Discussion of "Seismic Behavior of Batter Piles: Elastic Response" by A. Giannakou, N. Gerolymos, G. Gazetas, T. Tazoh, and I. Anastasopoulos

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Significant advances have been made on this important research topic in the last few years because of Giannakou et al., who have faced, in urgent terms, the matter of whether inclined piles have a beneficial or detrimental role.

The discusser agrees with the authors on the fact that the horizontal drift of a superstructure supported on a group of batter piles is generally smaller than with the exclusively vertical pile group; however, it could not really be generalized that this reduction is appreciable only with tall structures.

The discusser has carried out work in his Ph.D. thesis about the inclined piles, studying the behavior of a couple of piles supporting a tall superstructure ($h_{str} = 10\,\mathrm{m}$) and a short superstructure ($h_{str} = 2\,\mathrm{m}$), in different geometrical conditions and seismic excitations than those of the authors, reaching quite different results. Specifically, from results obtained performing FEM three-dimensional analysis with the computer program *ADINA* (ADINA 2010), and using the base of the model with two real acceleration time histories (El Centro component NS 1940 [$a_{\max} = 0.318g$]; Bagnoli Irpino Earthquake 1980 [$a_{\max} = 0.358g$]), the following can be concluded. The reduction of horizontal drift because of inclined piles with regard to vertical piles was more important in short superstructures than tall ones (Figs. 1 and 2).

To explain these results, it is useful to keep in mind that under seismic excitation, the horizontal drift of the superstructure mass, u_m, is made of three parts: horizontal translation of the cap, horizontal translation because of rotation cap, and horizontal deflection of the column.

The discusser has found out that the cap's horizontal translation founded on vertical piles tends to be higher than the one with the inclined piles. Instead, the contribution because of the cap rotation can increase or reduce the horizontal drift depending on the sign of the rotation.

In the case of the short superstructure, Fig. 3 shows the horizontal displacement of the cap on the inclined piles, u_c, the vertical displacement of the pile on the left, v_{cl}, and the vertical displacement of the pile on the right, v_{cr}. For better understanding of the figures, the time considered was limited to the first 3 s. Once the vertical displacements are confirmed, the rotation is obtained by dividing the difference in the vertical displacement at the head of the piles by the distance between the two piles. In Fig. 3, the horizontal oscillation frequency of the cap is quite lower than the one in the vertical direction; the vertical displacement, v_{cl}, also has the opposite sign and basically the same amplitude of v_{cr}. The difference in frequency

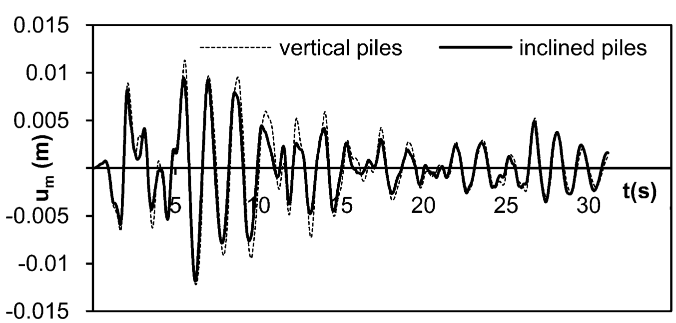

Fig. 1. Horizontal displacement time history of superstructure mass for $h_{str} = 10\,\mathrm{m}$ (El Centro Earthquake 1940)

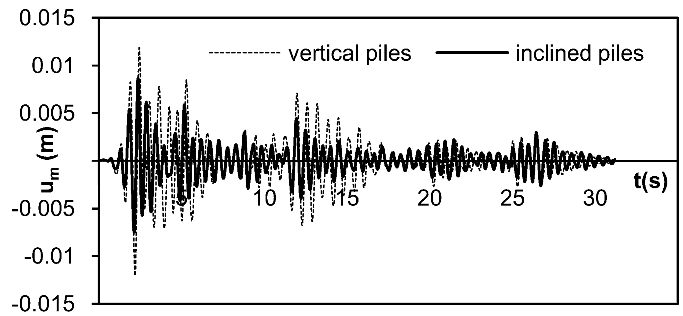

Fig. 2. Horizontal displacement time history of superstructure mass for $h_{str} = 2\,\mathrm{m}$ (El Centro Earthquake 1940)

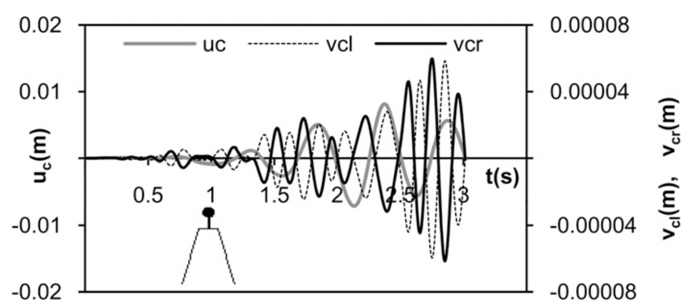

Fig. 3. Displacement time histories of the cap on inclined piles ($h_{str} = 2\,\mathrm{m}$)

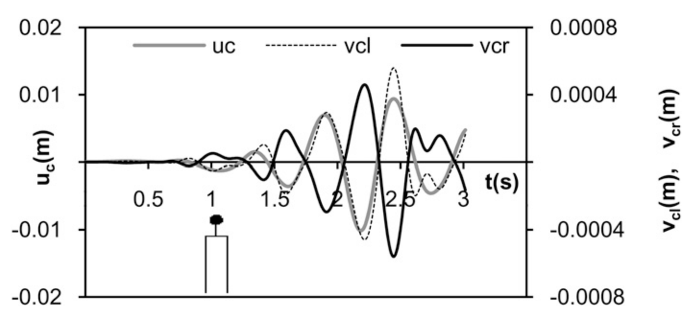

Fig. 4. Displacement time histories of the cap on vertical piles ($h_{str} = 2\,\mathrm{m}$)

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entails that while the horizontal displacement has the same sign, the vertical displacements (then rotations) of the opposite signs are simultaneously produced; therefore, the overall result reduces the horizontal drift of the superstructure.

In the case of the cap supported on vertical piles (Fig. 4), the oscillation frequencies of the cap, both in the vertical and horizontal directions, tend to be almost the same, which may help us understand the highest values of horizontal drift.

It is confirmed that the behavior of seismic inclined piles is a highly frequency-dependent issue and very complex to deal with, even in simplifying assumptions of linear elasticity and full bonding at the soil-pile interface.

It is acknowledged that the authors had bright insight into the concerns of such a complex matter.

References

ADINA (2010). [Computer software]. Watertown, MA, ADINA.

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The writers thank the discusser for his kind comments, and his useful observations that are well taken. Indeed, when comparing

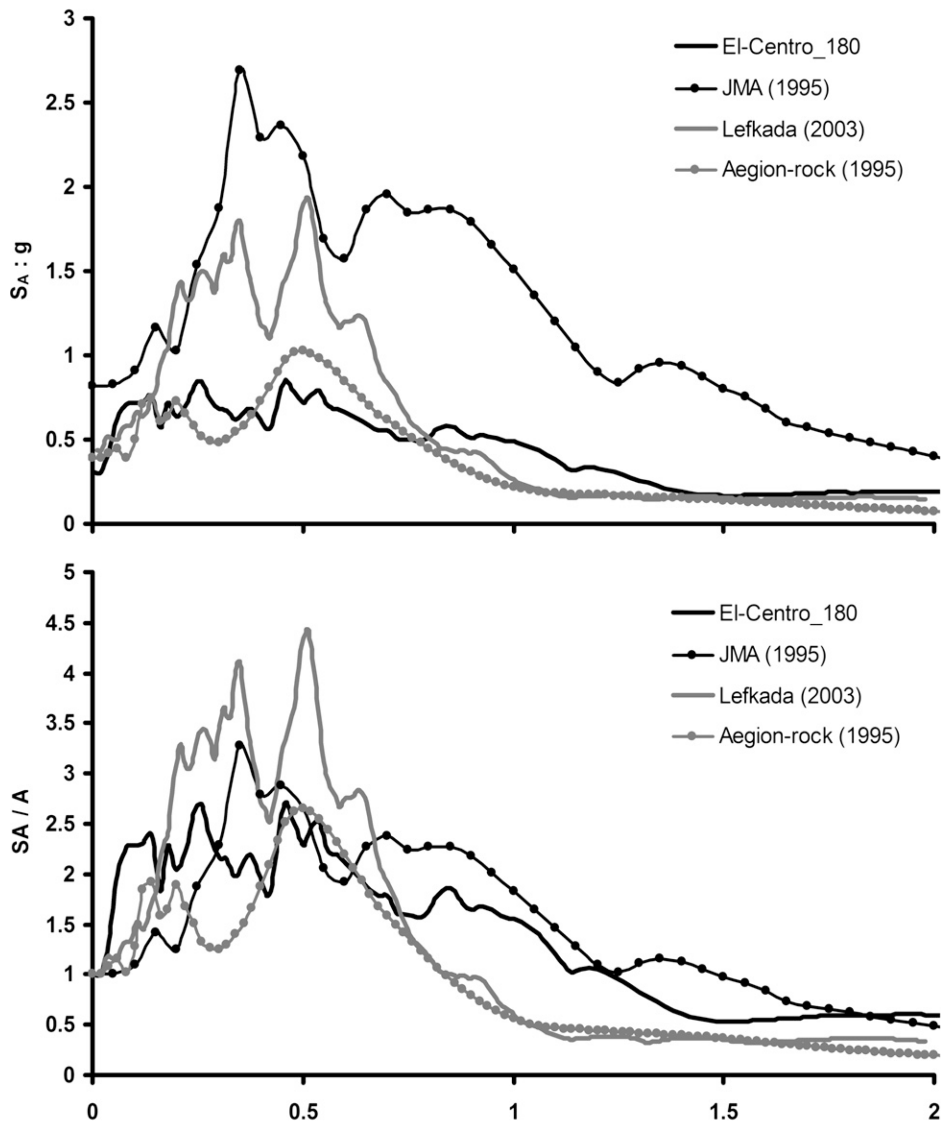

Fig. 1. Comparison of the 5%-damped acceleration response spectra of the motions used in the original paper (JMA, Aegion-rock, and Lefkada) and the motion used by the discusser (El Centro): top, absolute values; bottom, normalized values

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the seismic response of structures on vertical or batter piles the results of a small parameter study should not be overgeneralized. Even with two piles, the (elastic) response of a structure on a piled foundation will depend on the frequency content of the excitation.

The results of the discusser are quite interesting, although some additional factual information (soil profile, pile diameter, spacing, etc.), if available, would be useful. Figs. 3 and 4 (of the discusser), in particular, illustrate the different nature of the cap response when it is supported on vertical or inclined piles. In the former case (vertical), the time histories of the horizontal translation and rotation of the cap have the same frequency of oscillation. In the latter case (batter piles) the frequency of rotational oscillation of the cap is about two times larger than that of the horizontal oscillation. This is quite an interesting observation; however, it deserves further interpretation. It is not clear, for example, why this pair of frequencies is not somehow reflected on the displacement time history of his Fig. 2, which is completely monochromatic.

Finally, two differences may be noted between the results of the two studies: one is a misunderstanding of terminology; i.e., by drift, the writers' mean structural distortion-caused displacement, whereas the discusser means total displacement, and the other is the difference in frequency content between the El Centro motion of the figures provided by the discusser and the three motions (JMA-Kobe, Lefkada, and Aegion-rock) used in the writers' paper, as depicted in Fig. 1.

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