05 Apr 1995, 1:30 pm - 3:30 pm

Discussions and Replies — Session V

Multiple Authors

DISCUSSIONS AND REPLIES SESSION V

Discussion on paper titled: "Improved Soil-Spring Method for Soil-Structure Interaction-Vertical Excitation", by A.H. Hadjian and H.T. Tang, (Paper No. 5.14)

By: Y. C. Han, Faculty of Engineering & Applied Science, Memorial University of Newfoundland, Canada.

The authors propose a simpler method, an improved Soil-Spring Method (SSM), to conduct the seismic analysis for soil-structure system based on a clear understanding of the basic elements of SSI. The SSM is applied to the Lotung 1/4-scale containment model for three recorded earthquakes. The comparisons of the SSM results with results obtained using the more sophisticated methods of SASSI and CLASSI establish the improved SSM to be viable as a comparable analysis tool.

In either case of the sophisticated methods and the simpler methods to be used, the correctly specified characteristic of soil is needed to obtain the adequate response results. The earthquake degraded soil properties will vary with the excitation intensity in an earthquake environment. The values of wave velocity for earthquake degraded, as shown in dashed lines in Figure 2 , were generated by use of the SHAKE computer code, and the values of the system equivalent shear wave velocity were calculated with SSM and listed in Table 2. It is not clear what relationships these values in Figure 2 and Table 2 might have.

The soil was divided into some layers, and the elastic wave would be reflected from the boundary surface between layers. Therefore, the radiation damping of foundation was smaller than that one from the theory of elastic half space, based on some measured data. For example, a vertical damping ratio of 42 percent was measured for a foundation with base of $15 \times 15m$ (Han, 1987). It is noticed that some values of the vertical radiation damping ratio in Fig. 3 are very large, even over 100 percent. The damping ratio will increase with the reduction of the mass ratio $b_z, b_z = M/\rho R^3$, where M is the mass of structure (including footing), ρ is the mass density of soil and R is the equivalent radius of footing.

The authors assume that the backfill properties are the same as the free-field data. However, the embedment backfill properties have important influence to the dynamic response of the embedded structures. The mass density and shear modulus of the backfill are often less than that ones in the free-field. (see Han, 1989).

References

Han, Y. C. (1987). "Design of the foundation of the $5 \times 5m$ seismic vibration simulation table", Proc. of 5th Canadian Conf. on Earthquake Engineering, Ottawa, 475-481.

Han, Y. C. (1989). "Coupled vibration of embedded foundation", Journal of Geotechnical Engineering, ASCE, 115 (9), 1227-1238.

Discussion on paper titled: "Foundation Soil Influence on the Seismic Response of Piers", by P.P. Diotallevi and R. Poluzzi, Paper No. 5.19.

By: Fabrizio Pelli, Consulting Engineer, Bogliasco (Genoa), Italy.

The authors present interesting results from vibrodyne tests on two viaduct piers characterised by different soil conditions (soft and firm clay respectively).

a) Unfortunately no details on the soil properties at the two test sites and on the foundation types (pile groups, single large piers, floating or end bearing) are given in the paper. Having this information would be most useful to the reader for evaluating the results presented by the authors.

b) The authors present diagrams (Figures 1 and 2) where the accelerations recorded during the tests are normalised with respect to the applied force, and plotted vs. frequency. However no indication is given on the adopted force magnitudes. It should be noted that due to soil non linearity, the system resonant frequencies are expected to decrease as F increases, where the acceleration magnitudes (and a/F) may also change considerably.

c) Vibrodyne testing can provide useful information for seismic design. However, it should be considered that the number of cycles exerted during the test may be considerably larger than expected during typical earthquakes. This difference may not be negligible in saturated soft soils, where sensible pore-pressure build-up may take place near the pile during strong shaking.

d) In addition to b), the effects of earthquake shaking on the dynamic properties of the soil mass must also be considered separately, for instance based on free field site response analyses. Note that points b) and c) tend to have opposite effects on the foundation stiffness.

Discussion on paper titled :"Recommendations of a Workshop for a Soil-Structure Interaction Experiment", by M.Geleby & J.E.Luco, Paper N 5.35.

By: A.Tetior, Crimean Institute of Nature Preserving and Resort Construction, Ukraine.

The authors generalized the specific peculiarities of experiment in a seismically active region of the USA . They propose a complex of recommendations for a soil-structure interaction(SSI), which is very interesting for any seismic region (not only for USA). A problem of SSI investigation is an importantest of all problems of accuracy calculation increase of buildings in seismic regions.

There are in the complex 5 recommendations: needs and motivation, site and soil conditions, foundation, superstructure, instrumentation. The paper has a compact information, therefore some questions may be a consequence of a small volume of paper: for example, there is in both Figures 1 and 2 a high building with small horizontal size; for long building a scheme of instruments may be quite different; there are in tests theory a recommendation to set not smaller than a 5 instruments (sensors) in array (for increase of test accuracy); there is in ground vicinity a necessity to measure cut strains (not only a pressure), etc.

The paper is very interesting, I propose to spread this paper to all research organizations in seismically active regions.

Discussion on paper titled: "Prediction of Non-Linear Pile Foundation Response to Vertical Vibration", by Nogami, T., and Hsiao-Lian Chen, (Paper No. 5.39)

By: Y. C. Han, Faculty of Engineering & Applied Science, Memorial University of Newfoundland, Canada.

The authors present an approach to determine the dynamic nonlinear soil stiffness with a CULT curve in the static condition, which is verified by FEM and FEM-BEM and compared with static load tests and vibration tests in the field.

The concept of far and near field elements for a pile employed by the authors is similar to that one of boundary zone, weakened zone and N zone (non-linear zone). Size R used in the analyses to compute the dynamic soil stiffness are $1.5r_o, 2.0r_o$ and $3.0r_o$. It is found that the stiffness is very little affected by the difference in size R. This conclusion is agree with other calculated and experimental results by Han and Novak (1988), Novak and Han (1990) and Miura et al. (1995). Therefore, it is suggested that the range of the near field element thickness may be taken within $0.5r_o$ or $1.0r_o$.

The analysis did not consider the loose soil-pile contact within a shallow depth (about 7 ft). The stiffness of the pile observed should be lower than that one predicted. However, it is strange that the observed natural frequencies were higher than those predicted for the loading amplitudes 4000 lbs and 8000 lbs in Fig. 11.

The authors conclude that if the model parameters are defined by the elastic constants of soil and static CULT curve, it can reproduce very well the nonlinear behavior and dynamic behavior mutually coupled and thus the nonlinear dynamic soil-pile interaction force. However, the distribution of Young's modulus with depth varies widely depending on a test method as shown in Fig. 8. The difference of the Young's modulus may be more than 2 or 3 times with the different test methods. It seems that the shear modulus measured from the cross-hole test are suitable for used in the analysis.

References:

Han, Y. C., and Novak, M. (1988). "Dynamic behavior of single piles under strong harmonic excitation", Canadian Geotechnical Journal, 25, Aug., 523-534.

Miura, K., Masuda, K., Maeda, T., and Kobori, T. (1995). "Nonlinear dynamic impedance of pile group foundation", Proc. of 3rd Int. Conf. on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, April 2-7.

Novak, M., and Han, Y. C. (1990). "Impedances of soil layer with boundary zone", Journal of Geotechnical Engineering, ASCE, 116(6), 1008-1014.

Discussion on paper titled : "Prediction of Non-Linear Pile Foundation Response to Vertical Vibration", by Toyoaki Nogami & Hsiao-Lian Chen, Paper N 5.39.

By: A.Tetior, Crimean Institute of Nature Preserving and Resort Construction, Ukraine.

The authors propose an original theoretical and experimental investigation of pile foundation responce to vertical vibration. The both near and far field elements in soil vicinity around pile shaft are used for soil-pile interaction research. As a reasonable results are the comparisons of computed and observed distributions of amplitudes of pile displacement and axial force along shaft, variations of displacement amplitude at rigid cap with different frequency for various loading amplitudes, etc.

Some questions appear with paper analysis: 1. Does a Winkler subgrade model suitable for different soil types ? (there are known defects of this model); 2. If the prediction of pile foundation responce can be used with analysis of pile foundations in seismic regions, may be pass vibrations to pile from soil? 3. There is in test a single pile, but in building pile groups use in pile foundations. Apparently adjoining piles will be influence to responce to vertical vibrations.

Discussion on paper titled: "Evaluation of Seismic Response of Pile-Supported Structures with a 3-D Nonlinear Approach", by Y.X. Cai, P.L. Gould and C.S. Desai, Paper No. 5.45.

By: Fabrizio Pelli, Consulting Engineer, Bogliasco (Genoa), Italy.

The authors present an advanced 3-D numerical method for soil structure interaction analysis.

a)The method appears suitable to keep into account the three-dimensional effects and the variable pile head motions. The vertical response is probably enhanced by the modelled soil type (which is understood to be soft and deforming at nearly constant volume).

b)It appears that modelling localised near field effects at the pile soil interface might be difficult as it would require a very refined discretisation. On the other hand, this localised effects are believed to be quite relevant to define the foundation dynamic behaviour. If these observations are correct, adopting a structural subsystem inclusive of piles (where the lower subsystem would model the soil only) and of non-linear interaction springs (both vertical and horizontal) representing the softened zone could perhaps be considered.

c)The reason of developing a subsystem method is not explained in the paper, but probably this approach would be more computationally efficient with respect to a model where both structure and soil are included in the same mesh. It would be interesting to have some indications on the computation effort and computer capabilities required.

Discussion on paper titled: "Nonlinear Dynamic Impedance of Pile Group Foundation", by K. Miura, K. Masuda, T. Maeda & T. Kobori, (Paper No. 5.46)

By: Y. C. Han, Faculty of Engineering & Applied Science, Memorial University of Newfoundland, Canada.

With a nonlinear 3-D FEM analysis, the authors verify the assumption, that the zone of soil nonlinearity is limited to the vicinity of the pile, to be valid. The model with a N zone is very useful, and agrees well with experimental results.

Figure 3 provides the shear strain distribution in the soil on a line lying 5 cm below the ground surface in the direction of the load application. However, the deflections of the pile under lateral load will vary with the depth. It would be helpful if the shear strain distribution along the depth is provided to show how the boundary of the N zone changes with depth.

The experimental study on the piles in the field showed that the model of the N zone (so called the boundary zone or weakened zone) is capable of reproducing the nonlinear dynamic response of piles (see Han and Novak, 1988). For a practical application, the determination for the parameters of N zone should be studied further, such as $R_1/R_o, G, h-\gamma$ relation. In this paper, $R_1/R_o = 1.25$ is given, with no explanation.

Explaining the damping variation, the authors mention that the waves reflect at the interface between the N and L zones. However, the interface between the two zones is in most applications only fictitious, actually nonexistent. The ideal N zone should have properties smoothly approaching those of the L zone to alleviate wave reflections from the interface (see Novak and Han, 1990).

The authors conclude that the influence of soil nonlinearity on the impedance of a single pile is remarkable, while it becomes less so for a pile group as the number of piles is increased. However, this conclusion is based on the numerical results in very low frequency domain. If higher frequency domain, such as the range of the fundamental natural frequency of pile group, is included, the influence of soil nonlinearity on the impedance of pile group might also be significant.

References:

Han, Y. C., and Novak, M. (1988). "Dynamic behaviour of single piles under strong harmonic excitation", Canadian Geotechnical Journal, 25, Aug., 523-534.

Novak, M., and Han, Y. C. (1990). "Impedances of soil layer with boundary zone", Journal of Geotechnical Engineering, ASCE, 116(6), 1008-1014.

Discussion on paper titled "Nonlinear Dynamic Impedance of Pile Group Foundation", by K.Miura, K.Masuda, T.Maeda, T.Kobori., Paper N 5.46.

By: A.Tetior, Crimean Institute of Nature Preserving and Resort Construction, Ukraine.

There are in this paper the interesting investigation in field of interaction of pile group foundation with nonlinear and linear soil.

The methodology is based on the Green's-function-based formulation. Authors propose a new scheme of interaction of piles and soil: the nonlinear soil zone is concentric around each pile shafts and under pile tip.

As a result authors proposed some interesting conclusions: the distribution of forces on pile caps (there is a favourable levelling of forces distribution with nonlinear soil); the influence of soil nonlinearity on the impedance depend on the number of piles (it is remarkable for a single pile and less remarkable for pile group, etc.).

The results of the theoretical research are very important for understanding of nonlinear soil interaction with piles. But some questions nevertheless appeared: does a nonlinear soil zone depend on a pile type?; why a nonlinear soil zones around pile shaft and under pile tip are equal?; does a nonlinear soil thickness depend on soil compacting between piles ?;, etc.

Discussion on paper titled: "Seismic Response on Full-Size Pile Group", by Y.C. Han and G.C.W. Sabin, Paper No. 5.47.

By: Fabrizio Pelli, Consulting Engineer, Bogliasco (Genoa), Italy.

This interesting paper describes the results of experiments carried out on a full-size pile group, and of theoretical analyses where the effects of a softer boundary zone with non-reflective interface are considered.

a) Soil properties for the test site are not given in the paper, and no indication is provided on how the soil parameters adopted in the analyses for the no-boundary-zone condition were established. This quantitative reference would help in evaluating the results presented in Fig. 3.

b) With reference to Fig. 3 and in consideration of the maximum recorded pile displacement and of the pile size, a representative shear strain on the order of 10^{-4} may have developed near the pile head (e.g. Kagawa and Kraft, 1981). At this strain level, a certain non linearity appears to be possible provided that soil plasticity is sufficiently low (Vucetic and Dobry, 1991).

c) With reference to Fig. 4, the proposed model fits very well the test results at various load levels. Back-analysis of the seismic design parameters based on field tests appears a good approach, provided that the test pile group is similar to the actual foundation. However a correction should be applied to keep into account that the shear modulus characterising the soil in the far field will be reduced during a strong motion earthquake, due to seismic shaking. This correction could be applied by decreasing the G_0 value based on free field site response analyses. On the other hand, G_i could be kept unchanged in those cases where relatively high pile-soil interaction forces control the soil properties within the boundary zone.

REFERENCES

Kagawa T. and L.M. Kraft (1981), "Lateral Pile Response during Earthquakes", J. Geotech. Engrg. Div., ASCE, Vol. 107, No. GT12, pp.1713-1731.

Vucetic M. and R. Dobry (1991), "Effect of Soil Plasticity on Cyclic Response", J. Geotech. Engrg., Vol. 117, No. 1, pp.89-107.

Paper No. 5.19
Reply by: P.P. DIOTALLAVI, R. POLUZZI

a) We hereby integrate some information on piers and foundations that we could not report for problems of length:

Both the piers which underwent experimentation have similar features as for height, stiffness and mass, and even the foundations of both of them are on pile groups having diameter 1200 mm. In particular, the piles of the Coltano viaduct, inserted into soft soil and water bed, are approximately 60 metres in length and on top they are protected for 15 ÷ 20 metres with sheet-steel to reduce negative friction.
In our opinion, especially this makes the difference between the Gonnellino viaduct and other similar viaducts, in which piles are inserted into firmer soil and without water bed.
Figure 1 schematically shows piers and pile groups, and gives some synthetic indications on the soil stratigraphy.

b) As for the force magnitude, to which acceleration is compared for each frequency, we are convinced that it is not high if compared to the pier and the soil involved. In fact, the vibrodyne gives 20,000 N maximum at the highest frequency (25 Hz), while the pier and foundation block mass is over 500,000 kg.
During experimentation, we are convinced not to have produced behaviours far from linearity. On this matter, we would like to highlight that, especially for the pier on soft soil, a test repetition, carried out after a short time, had identical results. A marked non-linearity would have probably had a different influence on response frequencies.

c) and d) We do not have specific experimental information on possible pore-pressure build-up, both during the test and in the case of episodes characterised by a lower number of cycles, and higher amplitudes, if any.
We underline that the scope of the investigation was basically to compare the responses of similar structures, but founded on very different soils, to the same accelerogram. The comparison can be conducted only on the quality and magnitude basis; in fact, in these terms, results are significantly very different.
Even with the necessary limits (from which the opportunity of specific investigation), we deemed significant to exploit the response experimental knowledge, in terms of interaction among structure, piles and soil, for many aspects in scale 1:1.

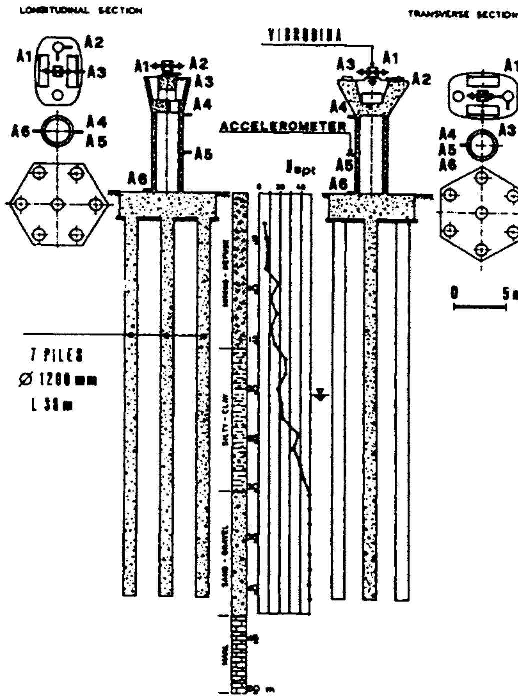

Fig. 1