

Reply to reviewer's comments

1. The authors only added the names of the design standards, manual, and codes of practices; however, fail to highlight the codal guidelines and provisions.

Answer : Thanks very much for the reviewer's comment. In accordance with your suggestions, an explanation of the guiding roles of the three research approaches, namely comprehensive analysis method, numerical analysis method, and physical experimental method, in this study is provided from line 41 to 59. Additionally, the methods employed in this research are elucidated from line 78 to 85.

2. Most of the papers added by the authors are very old and insignificant;

Answer : Thanks very much for the reviewer's comment. Based on the content of this study, the article referenced recent and highly valuable literature as follows:

References

- [1] Anas, S.M.; Alam, M.; Umair, M. Experimental and numerical investigations on performance of reinforced concrete slabs under explosive-induced air-blast loading: A state-of-the-art review. *Structures* 2021, 31, 428-461, doi:10.1016/j.istruc.2021.01.102.
- [2] Naggar, M.H.E.; Shayanfar, M.A.; Kimiaei, M.; Aghakouchak, A.A. Simplified BNWF model for nonlinear seismic response analysis of offshore piles with nonlinear input ground motion analysis. *Canadian Geotechnical Journal* 2005, 42, 365-380, doi:10.1139/t04-103.
- [3] Li, Y.; Kitazume, M.; Takahashi, A.; Harada, K.; Ohbayashi, J. Centrifuge study on the effect of the SCP improvement geometry on the mitigation of liquefaction-induced embankment settlement. *Soil Dynamics and Earthquake Engineering* 2021, 148, doi:10.1016/j.soildyn.2021.106852.
- [4] Yang, X.; Zhang, Y.; Liu, H.; Fan, X.; Jiang, G.; El Naggar, M.H.; Wu, W.; Liu, X. Analytical solution for lateral dynamic response of pile foundation embedded in unsaturated soil. *Ocean Engineering* 2022, 265, 112518, doi:10.1016/j.oceaneng.2022.112518.
- [5] Yang, X.; Zhang, Y.; Liu, H.; Fan Newson, T.; El Naggar, M.H. Analytical solution for kinematic response of offshore piles under vertically propagating S-waves. *Ocean Engineering* 2022, 262, 112018, doi:10.1016/j.oceaneng.2022.112018.
- [6] Huang, Y.; Wang, P.; Zhao, M.; Zhang, C.; Du, X. Dynamic responses of an end-bearing pile subjected to horizontal earthquakes considering water-pile-soil interactions. *Ocean Engineering* 2021, 238, 109726, doi:10.1016/j.oceaneng.2021.109726.
- [7] Zhao, M.-h.; Heng, S.; Zheng, Y. Numerical simulation on behavior of pile foundations under cyclic axial loads. *J. Cent. South Univ.* 2017, 24, 2906-2913, doi:10.1007/s11771-017-3704-5.
- [8] Rouholamin, M.; Lombardi, D.; Bhattacharya, S. Experimental investigation of transient bending moment of piles during seismic liquefaction. *Soil Dynamics and Earthquake Engineering* 2022, 157, 107251, doi:10.1016/j.soildyn.2022.107251.
- [9] Padmanabhan, G.; Shanmugam, G.K. Liquefaction and reliquefaction resistance of saturated sand deposits treated with sand compaction piles. *Bulletin of Earthquake Engineering* 2021, 19, 4235-4259, doi:10.1007/s10518-021-01143-8.
- [10] Balaam, N.P.; Booker, J.R. Effect of stone column yield on settlement of rigid foundations in stabilized clay. *Num Anal Meth Geomechanics* 1985, 9, 331-351, doi:10.1002/nag.1610090404.
- [11] Aboshi, H.; Mizuno, Y.; Kuwabara, M. Present State of Sand Compaction Pile in Japan. In *Deep Foundation Improvements: Design, Construction, and Testing*; ASTM International: 100 Barr

Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, pp. 32-32-15.

3. Past contribution of the research works including recent papers must be properly reviewed and summarized in the manuscript; highlighting the unique contribution and also the research gaps; recommended papers: - Structures, Elsevier, 31, pp. 428-461, DOI: 10.1016/j.istruc.2021.01.102.

Answer : Thanks very much for the reviewer's comment. The references you provided are highly valuable and help to compensate for the shortcomings in summarizing the existing research in this paper. They have been included in the article at line 40.

References

[1] Anas, S.M.; Alam, M.; Umair, M. Experimental and numerical investigations on performance of reinforced concrete slabs under explosive-induced air-blast loading: A state-of-the-art review. Structures 2021, 31, 428-461, doi:10.1016/j.istruc.2021.01.102.

4. Novelty of the work is still not highlighted and unclear to this reviewer. Same as the application of conducting such a study is not clear.

Answer : Thanks very much for the reviewer's comment. This paper primarily analyzes the relationship between the plastic zone of pile foundations and their arrangement under seismic conditions. The study involves the use of numerical analysis and physical experiments. It provides optimal pile arrangement design for constructing pile-supported structures, as explained in lines 41-55 and 74-81. This research has practical engineering applications that can reduce human casualties and economic losses in seismic disasters, as outlined in lines 34-35.

5. Authors fail to address the following previous comment "A number of response parameters were considered, viz., ALLKE, ALLSE etc., but on what basis these parameters have been selected is not clear to this reviewer."; proper explanation need to be given why such energy based parameters were considered? the mechanism of these parameters.

Answer : Thanks very much for the reviewer's comment. The seismic performance of a structure fundamentally relates to its ability to dissipate seismic energy. This dissipation of energy within the structure occurs in two primary forms: 1. Internal damage is transformed into thermal energy and dissipated into the surrounding space. 2. Externally, energy dissipation happens through the interaction between piles and the surrounding soil. Corresponding to these mechanisms are the internal strain energy (ALLSE) and the external kinetic energy (ALLKE). Therefore, an analysis of these two energy transformations helps determine the location and size of the plastic region of the pile. Additional explanations have been provided in Section 3.3, lines 187-193. For more details, please refer to the following references:

References :

[1] Gajan, S.; Saravanathiiban, D. S. Modeling of Energy Dissipation in Structural Devices and Foundation Soil during Seismic Loading. Soil Dynamics and Earthquake Engineering, 2011, 31, 1106–1122. <https://doi.org/10.1016/j.soildyn.2011.02.006>.

[2] Takewaki, I. Frequency-Domain Analysis of Earthquake Input Energy to Structure–Pile Systems. Engineering Structures, 2005, 27, 549–563. <https://doi.org/10.1016/j.engstruct.2004.11.014>.

6. Very basic discussion of the results are given by the authors; and hence need to be revised properly

Answer : Thanks very much for the reviewer's comment. Based on your feedback, the

conclusions have been extensively reviewed and rewritten as follows:

This study investigates the seismic response of the SIS system. Physical experiments were conducted to analyze the distribution of pile bending moments, pile-soil interface interactions, and plastic hysteresis loops of the pile foundation in a detailed parameterized manner. Subsequently, numerical analysis was employed to validate the physical model, and further analysis was carried out to examine the energy variations in the sand pile and foundation within the seismic energy field. The key research findings are summarized as follows:

(1) The "X-shaped" and rectangular pile groups only exhibit heavy plastic region *A* with significant mass distribution and mild plastic region *C* with less soil compression. The absence of a moderate plastic region *B* is attributed to the variations in pile spacing and instability caused by the formation of quadrangular prism damping units between the piles.

(2) The hexagonal pile group, which forms a triangular prism damping unit with the surrounding soil, mitigates the piled foundation response. It partially counteracts the seismic wavefront, reducing the extent of injury to structures with a top-heavy mass distribution. This enhances the energy dissipation capacity of the piled foundation and stabilizes the damping characteristics.

(3) The greater the Energy Residual Index (ERI), the lower the structural energy dissipation, indicating poorer seismic performance. Irregular pile spacing and the in-stability of the quadrilateral prism damping unit formed by piles and soil increase the ERI of the piled foundation. An increased underwater pressure results in higher ERI due to the enhanced suppression of vertical seismic frequencies. The occurrence of frequency resonance-induced injury leads to additional energy.

(4) The relationship between the plastic region and pile arrangement was determined based on the mechanical behavior of the pile-soil interface and the energy changes. For the "X-shaped" pile group, the boundary between the heavy and mild plastic regions is located at a depth of $L = 2.25D$. In the hexagonal pile group, the boundaries between the heavy, moderate, and mild plastic regions are situated at depths of $L = 4D$ and $L = 8D$. The boundaries between the heavy and mild plastic regions are found in the rectangular pile group at a depth of $L = 2.08D$.