



HAL
open science

Dynamic response of shallow foundations on reinforced soil with rigid inclusions

Yuxiang Shen, Jesús Pérez-Herreros, Fahd Cuiira, Jean-François Semblat,
Sébastien Burlon

► **To cite this version:**

Yuxiang Shen, Jesús Pérez-Herreros, Fahd Cuiira, Jean-François Semblat, Sébastien Burlon. Dynamic response of shallow foundations on reinforced soil with rigid inclusions. 17th World Conference on Earthquake Engineering, 17WCEE, Sep 2021, Sendai, Japan. PROCEEDINGS OF THE SEVENTEENTH WORLD CONFERENCE ON EARTHQUAKE ENGINEERING JAPAN 2021. hal-04478322

HAL Id: hal-04478322

<https://hal.science/hal-04478322v1>

Submitted on 26 Feb 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Dynamic response of shallow foundations on reinforced soil with rigid inclusions

Y. Shen ⁽¹⁾⁽²⁾⁽³⁾, J. Pérez-Herreros ⁽¹⁾, F. Cuira ⁽¹⁾, J-F. Semblat ⁽²⁾⁽³⁾ and S. Burlon ⁽¹⁾

(1) TERRASOL (SETEC group), France

(2) Ecole Nationale Supérieure de Techniques Avancées (ENSTA Paris), France

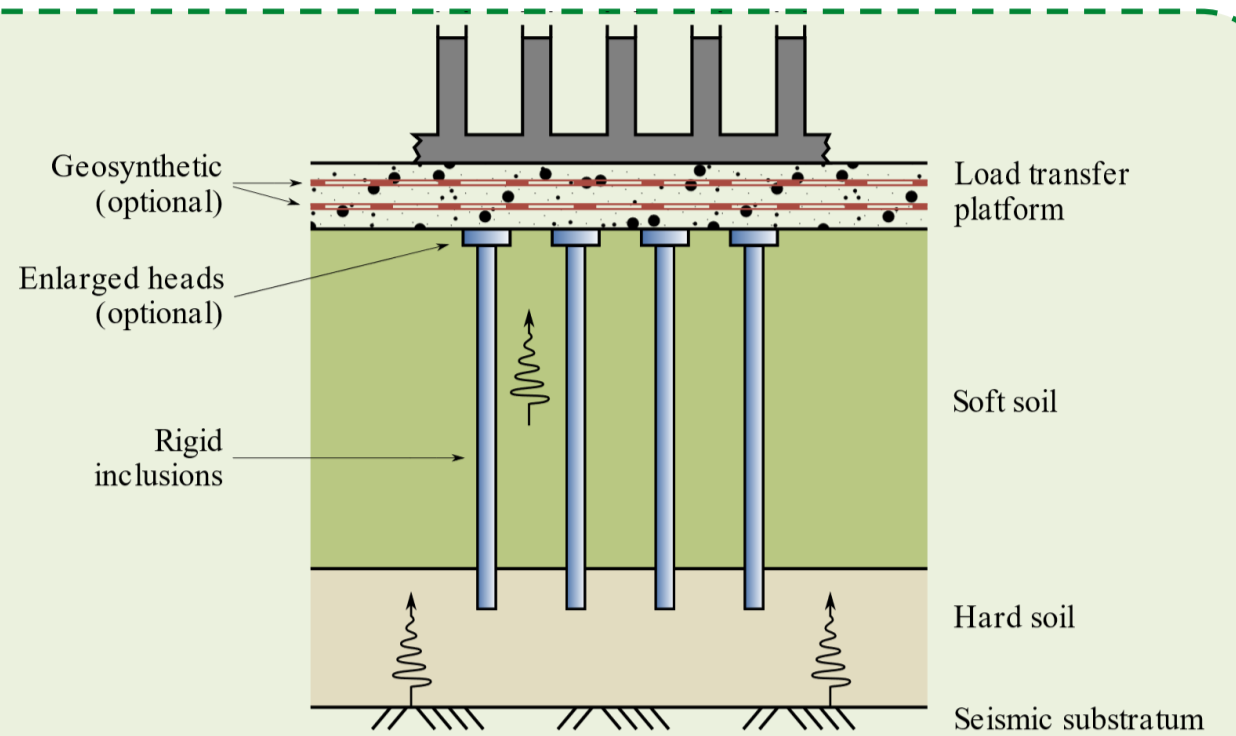
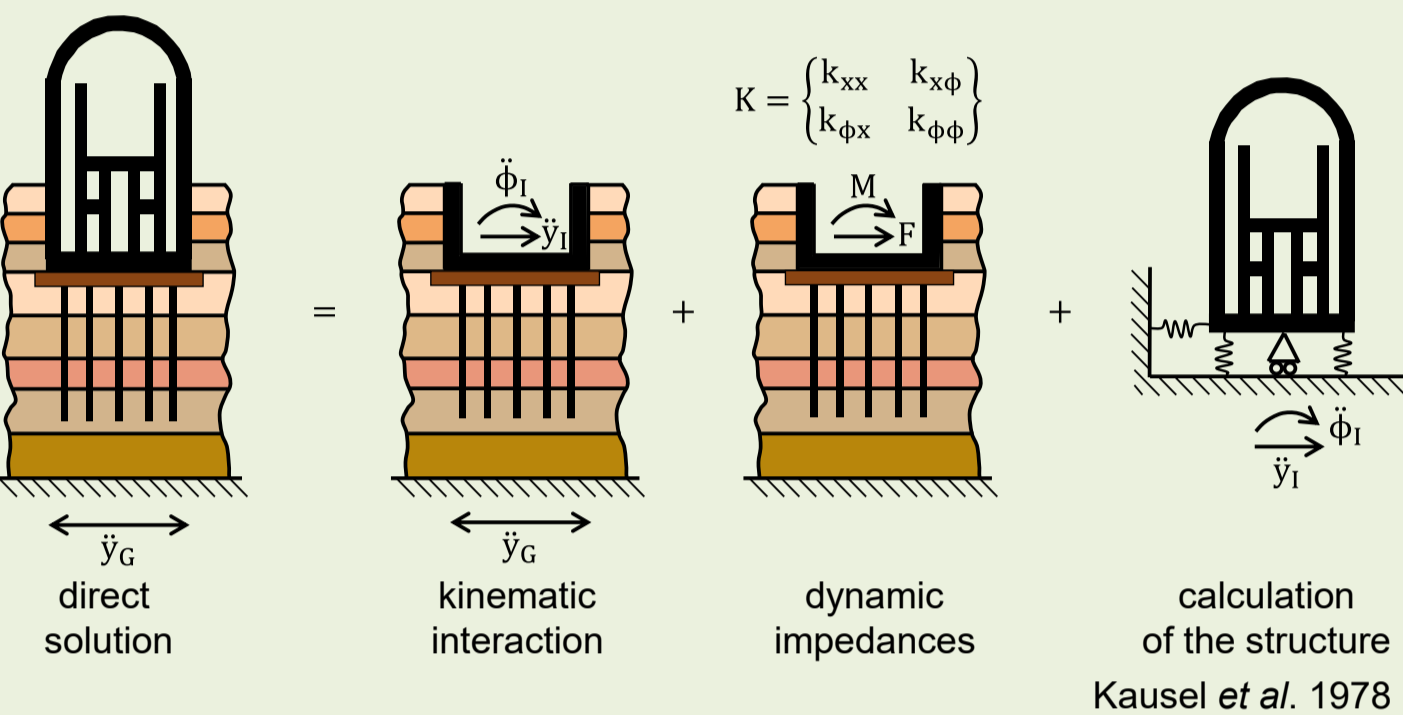
(3) Institut Polytechnique de Paris, France

Overview

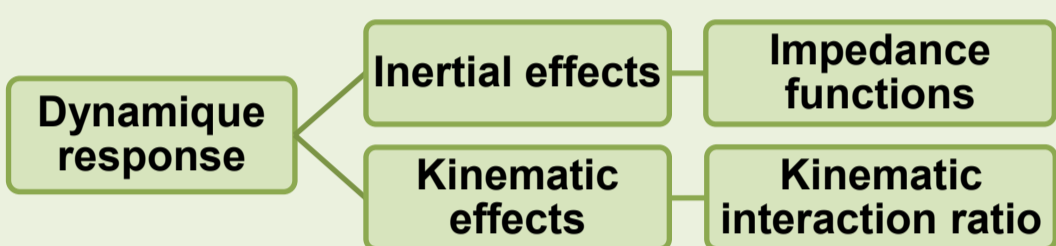
Introduction

The soil reinforcement technique using rigid inclusions is a practical, economical and time saving solution that allows the use of shallow foundations on soft soils. The load transfer from the structure to the rigid inclusion reinforced soil is carried out via the load transfer platform as well as by the negative shaft skin friction. A particular aspect of the dynamic response is the fact that the piles representing the rigid inclusions are disconnected from the supported structure. This is of obvious interest under seismic action.

Superposition theorem and substructuring approach

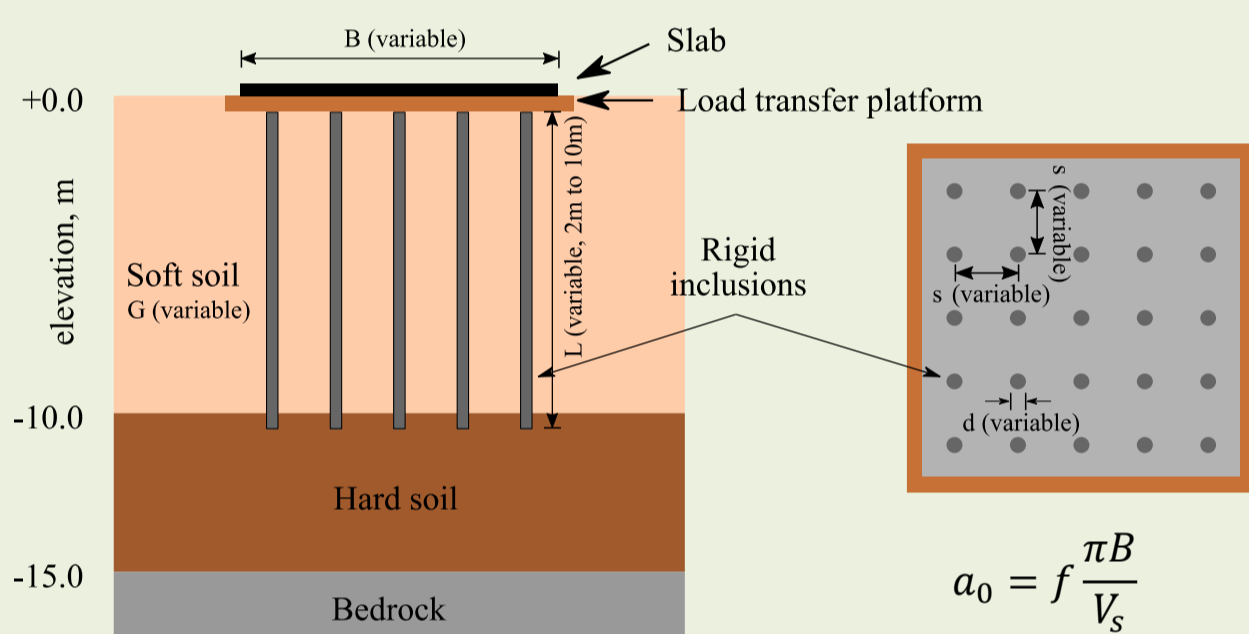


- Decomposition of the SSI problem;
- Resolution by substructuring approach with a 3D model;
- Rigid inclusions modelled explicitly by beam elements;
- Nonlinear behavior of soil represented by a viscoelastic equivalent linear model compatible with the seismic distortion level.



Parametric study

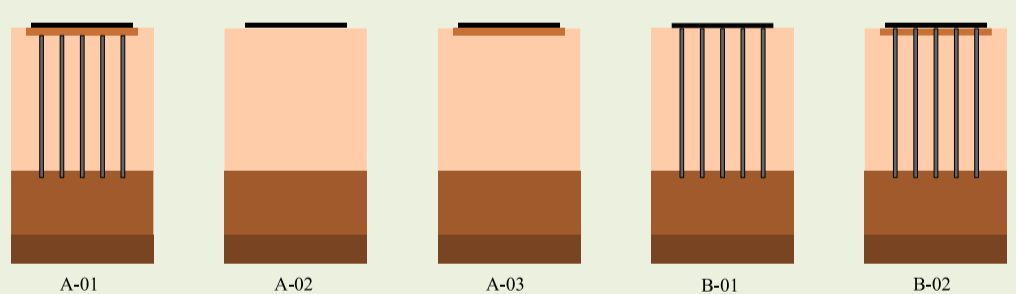
Reference case and soil profile



Dynamic characteristic	Symbol	Soft soil	Hard soil	Bedrock	Transfer platform	Inclusions
Shear Modulus (MPa)	G	45 (20, 80)	320	2 500	125	12 500
Poisson ratio (-)	ν	0.45	0.45	0.45	0.35	0.2
Mass density (t/m^3)	ρ	2.0	2.0	2.5	2.0	2.5
Material damping ratio (-)	ξ	0.05	0.05	0.05	0.05	0

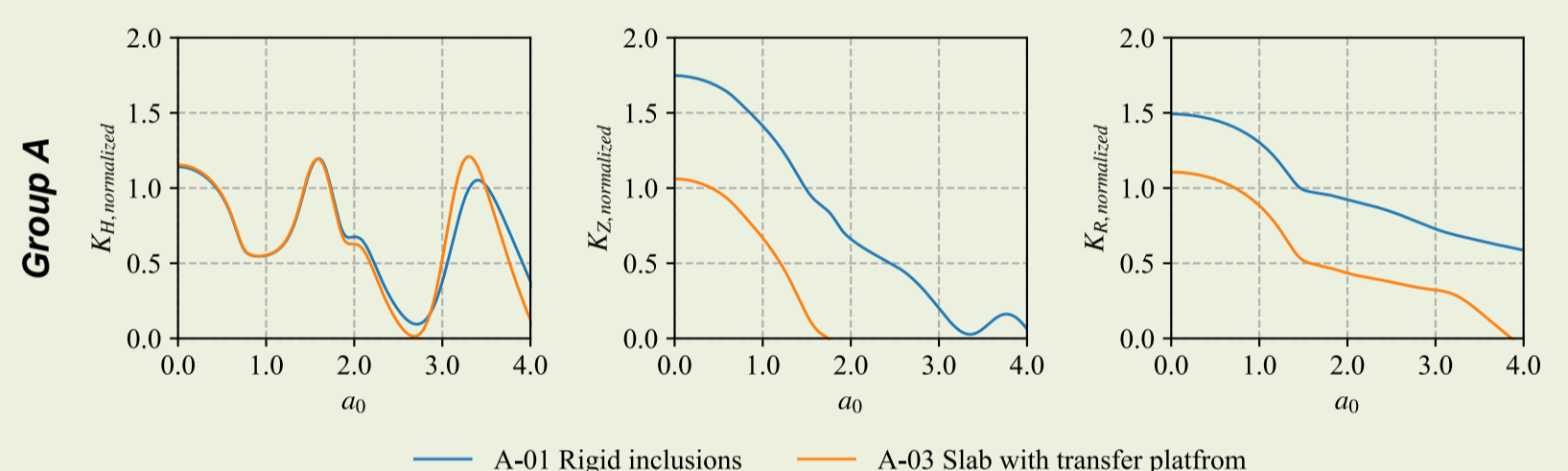
Questions addressed in this work

- **Group A:** Comparison with shallow foundation configurations;
- **Group B:** Comparison with pile foundation configurations;
- **Group C:** Comparison with different d/L ratio configurations (impact of the diameter of the rigid inclusions);
- **Group D:** Comparison with different e/B ratio configurations (impact of the spacing between the rigid inclusions);
- **Group E:** Comparison with different B/L ratio configurations (impact of length of the rigid inclusions).

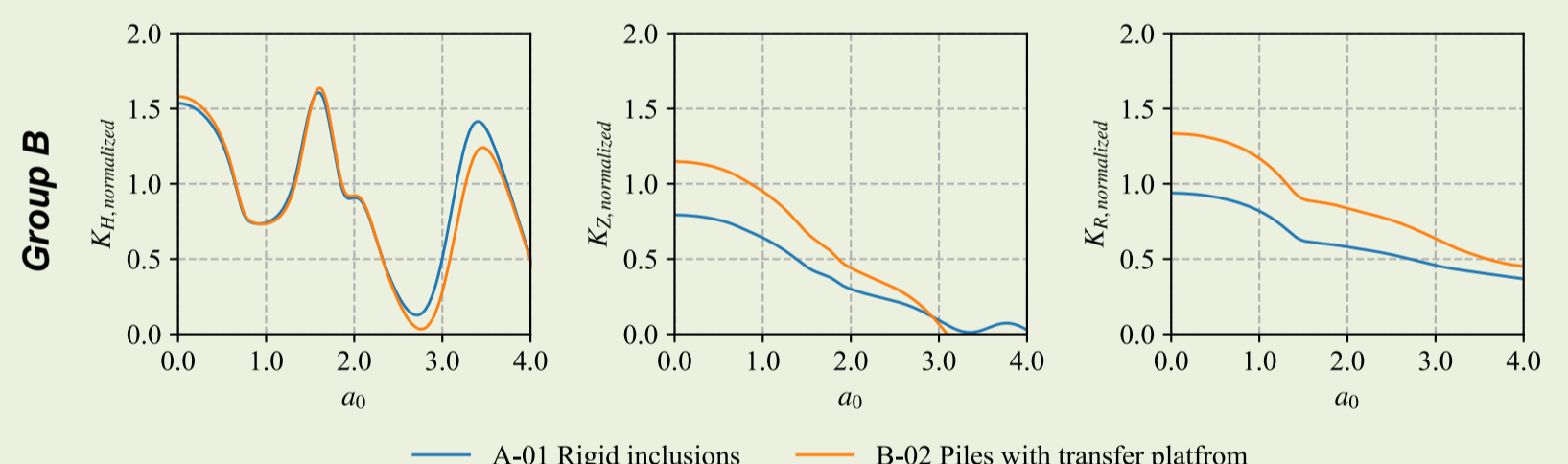


- A-01: Foundation over rigid inclusions with transfer platform;
- A-02: Shallow foundation;
- A-03: Shallow foundation with transfer platform;
- B-01: Pile foundation;
- B-02: Pile foundation with transfer platform.

Inertial effects: impedance functions

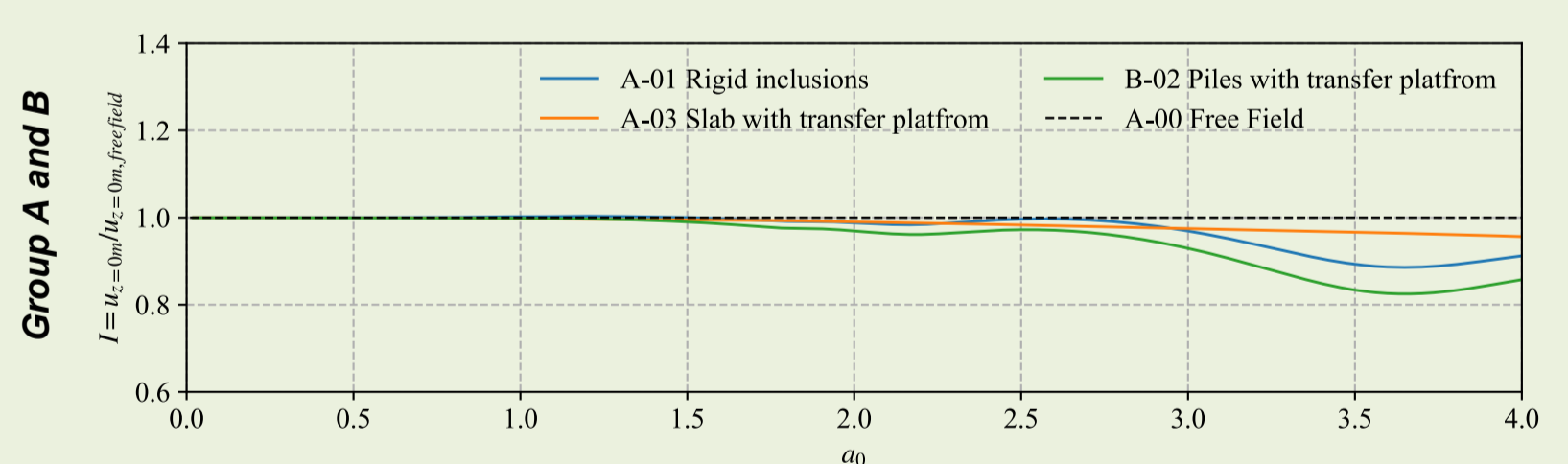


- The results of Group A are normalized by the static stiffness of the slab foundation;
- In the horizontal direction, the dynamic inertial response of the foundation over rigid inclusions is similar to the case of slab foundation with transfer platform;
- The same conclusions are valid for all studied configurations.



- The results of Group B are normalized by the static stiffness of the pile foundation;
- In the vertical and rotational direction, the dynamic inertial response of the foundation over rigid inclusions is similar to the case of pile foundation with transfer platform;
- The same conclusions are valid for all studied configurations.

Kinematic effects: kinematic interaction ratio



- The results confirm that the kinematic interaction effects have no significant impact in the low frequency range;
- The same conclusions are valid for all studied configurations.

Conclusion and perspective

- The 3D numerical study demonstrates the complicated phenomenon of the dynamic performance of shallow foundation on rigid inclusions;
- The presence of rigid inclusions influences the vertical and rotational direction of SSI stiffness in low frequency range;
- The presence of transfer platform influences all the directions of SSI stiffness throughout the studied frequency range;
- Different configurations of rigid inclusions (diameters, spacing and lengths) have negligible impact on the horizontal behavior of the foundation;
- Future work will consider a set of real seismic recordings with different

- characteristics and nonlinear phenomena during the earthquake;
- Development of macroelement to simulate the nonlinear dynamic response of inclusion reinforced foundations will be developed based on the observations of this study;
- This present work is conducted within the framework of ASIRI+ French national research project.



References

- Projet national ASIRI (2013): Recommendations for the design, construction and control of rigid inclusion ground improvements. Presses des Ponts.
- Briançon L, Kastner R, Simon B, Dias D (2004): Etat des connaissances-Amélioration des sols par inclusions rigides. International Symposium on Ground Improvement (ASEP-GI 2004), Paris, France.
- Kausel E, Whitman RV, Morray JP, Elsabee F (1978): The spring method for embedded foundations. Nuclear Engineering and design, 48 (2-3), 377-392.
- Gazetas G (1991): Formulas and charts for impedances of surface and embedded foundations. J Geotech Eng.;117 (9), 1363-1381.
- Ostadan F, Deng N (2010): SASSI2010: A system for analysis of soil-structure interaction. University of California, Berkeley, CA, USA.
- Pérez-Herreros, J. (2020): Dynamic soil-structure interaction of pile foundations: experimental and numerical study (Doctoral dissertation, Ecole centrale de Nantes).