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Static load tests on raft on rigid inclusions

Essais de chargement statiques sur fondations superficielles posées sur des inclusions rigides

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ABSTRACT: A full-scale experimentation of static loading tests on square footings on rigid inclusions has been performed in the framework of the research project ASIRI+. This experiment aimed to assess the effect of a load transfer platform between the shallow foundation and the rigid inclusions on the behaviour of the footing and the reinforced soil. To do so, three configurations of load distribution platforms were tested, under different loading conditions (vertical catered, vertical with eccentricity, horizontal-vertical combined loading…). Preliminary load tests on instrumented isolated rigid inclusions were carried out to study their behaviour under compression. A complete instrumentation solution was designed and implemented (including strain gauges, inclinometers, and total stress sensors…), to assess in detail the distribution of the load between the soil and the inclusions, This publication presents the geotechnical context of the study, the instrumentation implemented, and the different load cases. Results as then presented, and conclusions are drawn, allowing a better understanding of the behaviour of the reinforced soil under the footings.

RÉSUMÉ: Une expérimentation en grandeur réelle d'essais de chargement statique sur des semelles carrées sur inclusions rigides a été réalisée dans le cadre du projet de recherche ASIRI+. Le but de cette expérience était d'évaluer l'effet de la présence d'une plate-forme de transfert de charge entre la fondation superficielle et les inclusions rigides sur le comportement de la semelle et du sol renforcé. Pour ce faire, trois configurations de plates-formes de répartition des charges ont été testées, dans différentes conditions de chargement (vertical avec trappe, vertical avec excentricité, chargement combiné horizontal-vertical...). Des essais de charge préliminaires sur des inclusions rigides isolées et instrumentées ont été réalisés pour étudier leur comportement en compression. Une solution d'instrumentation complète a été conçue et mise en œuvre (comprenant des jauges de déformation, des inclinomètres, des capteurs de contrainte totale...), afin d'évaluer en détail la répartition de la charge entre le sol et l'inclusion. Cette publication présente le contexte géotechnique de l'étude, l'instrumentation mise en œuvre, et les différents cas de charge. Les résultats sont ensuite présentés et des conclusions sont tirées, permettant une meilleure compréhension du comportement du sol renforcé sous les semelles.

Keywords: Soil improvement; rigid inclusions; foundations; static load tests.

1 STUDY BACKGROUND

This study aimed to compare the behaviour of the footing with or without the presence of a granular load-transfer platform. Indeed, current French recommendations (ASIRI, 2012) recommend only a solution with a granular platform interposed between the inclusions and the footing. However, more and more companies want to be able to dispense with this platform constraint.

The ASIRI+ project therefore aims to offer a more open solution for dimensioning footings on rigid inclusions.

Centered vertical, eccentric vertical and horizontal loading tests was thus performed footings on rigid inclusions, with instrumentation used to monitor load transfer to the inclusions, footing displacement, soil and inclusion settlement. Two isolated inclusions were also tested to determine their behavior under static and cyclic loading.

2 TEST SITES AND TEST SPECIFICATIONS

The loading tests were carried out in Dourges, in the northern part of France. The geological/geotechnical context was quite simple, with a single layer of silts encountered.

All the tests were performed on the same precast reinforced concrete 1.8 m x 1.8 m x 0.5 m footing.

The implemented instrumentation included vibrating wire strain gauges, displacement sensors, soil settlement sensors, total earth pressure cells, and an inclinometer.

The rigid inclusions executed on this site were continuous flight auger inclusions, 4.5 m long and with a 0.27 m diameter.

The different test configurations are shown schematically in Figure 1, along with the results of the penetrometer tests, and summarized as follows:

- Configuration 0: two isolated inclusions.
- Configuration 1: a footing on four rigid inclusions without a load transfer platform.
- Configuration 2: a footing on four rigid inclusions with a load transfer platform of 30 cm of granular material.
- Configuration 3: a footing on four rigid inclusions with a 10 cm leveling sand layer.

The testing program is shown in Table 1.

Table 1. Testing program for each configuration

Test	Eccentricity	Loadings
E1	e = 0	V : 0 → 650 kN
E2	e = 0.3 m	V : 0 → 650 kN
E3	e = 0.45 m	V : 0 → 450 kN
E4	e = 0	V = 650 kN,
E5	e = 0	V = 650 kN, H : 0 → 250 kN
E6	e = 0	V : 0 → failure

The vertical loads were applied through the solicitation of a reaction frame identical to a typical one used for piles testing. For the horizontal solicitations, the reaction was achieved via the use of a concrete block founded on four large piles.

A 5 MN hydraulic jack was used for the vertical loadings and a 1 MN hydraulic jack for the horizontal loadings. Each of the two jacks was actuated independently, with its own hydraulic pump.

The testing program was very dense and rich, with many loading configurations tested (Table 1), and this communication will only present some of them.

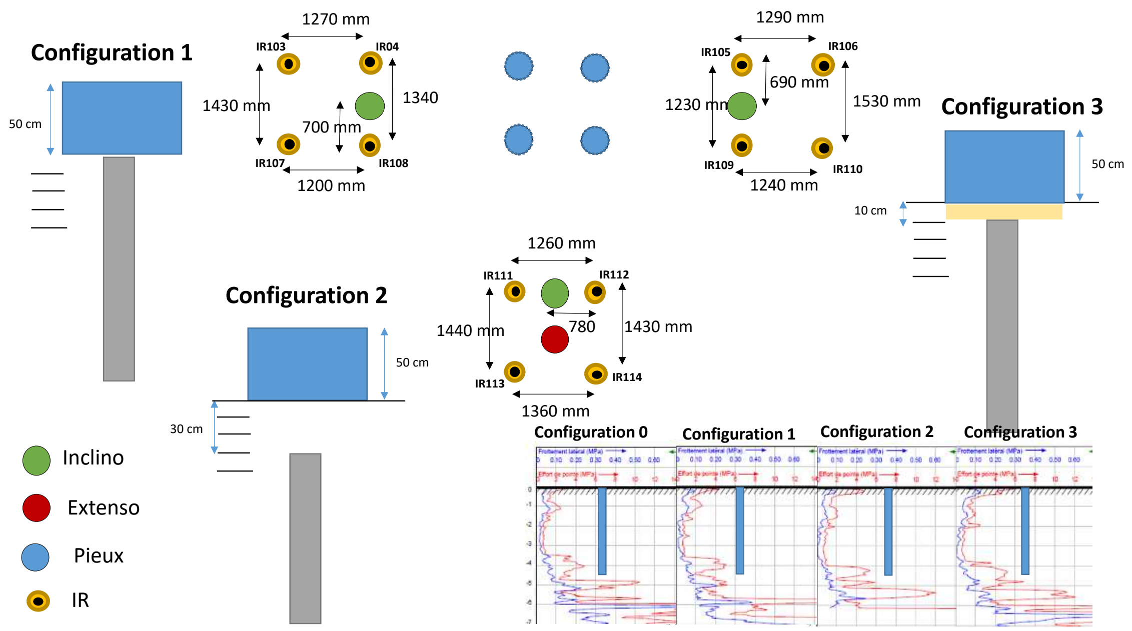


Figure 1. Tests configurations, implemented instrumentation, and CPT results.

3 LOADING TEST RESULTS

3.1 Stress distribution over the four inclusions

Figure 2 shows the stress increases measured on the rigid inclusions of configurations 1, 2 and 3 at the end of the test for the centered vertical loading E1 and E4.

It can be seen that for all three configurations, the footing never rests on the four inclusions. The same observation was made on a similar experimental test (Pham et al., 2019). Nevertheless, configuration 3, with the leveling sand layer, seems to allow a better distribution on the inclusions.

Configuration 2, with the granular platform, generates lower stress on the inclusions.

Furthermore, there is a difference in stress distribution between tests E1 and E4, which can be attributed to the installation of the soil reinforcement device during the first loading. This effect of the first loading has been observed in the footing displacement recorded at the end of tests E1 and E4.

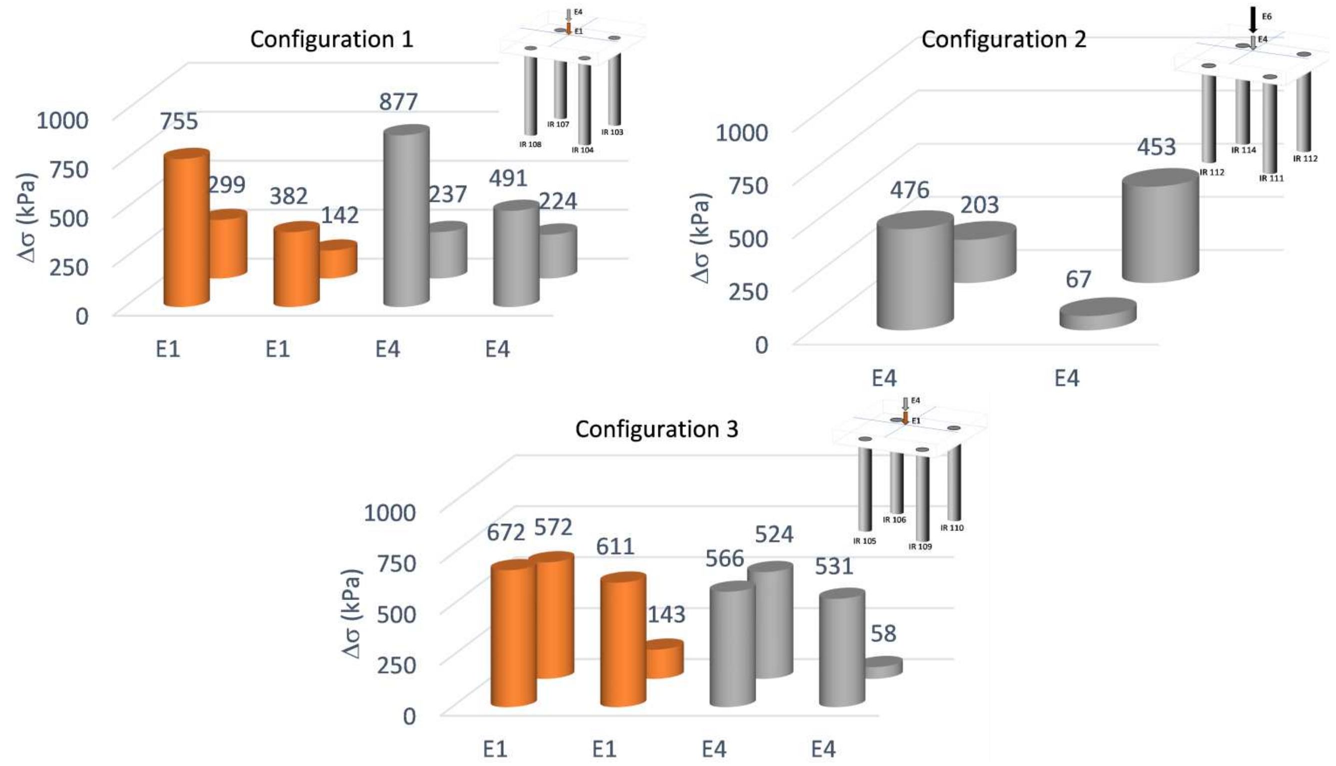


Figure 2. Stress measures at inclusions head, for configuration 1 to 3, during tests E1 and E4.

3.2 Influence of the eccentricity

Figure 3 shows the stress increases measured on the rigid inclusions of configurations 1 and 3 at the end of the test for centered vertical loading (E4), eccentric vertical loading at 30 cm (E2) and eccentric vertical loading at 45 cm (E3).

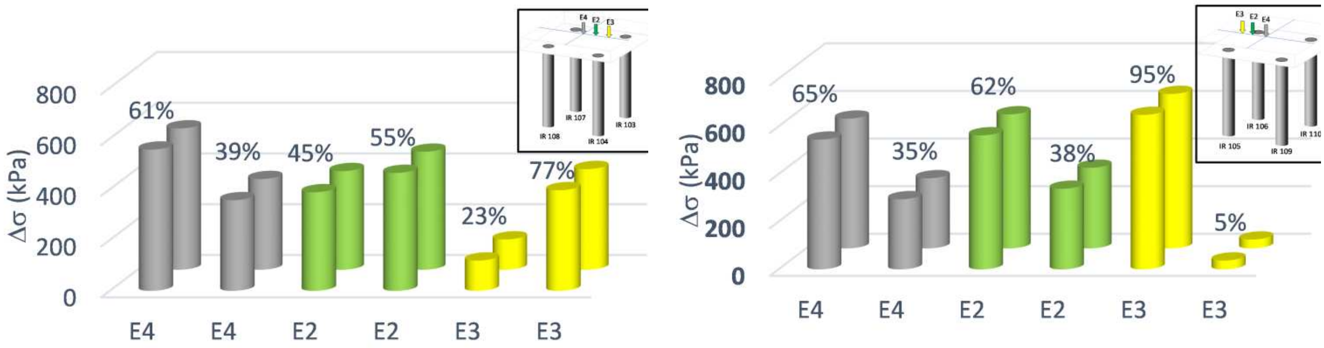
To avoid errors linked to the first loading, the E4 centered vertical test was preferred to the first E1 test for this comparison. Furthermore, to verify the influence of eccentricity, average values are presented for the two inclusions perpendicular to the direction of eccentricity.

An imbalance (60%-40%) is observed for the centered vertical test, even when a leveling layer of sand is disposed between the footing and the inclusions. At the 30 cm eccentricity, there is a slight tilting towards the two inclusions located on the eccentricity side. This tilting is much more pronounced at an eccentricity of 45 cm, where two inclusions take up 77% and 95% respectively of the load applied to configurations 1 and 3, respectively. This difference can be explained by the fact that, in configuration 1, the eccentricity was applied in the opposite direction to the two most heavily loaded inclusions, whereas for configuration 3, the eccentricity was applied in the same direction.

3.3 Failure tests

Test E6 brought each configuration to failure. The creep load was estimated at 900 kN, 950 kN, and 850 kN respectively for configurations 1, 2, and 3.

Results also showed that the settlement of the soil was greater than that of the inclusions. Plotting the differential settlement of soil and inclusions (Figure 4), we can see a change in behaviour from creep load onwards: for configuration 1, the soil-inclusion assembly settles homogeneously; for configuration 3, this homogeneous settlement occurs later. It should be noted that the differential measurements recorded are millimetric, and we can conclude that the reinforced soil settles homogeneously after the creep load for both configurations.



a *b*

Figure 3. Stress evolution at inclusions head, for configuration 1 (a) and 3 (b), during tests E4, E2 and E3.

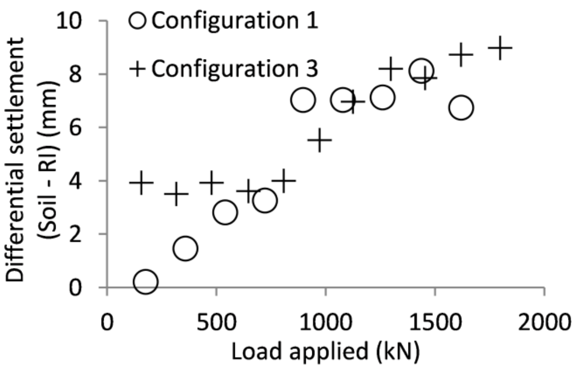


Figure 4. Differential settlement between soil and inclusions for configurations 1 and 3.

4 CONCLUSIONS

This full-scale experiment with footings on rigid inclusions is rich in lessons learned, despite the difficulty of accurately comparing the results of the three plots, particularly due to the different initial conditions. In fact, for each block, the first test highlighted conditions of preferential load transfer to two or three inclusions, making it difficult to exploit the results.

Tests with vertical load eccentricity revealed a strong load transfer to two inclusions. The presence of a granular platform reduces the load transferred directly to the inclusion heads (part of which must be transmitted by friction), but does not modify the overall behavior for vertical loading to failure. Load tests carried out to the failure demonstrated the behaviour of the reinforced soil after the creep load. These tests will enable the ASIRI+ project partners to calibrate their numerical models. This experimental study will be completed by another on-site tests campaign as well as a centrifuge test campaign, for which the initial conditions will be better controlled and which will enable an easier analysis of the behaviour of the various configurations tested, as the setup conditions and the reliability and reproductibility of all measures are difficult to assess with only one campaign.

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REFERENCES

ASIRi (2012). Recommandations pour la conception, le calcul, l'exécution et le contrôle des ouvrages sur sols améliorés par inclusions rigides verticales (Recommandations Projet National ASIRi), Presse des Ponts - IREX Paris.

Pham V.H., Briançon L., Dias D., Racinais J. (2019). *Footings over rigid inclusion-reinforced soft soil. Experimental and numerical approaches*. Canadian Geotechnical Journal, 56(12), pp. 1940-1952. https://doi.org/10.1139/cgj-2018-0495