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SC-C

# Session Report
# DISCUSSION AND CLOSURE OF SPECIAL THEME SESSION SC: DYNAMIC AND PERMANENT DISPLACEMENTS OF GROUND AND STRUCTURES
## SUB-THEME 1: PERMANENT GROUND DISPLACEMENTS DUE TO EARTHQUAKES

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## CLOSURE OF SUB-THEME 1: PERMANENT GROUND DISPLACEMENTS DUE TO EARTHQUAKES

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### PRESENTATIONS

The session of sub-theme 1 was chaired by Professor Hamada and Dr. D. K. Paul, and following presentations were made.

| No. | Title | Speaker |
|---|---|---|
| SC-R1: | (State-of-the-Art Report): Permanent deformations in ground and earth structures during earthquakes | W.D.L. Finn |
| SC-01 | Earthquake damage by liquefaction-induced permanent ground displacement | M. Hamada |
| SC-02: | Direct computation of permanent seismic deformation | N. Yoshida |
| SC-03: | Nonlinear dynamic behavior of saturated sandy soil including liquefaction | D.K. Paul |
| SC-05: | Sand liquefaction analysis by granular assembly simulation | M. Hakuno |
| SC-06: | Nonlinear seismic analysis of the upper San Fernando Dam under the 1971 San Fernando Earthquake | Y. Moriwaki |

### OUTLINE OF DISCUSSION

Prof. Hamada: Professor Toki, the head of coordinators in this session, asked me to call your attention to that the main purpose of this special theme session is to exchange general opinions and views in the present field rather than to make questions and answers about the detailed contents of individual papers.

Prof. Finn: I think there are important points made by Dr. Moriwaki. There are some very special requirements that must be fulfilled when we tried to make a computational method as exact as we can. The first of these is preferably you should be able to get soil properties from cone penetration test or with some measurements of in-situ shear wave velocities. If you get some of the properties, you would have to go back to simulation. Those are very severe limitation, but it is very difficult to convince people to deal with properties that don't have direct physical meaning for them. That is one of the problems which more advanced plasticity methods have to overcome.

Prof. Ishihara: Listening to the two presentation, one by Dr. Yosida and one by Dr. Moriwaki I realized there are some interesting points in common. They dealt with the cross section of the dam having saturated zone together with partially saturated zone. I think treatment of these two different zones in one computational scheme causes some difficulties in modeling correctly the soil behaviors. In case of soft and loose materials shear behavior is contractive. Therefore one model may be able to accommodate to both behaviors of partially saturated zone and fully saturated zone. However if we are concerned with the settlement or deformation of rolled fill dams, which has soil characteristics in which the behavior is dilative, existence of partially saturated zone might be difficult to model. If the same model is applied to well compacted material then the partially saturated material will show softer behavior than the fully saturated zone. In this case permanent deformation will be reverse in the direction. This kind of problems is the matter which concerns me.

Prof. Saxena: Basically our problem is that in geotechnical engineering we oversimplify a lot of things. We may talk about deformation based on elastic theory, and when we go to large strain we need to go to plastic theory. Combination of both of them and developing a constitutive model which can take care of all conditions is stepping on the right directions. What we really need to know is how far or how close to failure we are at a given deformation. That question remains still not answered.

Dr. Blazquez: I am delighted to see in the presentation by Prof. Finn. I was involved in this nonlinear model about ten years ago in North Western University with Prof. Bazant. It seems to me that in finding those simple parameters that would be appealing to the professions we must take into account the effects of real accelerogram or input to the problem. Many people have shown that liquefaction is very sensitive to the ratio of asymmetrical effects in input. You would be decidable to characterize the medium through some other parameters especially to emphasize that constitutive relation generate pore pressure load itself. If you input some kind of external load you are losing the advantage of nonlinear model.

Prof. Finn: Your point is close to the heart of development. We have to ask ourselves what we know about the liquefaction potential of any material that we have to use. There are only two ways together. You can take penetration test of some kinds and under basis of past experience you can get liquefaction resistance curve. The other way you can do is, if you can take a perfect sample and test it in the laboratory, either to test on the equal cycles or to test under some form of random loading. Most of the methods of the people working on this problem are from elastic plastic point of view. Their model is not limited to uniform cycles. But some of informations that we need is run on tests in uniform cycles. Our problems are getting basic information for input into the program. It is very severe limitation on what you can do.

Now I might make one brief comment when you say that constitutive model should do everything. If you have the real constitutive model, you are running to some problems in practice with those models because you have to calibrate. The model can do everything. But you can not test every conceivable situations to get parameters for. Normally what is done is certain specific routine. What is commonly used for the more complicated models are compressive triaxial tests and extension triaxial tests. The trouble is when we go to cyclic loading the performance could be quite different. Therefore in my judgment data should be calibrated using test which approximate the field. I personally recommend material constants not getting from static test if you are doing the dynamic problems.

Dr. Iai: At this point I would like to draw attention to the works done by Prof. Hamada and his colleagues. Some of his results actually showed the residual or permanent displacement of the order of 20m around the Shinano River during the 1964 Niigata Earthquake. The thickness of liquefied layer seems to be only of the order of 10m. That means the actual residual shear strain was reached more than 100%. When we do some kinds of standard undrained tests usually we say that liquefaction occurred at the shear strain level of just 5% or so. The actual phenomena seems to be something beyond the reach of engineering technique, but we have to somehow explain by kinds of model or simulation.

## CLOSURE

All of the studies presented in this session are to be praised because they have comprehensively covered several important aspects of large permanent deformation or displacement in soil structures and foundations caused by vigorous shaking. The state-of-the-Art report by Prof. Finn and other five presentations showed recent progress in computational techniques in geotechnical earthquake engineering.

The actual residual deformation observed in foundation ground due to earthquake was not always well documented, therefore it seems necessary to get precise information of case histories of the soil structures and foundations which had been actually damaged by strong earthquakes in the past. Aerial photograph analysis is one of the most powerful tools to investigate deformation over a wide area of the ground surface.

Studies on liquefaction from micromechanical point of view have also a wide range of application to liquefaction analysis. Mechanics of granular assemblies give us a basic concept of macromechanical "stress" and "strain" or meanings of continuum mechanical constitutive relations. Features of Distinct Element Method lies in the fact that the model can evaluate the discontinuity between particles or particle masses, and therefore the method seems to be appropriate to simulate flow slides in slopes due to liquefaction.

One of the main problems in the session is nonlinear response analysis of soil structures including liquefaction. Efficiency and accuracy of analysis depend substantially on the ways of modeling and consitutive relations used in the analysis. Model should be able to evaluate not only generation of pore pressure but also its dissipation through soil strata. Therefore soil properties of each part of structures and foundations must be carefully examined because response of soil structures would be significantly influenced by soil conditions. As pointed out in discussions some kinds of calibration will be needed to make the constitutive relation more realistic and rational. However there still remain some difficulties in getting post liquefaction behavior or post failure behavior.

In this session most of studies were limited to two-dimensional response analysis of soil structures. However there exist apparently three-dimensional effects on subsidence and residual deformation in real structures and foundations. In conclusion it is hoped that many studies on this particular problem will be made and aseismic design criteria of soil structures will be improved substantially in next four years.