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SC-C

SUB-THEME 2: UPLIFT AND SLIDING OF SOIL-STRUCTURE SYSTEMS DURING STRONG GROUND MOTION

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PRESENTATIONS

The following presentations were actually made, chaired by Dr. J. P. Wolf and Prof. K. Toki.

No.	Title	Speaker
SC-R2	(State-of-the-Art Report): Seismic uplift and sliding of structures from supporting ground	M. Hakuno
SC-07:	Application of recursive evaluation of interaction forces of unbounded soil in nonlinear soil-structure-interaction analysis	J. P. Wolf
SC-08:	Foundation uplift and radiation damping effects calculated in the Laplace domain	G. Schmid
SC-09:	Earthquake response analysis considering soil-structure separation using contact elements and dynamic flexibility of soil in time domain	Y. Hayashi
SC-10:	Non-linear seismic response analysis of a 3-dimensional soil-structure system	C. S. Fu
SC-12:	Proposal of analytical method on foundation uplift considering the damping effect	K. Ohtomo

OUTLINE OF DISCUSSIONS

Dr. Wolf: .... Who wants to break the ice ?

Dr. Takemiya: (To SC-10) In one of your slides, we noticed the big difference in response spectra between the 2-D and 3-D models. The difference at the bottom of the structure was from 50 up to 100 times or more. However as for the response spectra at the top of the structure, they are almost the same between the two models. So if the solutions are all right, then could you tell me how come such a big difference in terms of a physical sense ?

Dr. Fu: (Answer) Maybe something is like this. At repeated closings and openings of joint elements, a large body impacts on soft soil , and it produces a shock wave which is rich in high frequency components. So the shock wave can have a large influence on the response spectra in a region near the interface.

This is for the first point. The second is that the response at the top of the structure will reflect the basic dynamic structure. The basic dynamic structure is mainly determined by the fundamental period of the structure. So if the repeated closings and openings of the joint element occur in short time, it cannot shift the fundamental period of the structure. So it has little influence on the top-point response spectra. I think the shock wave with high frequency has little influence on the response spectra especially in a long period range.

Dr. Takemiya: So, you are including inertia impact in your numerical algorithm ?

Dr. Fu: Yeah.

Dr. Sato: I would like to make some comments from a standpoint of design purposes. If we design a soil-structure interaction system, we need a very simple model like the S-R (sway and rocking) model which was presented by several authors in this session. So how can we take into account the soil non-linearity and also the separation- and sliding-effects by using such a kind of very simple S-R models ? This is the most important thing that we have to make it possible in the future. If we can open the discussion about this matter, I am very happy.

Dr. Wolf: Well, one possibility is of our own possibility which was used about 12 to 30 years ago. It is to calculate the area of contact for different ratios of overturning moment and normal force before you actually do a dynamic calculation based on static considerations. And this allows you to determine equivalent radii for the different ratios and these radii turned out very simple, actually one of the radii is just a linear function of the ratio. Then they allow you to set up a very simplified non-linear analysis taking uplift into consideration. This is of course only approximate, but uses a falimiar sway and rocking springs. At each incident of time it calculated correspondingly to the uplifed position at that time. So, I would say, that is our certain possibilities to perform such non-linear soil-structure cases nowadays.

Dr. Toki: I would like to ask Mr. N. Kishi-Garmroudi who is one of our graduate students to talk about our hybrid experiment. We have recently started the hybrid test. Although our research is at the beginning, most of the research was studies related to the non-linear soil-structure interaction adapting analytical or computational approach.

Mr. Kishi-Garmroudi: The procedure of the hybrid experiment is like this. (He continued to explain the procedure and results of their experiments for about 5 minutes, using an overhead projector.)

Dr. Paul: This is my remarks for Dr. Sato on the approximate analysis, how we can do it. We take the mass lumped at the center of gravity, and this is a rigid link, and excitaion is given here .... (he went on explaining a simplified lumped-mass model which could take into account uplift effects, using the OHP.)

Dr. Sato: Besides your method, there has been much accumultion of data and research papers on non-linear soil-structure interaction. The importance for practical engineering is how to transfer them into simple modelings.

Dr. Takemiya: As for the simplification for design purposes, it depends on the importance of a structure, and does not depend on our preference. We should be more careful in dealing with the non-linear behavior. Sometimes we can interpret the behavior at the interface between structure and soil by use of an equivalent linear model. In that case, we must reduce soil properties in the vicinity of the foundation and we can confine some near-field and take some reduced soil properties. That can tell us a good result. One way to do is to go deep and rigorously into numerical methods and the other way is to take linearization techniques. By comparing those data, we can care of how much non-linear behavior are included in the structure. This is just my comments.

CLOSING REMARKS

Dynamic soil-structure interaction is widely recognized to be important for structural response to and stability against earthquakes. It is also recognized to be not a little difficult to deal with even in the range of linear response. What is worse, uplift and sliding involve non-linear response of structures. In fact, they cause residual and permanent displacement of structures on one hand, and decrease in earthquake response of structures on the other hand. Thus, they can be harmful to structures in one sense, but advantageous in the other sense. If we can make use of their advantageous nature, we can apply them even to vibration isolation. Unfortunately the paper No. SC-11 was not presented, its abstract describes about an example of such technique.

The state-of-the-Art report by Prof. Hakuno followed by individual presentations were made on new methods and ideas for numerical evaluation of uplift and sliding of soil-structure systems as described previously. All these innovative methods look prospective, but at least at present, some of them do not necessarily look simple enough or adequet enough for practical application. From many discussions held in the first and this second sessions, topics which require urgent solutions for future advancement in the associated field include;

1. Reasonable parameter identification for the non-linear analysis
2. Evaluation of static stress effects on the non-linear response
3. Prediction of extraordinary large deformation of ground
4. Reasoning of any significant difference between 2-D and 3-D analyses
5. Simplification of complicated models for design purposes
6. Development of new techniques like the hybrid experiment

Generally, one of the difficulties in non-linear analyses of this kind lies in a fact that we can hardly check validity of an analitical result by itself. In some cases, solutions obtained by different methods show large discrepancy. Even if two or more methods give the same solution, it does not always demonstrate their validity in a strict sense. A possible way to check the validity is comparison with physical experiments or field observation. Maybe everybody knows this, and at the same time everybody knows its difficulties. But it is commonly believed that there is no alternatives so far.

Non-linear analysis on uplift and sliding of soil-structure systems inevitably requires to specify allowable amount of residual or permanent displacement of ground and structures. The specification is another important subject for us to make practical application of our engineering research.

As a matter of fact the soil-structure interaction has a long history, but it seldom appears in present earthquake resistant codes of structures. Thus, it seems quite natural and constructive that active discussions held in this session should have mainly focused on how to cope with such present situations.