations have been performed with Hardening Soil since the model show no volumetric reaction, and hypoplasticity with intergranular strain since there are just very small differences between the two hypoplastic models". Please add also Hardening soil model istrain hypoplasticity simulations: if there are no volume strains in hardening soil, it would be good to demonstrate it. There will also be some shear strains, which would be good to show in epsilon(V,q) vs. number of cycles graphs. If istrain hypoplasticity gives very similar results to basic hypoplasticity, it would also be good to provide it to demonstrate this statement.
- Please also provide epsilonV vs epsilonq graphs for hollow cylinder simulations.
- Comment at page 8 bottom left "The other here used models are even simpler than this Sanisand-model" should be reformulated. The authors only want to say they have smaller number of parameters and so they should say it. Something like "model simplicity" as an arguable term, with probably much wider scope than the number of parameters only.

Reviewer 2 (Xiusong Shi)

General comments
The authors chose several constitutive models to simulate soil behavior in case of stress rotation. These models include two elastoplastic models, one hypoplastic model and one barodetic model. The work may provide a reference for others working in this area. The paper is well written, tables and figures are well presented. Therefore, I would like to recommend the acceptance of the paper. In addition, some specific comments are listed below for the authors to consider.

Specific comments
(1) Simulation of the models reveals a good consistency in case of conventional triaxial tests and simple shear tests (Figs 1 and 3). However, there is a significant difference while simulating hollow cylinder tests. Can you give more explanations for this discrepancy, e.g., the parameters calibrated based on conventional triaxial tests, the yield surface (elastoplastic models) or limit stress surface (hypoplastic model) related to different stress components, etc.

(2) Section 4.2, regarding the cyclic shear tests done by Joer et al. (1998), can you provide more details of the tested soil, e.g., the initial void ratio and the limit void ratios which controls the soils behavior.

(3) The authors simulate both the volumetric and deviatoric strains in hollow cylinder tests, however only the test data of volumetric strain was given (Fig. 14). Can you provide the test data of deviatoric strain for comparation with the simulations?

(4) The soil shows contraction in cyclic hollow cylinder tests; however, all simulations show an opposite results (dilatancy). Can you give an explanation if possible? E.g., take the elastoplastic models as an example, check the penitential surface and the plastic flow, etc.

Other minor ones:
(1) In the abstract part," "The obtained numerical simulations are compared to each other", "compared to" should be "compared with". (2) Fig. 12, the x-tick labels are overlapped.

Author Response

We are grateful for the suggestions of the referees and have revised our manuscript carefully. In the following we give detailed answers to the comments. Changes concerning the remarks of reviewer A are marked in green in the manuscript. Changes concerning reviewer B, are marked in blue.

Reviewer: Graphs in Figs. 10, 11 and 12 are for some reason half-width of a column. I recommend to enlarge them for full-width for clarity. Also, it might be better to use the same vertical scales, so that differences between the models can be better identified.

Response 1: We followed the recommendation and changed the figures.

Reviewer: For $1\gamma2\varepsilon$ simulations, please include also ε_v with respect to number of cycles and gamma with respect to number of cycles graphs.

Response 2: We added the plots.

Review: I do not find quite relevant comment "No simulations have been performed with Hardening Soil since the model show no volumetric reaction, and hypoplasticity with intergranular strain since there are just very small differences between the two hypoplastic models". Please add also Hardening soil model istrain hypoplasticity simulations: if there are no volume strains in hardening soil, it would be good to demonstrate it. There will also be some shear strains, which would be good to show in $\varepsilon_{(V,q)}$ vs. number of cycles graphs. If istrain hypoplasticity gives very similar results to basic hypoplasticity, it would also be good to provide it to demonstrate this statement.

Response 3: We added the plots.

Review: Please also provide ε_V vs ε_q graphs for hollow cylinder simulations

Response 4: We added the plots.

Review: Comment at page 8 bottom left "The other here used models are even simpler than this Sanisand-model" should be reformulated. The authors only want to say they have smaller number of parameters and so they should say it. Something like "model simplicity" as an arguable term, with probably much wider scope than the number of parameters only.

Response 5: We clarified the statement.

We are grateful for the suggestions of the referees and have revised our manuscr ipt carefully. In the following we give detailed answers to the comments. Changes concerning the remarks of reviewer B are marked in blue in the manuscript. Changes concerning reviewer A, are marked in green.

Reviewer: Simulation of the models reveals a good consistency in case of conventional triaxial tests and simple shear tests (Figs 1 and 3). However, there is a significant difference while simulating hollow cylinder tests. Can you give more explanations for this discrepancy, e.g., the parameters calibrated based on conventional triaxial tests, the yield surface (elastoplastic models) or limit stress surface (hypoplastic model) related to different stress components, etc.

Response 1: This is exactly the question addressed. To emphasize this, we added the following text in the conclusion: *The simulation of tests with rotation of principal axes (shear tests) is a veritable extrapolation if the constitutive model has been calibrated on the basis of rectilinear extensions only. Clearly, extrapolations are more risky than other tests, which can be understood rather as interpolations. Correspondingly, a realistic simulation of shear tests is more difficult to achieve and cannot be expected from every constitutive model. It should also be taken into account that deviations from homogeneity are more pronounced in shear tests, and this makes such tests less appropriate for calibration and also for validation.*

Unfortunately, we do not have an exact explanation for that discrepancy, however, some more insights are given in Response 4.

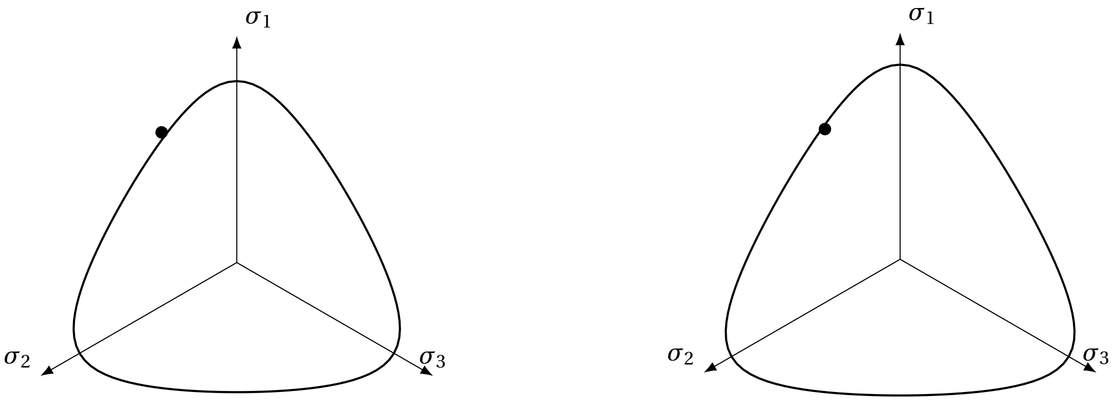
Reviewer: Section 4.2, regarding the cyclic shear tests done by Joer et al. (1998), can you provide more details of the tested soil, e.g., the initial void ratio and the limit void ratios which controls the soils behavior.

Response 2: Unfortunately, Joer et al. (1998) do not mention the initial void ratio nor the limit void ratio.

Reviewer: The authors simulate both the volumetric and deviatoric strains in hollow cylinder tests, however only the test data of volumetric strain was given (Fig. 14). Can you provide the test data of deviatoric strain for comparation with the simulations?

Response 3: Unfortunately, the deviatoric strain data have not been published by Tong et al. (2010).

Reviewer: The soil shows contraction in cyclic hollow cylinder tests; however, all simulations show an opposite results (dilatancy). Can you give an explanation if possible? E.g., take the elastoplastic models as an example, check the penitential surface and the plastic flow, etc.



(a) $\varphi_c = 30°$ (b) $\varphi_c = 32°$

Figure 1: Matsuoka-Nakai failure criterion for different friction angles with stress point

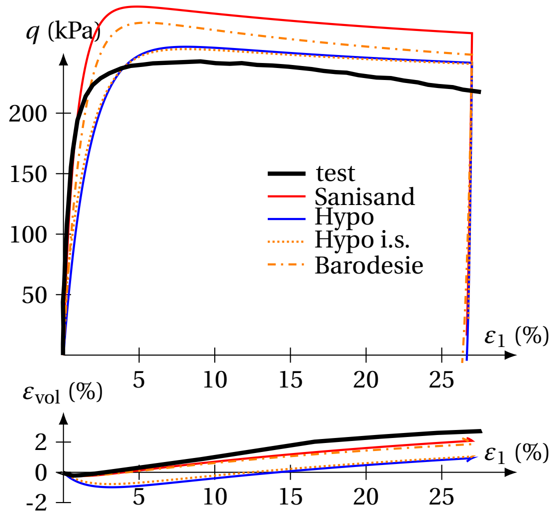
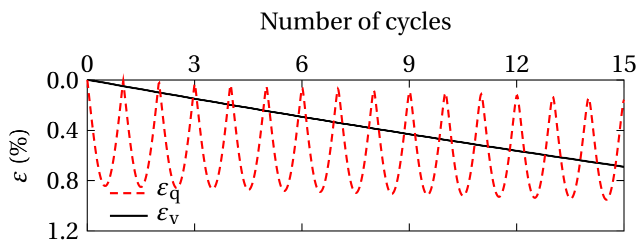


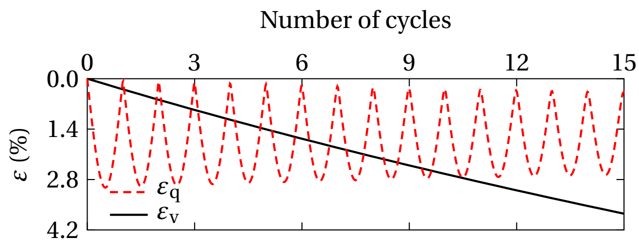
Figure 2: Stress-strain and volumetric strain curves for different constitutive models with $\varphi_c = 32°$ compared with a triaxial test in Verdugo and Ishihara [1996]

Response 4: Unfortunately we do not have a conclusive explanation. However, we have found out that the hollow cylinder test with the dilative behaviour has the speciality that the deviatoric stress imposed by the anisotropic consolidation is higher than the deviatoric stress at critical state, which is displayed in the principal stress space in Fig. 1a where the stress point is outside the critical state surface. Such a stress state can only be reached by a dense soil, for which a dilative behaviour is reasonable, at least for large deformations. Increasing the critical friction angle from $\varphi_c = 30°$ to $\varphi_c = 32°$ inflates the critical state surface, such that the stress at the end of the anisotropic consolidation is inside the critical state surface, see Fig. 1b. This changes the volumetric response of the computations with Hypoplasticity and Sanisand to contraction. Barodesy still predicts dilatancy, see Fig. 3. This poses the question whether the parameters are properly fitted for Hypoplasticity and Sanisand. As shown in Fig. 2 the triaxial experiments are poorly fitted with Sanisand with the higher critical friction angle. Hypoplasticity shows almost the same deviations as with the low critical friction angle (Fig. 4a), however, the peak is overestimated, and this can hardly be accepted as a good fit.

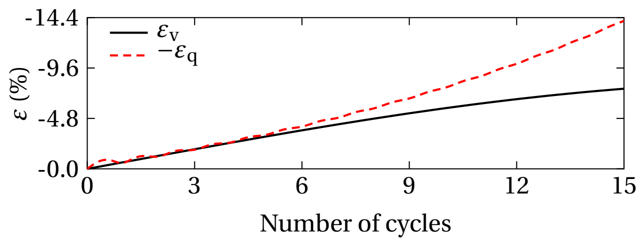
To show how peculiar the volumetric response of material models is, we compare the computational results for strain reversals in triaxial test. The question whether dilatancy or contractancy has to be expected after a strain reversal of triaxial and shear experiments is a very interesting one and has consequences on densification at cyclic loading. The widespread opinion that strain reversals are always related with contraction is hard to check, but thorough tests by Wichtmann have confirmed it (http://www.torsten-wichtmann.de) whereas older ones by Desrues et al. [2000] show also some dilation in the very beginning of the reversal. The models used in our article respond to a strain reversal in a triaxial test as follows: Barodesy as well as Sansiand shows dilatancy, Hypoplasticiy contraction, see Fig. 4a and the zoom in Fig. 4b. This is also true for strain reversal before the peak, see Fig. 5. In this case of a strain reversal the volumetric response of Barodesy is qualitatively



(a) Sanisand

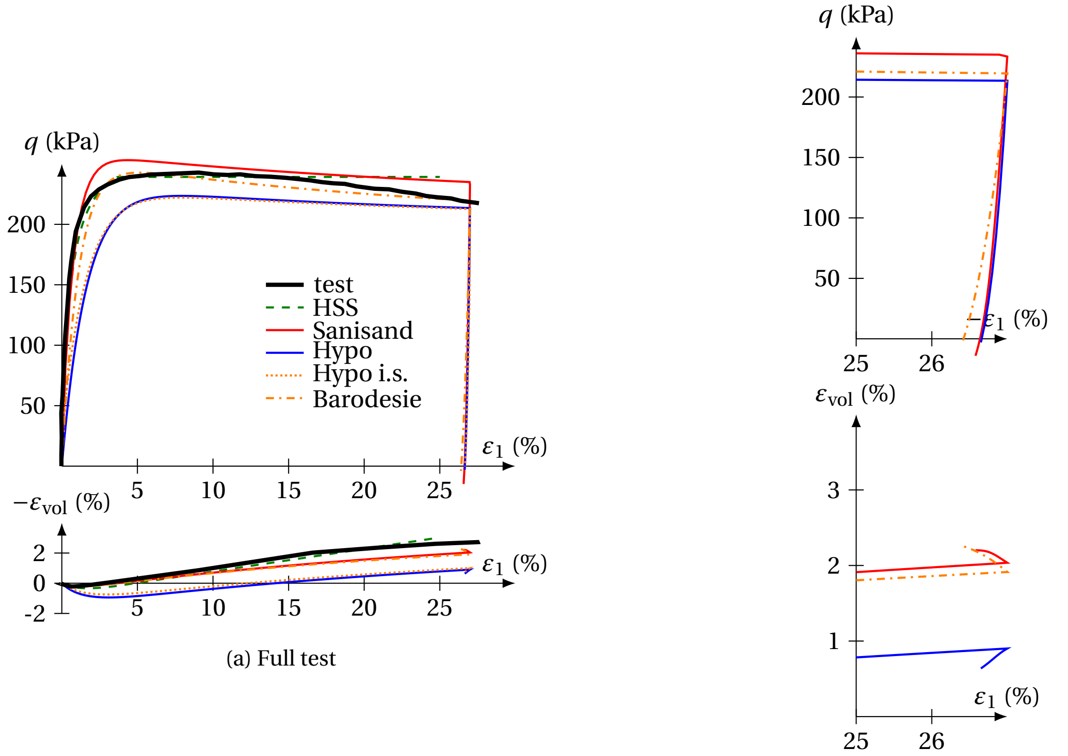


(b) Hypoplasticity



(c) Barodesy

Figure 3: Volumetric and deviatoric strains in a hollow cylinder simulation with $\varphi_c = 32°$



(a) Full test

(b) Detail with load reversal

Figure 4: Triaxial test with load reversal

equal to Sanisand, whereas for the stress rotation in Fig. 3 Hypoplasticity and Sanisand are qualitatively equal.

Reviewer: In the abstract part," "The obtained numerical simulations are compared to each other", "compared to" should be "compared with".

Response 5: Thank you very much. We have changed it.

Reviewer: Fig. 12, the x-tick labels are overlapped.

Response 6: We have changed the figure.

References

Desrues, J., Zweschper, B., and Vermeer, P. (2000). Database for tests on Hostun RF sand. Institutsbericht 13, Institut für Geotechnik, Universität Stuttgart.

Verdugo, R. and Ishihara, K. (1996). The steady state of sandy soils. *Soils and Foundation*, 36(2):81 – 91.

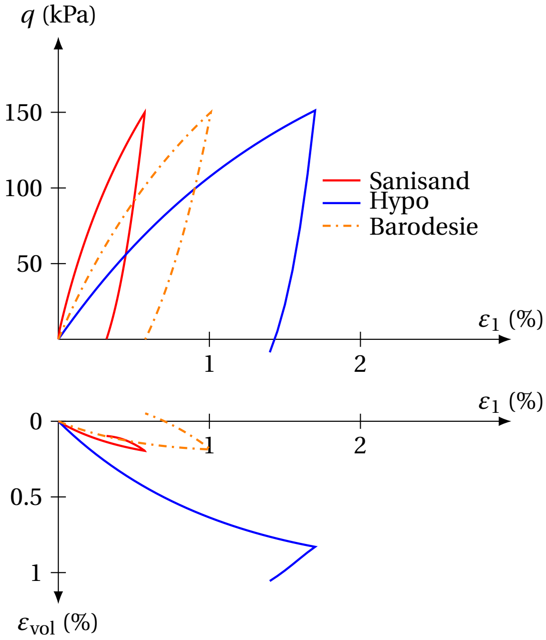


Figure 5: Triaxial test with load reverse before the peak

Review Round 2

Reviewer 1

The authors followed my recommendations and updated the manuscript accordingly. I am now in favour of its publication.

Reviewer 2

I am satisfied with the authors' reply and revision of this manuscript. It can be published.