Serial Report

History of Cambridge – GIKEN collaboration research (Part 1)

Yukihiro Ishihara, GIKEN LTD.

Stuart Haigh, University of Cambridge

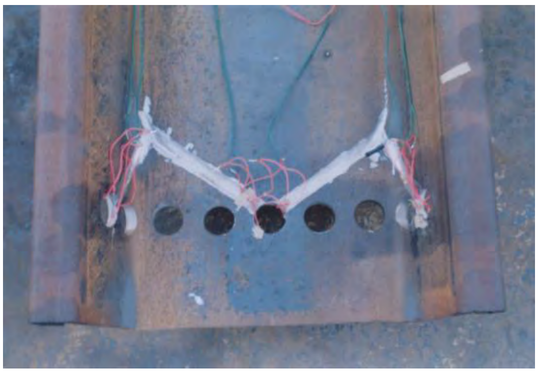
The Cambridge – GIKEN collaboration research started in 1994, based on the strong awareness of Mr. Akio Kitamura, President of GIKEN LTD., of issues relating to construction. Every summer two students visit Kochi, Japan, to carry out field and model tests using the press-in machines and other facilities of GIKEN, in order to learn this technology by experience. In some cases, they also conduct model tests or numerical analyses in their own laboratories on their return to Cambridge. In this report, research related to the tests carried out in Kochi from 1994 to 2003 are presented.

■ [1995-1996]

Project title	:	Effect of water jetting
Outline of tests in Kochi	:	Field tests were conducted using a press-in machine to investigate the effect of water jetting on reducing press-in time in dense sand. U-shaped sheet piles with a width of 400mm (SP-III) were used. The size of the water-jetting nozzle was varied between 6.5 and 8.5mm, with a flowrate of about 320ℓ/min. Two different nozzle shapes (directions of jetting) were also examined. The effect of these parameters on press-in time was analyzed, and the mechanisms were discussed qualitatively.
Main students	:	Matthew Carter, Fiona Gooch
Related publications	:	None

■ [1997-1998]

Project title	:	Investigation into pressure bulbs
Outline of tests in Kochi	:	The resistance on the base of the sheet pile during press-in was obtained by measuring the strain due to the hoop stress around the holes in the base of the sheet pile, as shown in **Picture 1**. The unit base resistance in dense sand was approximately constant at 35MPa, beyond a penetration depth of 3m, of the same order of magnitude as the crushing strength of coarse sand.
Main students	:	David White, Peter Kirkham, Naomi Lyons
Related publications	:	White, D. J., 1998. Deep penetration in sand. M.Eng. Project Report, Cambridge University Department of Engineering, 51p.



Picture 1

■ [1998-1999]

Project title	:	Press-in force and pile type / Press-in speed
Outline of tests in Kochi	:	The press-in force during press-in was compared using U-shaped sheet piles, H-shaped sheet piles and open ended tubular piles. Two press-in rates were adopted. An attempt to estimate the press-in force based on CPT data was discussed, and the necessity of considering the effect of soil plug in the pan of the sheet pile was pointed out.
Main students	:	Peter Kirkham, Haramrita Sidhu
Related publications	:	None

■ [1999-2000]

Project title : Measurement of soil plug strength

Outline of tests in Kochi : The phenomenon of plugging was investigated using a split tubular pile. The pile was pressed-in, extracted and separated into two, as shown in **Picture 2**, so that the inner soil column could be directly observed. The creation, dissolution and re-creation of the soil plug during press-in was confirmed, and the mechanism of the creation of soil plug was discussed.

Main students : Haramrita Sidhu, Timothy Finlay

Related publications : White, D. J., Sidhu, H. K., Finlay, C. R., Bolton, M. D. and Nagayama, T., 2000. Press-in piling: the influence of plugging on driveability. 8th International Conference of the Deep Foundations Institute, New York, pp. 299-310.

Picture 2

■ [2000-2001]

Project title : Friction cutter / Strain measurement

Outline of tests in Kochi : A double-walled tubular pile, shown in **Picture 3**, was pressed-in to investigate the horizontal earth pressure on the internal surface of the pile. Piles with and without friction cutters on their base were also pressed-in, to investigate their effect on reducing the press-in force. The friction cutter reduced the shaft resistance but had little effect on the base resistance during press-in.

Picture 3

Main students : Timothy Finlay, Yueyang Zhao

Related publications : Finlay, T. C. R., 2001. Press-in piling: noise, vibration and the relief of hard driving. M.Eng. Project Report, Cambridge University Department of Engineering, 49p.

Finlay, T. C. R., White, D. J., Bolton, M. D. and Nagayama, T., 2001. Press-in piling: the installation of instrumented steel tubular piles with and without driving shoes. 5th International Conference on Deep Foundation Practice, Singapore, 1, pp. 199-208.

■ [2001-2002]

Project title : Press-in force and bearing capacity

Outline of tests in Kochi : A double-tubed tubular pile was pressed-in. The static vertical load test was conducted and its bearing capacity was measured.

Main students : Yueyang Zhao, Gulin Yetginer

Related publications : Zhao, Y., 2002. Pile set-up in sand. M.Eng. Project Report, Cambridge University Department of Engineering, 48p.

Zhao, Y. & White, D. J., 2006. A model-scale investigation into 'set-up' of displacement piles in sand. Physical Modelling in Geotechnics - 6th ICPMG, pp. 889-894.

■ [2002-2003]

Project title : Features of pressed-in group piles / Vibration measurement / Time effect

Outline of tests in Kochi : Open-ended tubular piles with an outer diameter of 101.6mm were pressed-in as a cell foundation in a square or a circular manner. A static vertical load test was conducted as

shown in **Picture 4**, and the group effect on the press-in force and the bearing capacity of these pressed-in piles was investigated. The press-in force increased with the progress of the construction of the cell foundation. The group efficiency in terms of the bearing capacity, if the capacity of the single pile was taken as the press-in force of the first pile in the group, was slightly greater than but almost equal to unity.

Picture 4

Main students : David Rockhill, Gulin Yetginer, Andrew Deeks

Related publications : White, D. J., Finlay, T. C. R., Bolton, M. D. and Bears, G., 2002. Press-in piling: ground vibration and noise during pile installation. Proceedings of the International Deep Foundations Congress, Orlando, USA, ASCE Special Publication 116, pp. 363-371.

Yetginer, A. G., 2003. Press-in piling. M.Eng. Project Report, Cambridge University Department of Engineering, 50p.

Rockhill, D., 2003. Ground vibrations due to construction operations. M.Eng. Project Report, Cambridge University Department of Engineering, 46p.

Rockhill, D. J., Bolton, M. D. and White, D. J., 2003. Ground-borne vibrations due to press-in piling operations. BGA International Conference on Foundations: Innovations, Observations, Design and Practice.

Yetginer, A. G., White, D. J. and Bolton, M. D., 2003. Press-in piling: field testing of cell foundations. BGA International Conference on Foundations: Innovations, Observations, Design and Practice.

Yetginer, A. G., White, D. J., Bolton, M. D., 2006. Field measurements of the stiffness of jacked piles and pile groups. Geotechnique 56, No. 5, pp. 349-354.

■ [2003-2004]

Project title : Load test on groups of pressed-in piles

Outline of tests in Kochi : Open-ended tubular piles with an outer diameter of 101.6mm were pressed-in in a circular manner. Two circular groups of piles were constructed, one with a constant embedment depth **(Figure 1 (a))** and the other with two different embedment depths for each pile **(Figure 1 (b))**. The bearing capacity of these groups were comparable, even though the embedment depth of some piles in group (b) was smaller than the other piles. The group efficiency in terms of the bearing capacity, if the capacity of the single pile was taken as the press-in force of the first pile in the group and the capacity of the pile group was taken as the plunging load, was approximately equal to unity. On the other hand, the stiffness of the group decreased with the increasing number of piles in the group.

Main students : Andrew Deeks, Melvin Hibberd

Related publications : Deeks, A. D., 2004. An investigation into the strength and stiffness of jacked, driven and bored piles. M.Eng. Project Report, Cambridge University Department of Engineering, 51p.

Deeks, A. D., White, D. J. and Bolton, M. D., 2006. A comparison of jacked, driven and bored piles in sand. The 16th International Conference on Soil Mechanics and Geotechnical Engineering, Osaka, Japan, pp. 1685-1688.

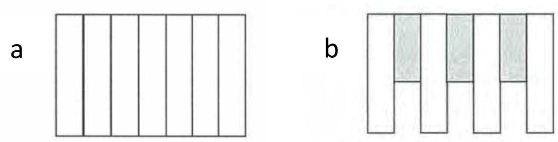


Figure 1 (Deeks (2004))

IPA News Letter Volume 3, Issue 1 March 2018

Serial Report

History of Cambridge – GIKEN collaboration research (Part2)

Yukihiro Ishihara, Giken, Ltd.

Stuart Haigh, University of Cambridge

The Cambridge – Giken collaboration research started in 1994, based on the strong awareness of Mr. Akio Kitamura, President of Giken, Ltd., of issues relating to construction. Every summer two students visit Kochi, Japan, to carry out field and model tests using the press-in machines and other facilities of Giken, in order to learn this technology by experience. In some cases, they also conduct model tests or numerical analyses in their own laboratories on their return to Cambridge. In this report, research related to the tests carried out in Kochi from 2004 to 2010 are presented.

[2004-2006]

Project title	:	Penetration resistance / Soil plug and bearing capacity
Outline of tests in Kochi	:	Cone Penetration Tests (CPTs) and load tests on pressed-in closed-ended tubular piles were conducted at two different sites in Kochi. The closed ended-pile had an outside diameter of 318.5mm and was equipped with a load cell on its base to measure the base resistance. It was found that the load-displacement curves for base resistance and shaft resistance during the load test was well modelled by a parabola considering G_0/q_c, where G_0 is the small strain shear modulus and q_c is the cone resistance in CPT. The load test results, together with this parabolic model, as shown in **Fig. 1**, suggested a higher stiffness of the pressed-in piles compared to conventional piling technologies.
Main students	:	Melvin Hibberd, Helen Dingle, Andrew Jackson
Related publications	:	Dingle, H., 2006. The testing and analysis of jacked foundation piles. M.Eng. Project Report, Cambridge University Department of Engineering, 50p. White, D. J. and Deeks, A. D., 2007. Recent research into the behavior of jacked foundation piles. Advances in Deep Foundations, pp. 3-26.

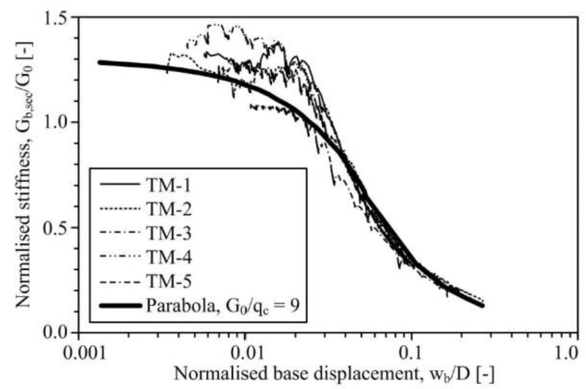


Fig. 1 (from White & Deeks, 2007)

[2006-2007]

Project title	:	Mechanism of increase in pull-out resistance
Outline of tests in Kochi	:	Three types of piles were used in this project: a U-shaped sheet pile with a width of 400mm (SP-III), a hat-shaped sheet pile with a width of 900mm (25H) and a closed-ended tubular pile with an outside diameter of 318.5mm. The closed-ended pile was equipped with a load cell on its base and several pore water pressure transducers on its shaft. Extraction resistance was investigated with different lengths of curing period. Although set-up was confirmed, the extent of set-up was not clearly linked with the dissipation of excess pore water pressure. In some tests, the peak value of extraction resistance appeared not at the commencement of extraction but when the pile was extracted by a substantial distance (more than 1m), as shown in **Fig. 2.** It was suggested, on the other hand, that the penetration resistance could be well expressed by modifying the UWA-05 pile capacity prediction method.
Main students	:	Andrew Jackson, Marcus Gillard

Related publications : Jackson, A., 2007. The setup of jacked piles. M.Eng. Project Report, Cambridge University Department of Engineering, 49p.

Jackson, A., M., White, D. J., Bloton, M. D. and Nagayama, T., 2008. Pore pressure effects in sand and silt during pile jacking. Proceedings of the 2nd BGA International Conference on Foundations, CD, pp. 575-586.

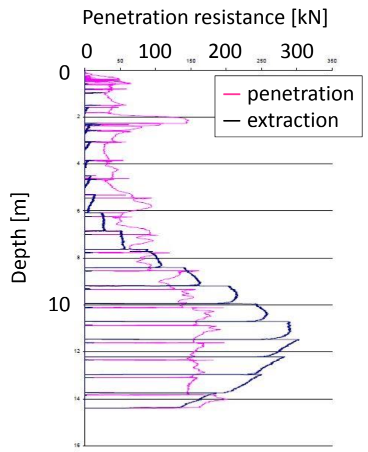
[2007-2008]

Project title : Penetration resistance and set-up

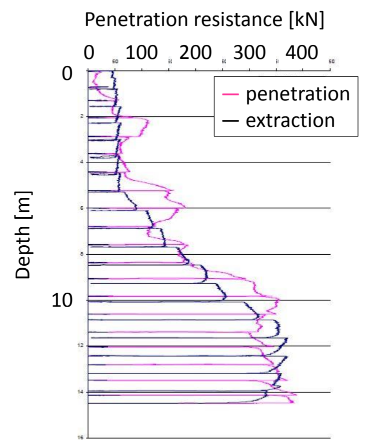
Outline of tests in Kochi : A closed-ended tubular pile with an outside diameter of 318.5mm, instrumented with a load cell on its base and several pore water pressure transducers on its shaft, was pressed-in at 3 different penetration rates (2, 12 and 30 mm/s). After 3 different curing periods (0, 15 and 60 min.), the pile was extracted to confirm the extent of set-up in extraction resistance. The base resistance was reduced at higher penetration rates, while the shaft resistance showed the opposite trend. Set-up in extraction resistance was confirmed. In some tests, peak values in extraction resistance were found not at the commencement of extraction but when the pile was extracted by more than 1 m. This tendency was more apparent for tests with shorter curing periods.

Main students : Marcus Gillard, Paul Shepley

Related publications : Ishihara, Y., Ogawa, N., Horikawa, Y., Kinoshita, S., Nagayama, T., Kitamura, A. and Tagaya, K., 2009. Utilization of pile penetration test data for ground information. Proceedings of the 2nd IPA International Workshop in New Orleans, Press-in Engineering 2009, pp. 105-120.



(a) U-shaped sheet pile with zero curing period



(b) Closed-ended tubular pile with zero curing period

Fig. 2

[2008-2009]

Project title : Plugging during press-in

Outline of tests in Kochi : A double walled open-ended tubular pile with outside and inside diameters of 318.5 mm and 199.9 mm, as shown in **Fig. 3**, was used in this project. The pile was equipped with 3 earth pressure transducers on its base to measure the base resistance. Four earth pressure transducers and pore water pressure transducers were placed inside the pile. The pile was pressed-in at two different penetration rates (2 and 10 mm/s), followed by load tests with different curing periods (85 minutes, 1 day and 10 days). It was confirmed that the strength of the soil plug was greater if the penetration rate was low. The set-up ratios at 10 days were confirmed to be around 1.5 and 2.5 for base and shaft resistance respectively.

Main students : Paul Shepley, Olusomi Delano

Related publications : Shepley, P., 2009. An investigation into the plugging of open-ended jacked-in tubular piles. M.Eng. Project Report, Cambridge University Department of Engineering, 47p.

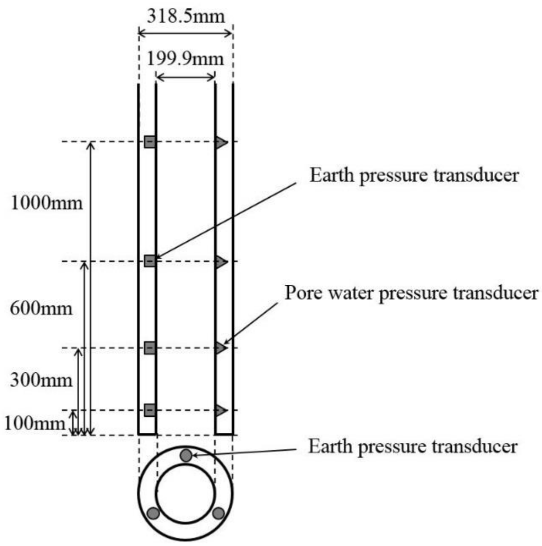
[2009-2010]

Project title : Effect of repeated penetration and extraction

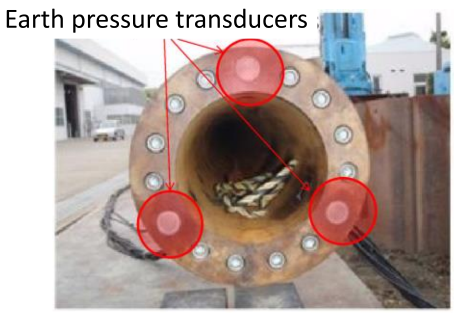
Outline of tests in Kochi : Two types of piles were used in this project: a U-shaped sheet pile with a width of 400 mm (SP-III) and a closed-ended tubular pile with an outside diameter of 318.5 mm. The closed-ended pile was equipped with a load cell on its base and several pore water pressure transducers on its shaft. The pile was pressed-in monotonically or with repeated penetration and extraction, at different sets of combination of rates and displacements of penetration and extraction. The results showed that shaft resistance was reduced by repeated penetration and extraction, regardless of the ground condition (penetration depth). On the other hand, base resistance was reduced in layers where cohesive soils were dominant. No clear trend was found between the pore water pressure and the penetration resistance in repeated penetration and extraction.

Main students : Olusomi Delano, Thomas Bond

Related publications : Delano, O., 2010. The application of surging on jacked-in piles. M.Eng. Project Report, Cambridge University Department of Engineering, 49p.



(a) Specification of pile



(b) View from the base

Fig. 3

Serial Report
History of Cambridge – GIKEN collaboration research (Part3)

Yukihiro Ishihara, Giken, Ltd.
Stuart Haigh, University of Cambridge

The Cambridge – Giken collaboration research started in 1994, based on the strong awareness of Mr. Akio Kitamura, President of Giken, Ltd., of issues relating to construction. Every summer two students visit Kochi, Japan, to carry out field and model tests using the press-in machines and other facilities of Giken, in order to learn this technology by experience. In some cases, they also conduct model tests or numerical analyses in their own laboratories on their return to Cambridge. In this report, research related to the tests carried out in Kochi from 2010 to 2018 are presented.

[2010-2011]

Project title	:	Reduction of penetration resistance during rotary press-in
Outline of tests in Kochi	:	Two types of piles were used in this project: a closed-ended tubular pile with an outside diameter of 318.5 mm and an open-ended tubular pile with an outside diameter of 500mm. The closed-ended pile was installed by standard press-in and rotary press-in at different penetration rates and rotation rates. It was found that the base resistance was reduced by increasing the penetration rate, showing a trend explained based on Finnie factor, in which the rate effect is attributed to the drainage condition. The rotation was confirmed to reduce the shaft resistance significantly but have little influence on the base resistance. The reduction of the shaft resistance was greater at larger velocity ratio (the ratio of the rotation rate to the penetration rate). This was attributed to a more horizontal direction of friction mobilized at the pile-soil interface. On the other hand, the extent of plugging was not mitigated by rotation; the length of the soil column inside a pile installed by rotary press-in was not shorter than that installed by standard press-in. This was concluded to be due to the difference in the ground condition.
Main students	:	Thomas Bond and Travis Winstanley
Related publications	:	Bond, T. 2011. Rotary jacking of tubular piles. M.Eng. Project Report, Cambridge University Department of Engineering, 50p. Nishigawa, M., Okada, K., Bond, T., Yamane, T., Ishihara, Y. and Kitamura, A. 2011. Reduction of friction in rotary jacking. Proceedings of the 3rd IPA International Workshop in Shanghai, Press-in Engineering 2011, pp. 107-113.

[2011-2012]

Project title	:	Spatial distribution of pore water pressure during press-in
Outline of tests in Kochi	:	Three closed-ended piles with the outside diameter of 318.5mm were used in this project. Each pile was equipped with a load cell on its base, 5 pore water pressure transducers and 5 earth pressure transducers on its shaft. Two of the piles were used as measurement piles while the other one was pressed-in as a test pile, as shown in Figure 1. The distance between the test pile and the measurement piles were maintained either as 1, 2, 3 or 5 times the outside diameter of the piles. During press-in, the pore water pressure measured by the measurement piles increased to its peak value until the pile base passed the depth of the transducers, and then started to decrease to a residual value. It was confirmed that the spherical cavity expansion analysis provides a lower bound of the peak values of pore water pressure during press-in.
Main students	:	Travis Winstanley and Ewa Hazla
Related publications	:	Winstanley, T., 2012. The significance of pore water pressures on press-in piles. M.Eng. Project Report, Cambridge University Department of Engineering, 50p.

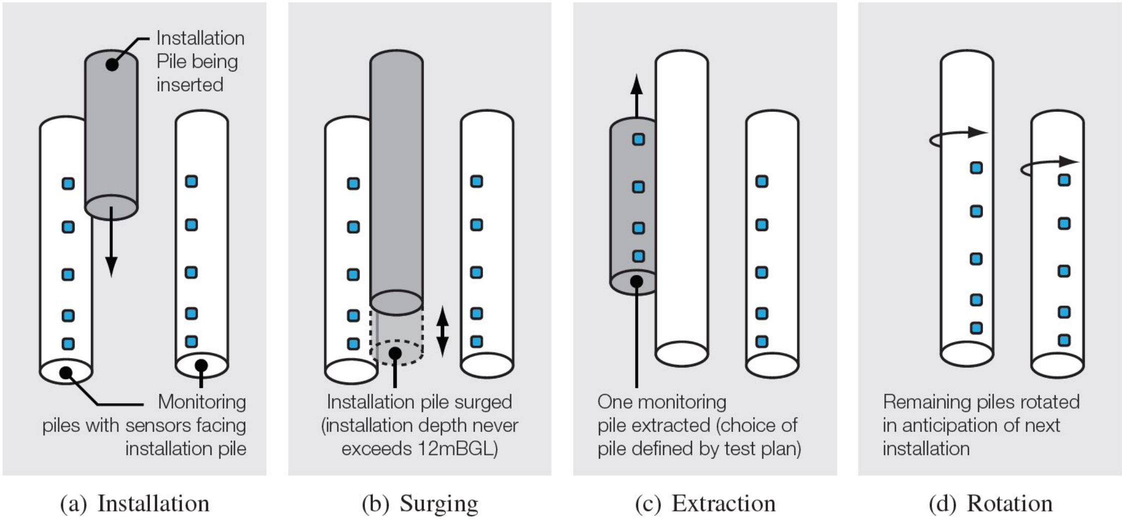


Figure 1 (from Winstanley (2012))

[2012-2013]

Project title	:	Reduction of friction during rotary cutting press-in of an open-ended tubular pile in sand
Outline of tests in Kochi	:	Open-ended tubular piles with the outside diameter of 800mm were used in this project. The piles were installed into a dense sandy ground by rotary cutting press-in method. When the pile was processed to have surface projections, which had been expected to be effective in reducing the shaft resistance, the penetration resistance was greater than when the pile did not have the surface projections, which was contrary to the expectation. When the non-processed pile was continuously rotated at a constant depth, the rotational torque did not keep decreasing with an increasing rotational displacement. This result was in contrast with the results confirmed in the previous year that the rotational torque decreased by around 50% with an increasing rotational displacement when a pile with the outside diameter of 318.5mm embedded in a soft alluvial ground was rotated at a constant depth.
Main students	:	Ewa Hazla and Gongyan Gao
Related publications	:	Hazla, E., 2013. Rotary press-in piling in hard ground. M.Eng. Project Report, Cambridge University Department of Engineering, 50p.

[2013-2014]

Project title	:	Performance of steel sheet pile walls
Outline of tests in Kochi	:	Three types of cantilevered sheet pile walls were dealt with in this project. One was the 'Normal wall' in which sheet piles were embedded vertically. Another was the 'Slanting wall' where sheet piles were embedded with the inclination angle of 5 degrees. The other was the 'Implant preload wall' in which sheet piles were embedded with the inclination angle at their base of 5 degrees and were elastically deflected toward the excavation side, as shown in Figure 2. When the backside surcharge was applied to the wall, the horizontal displacement of the walls was the largest in the Normal wall and the smallest in the Implant preload wall. Two underlying mechanisms were inferred. One was that the horizontal loading history on the soil in the excavated bottom associated with the horizontal displacement of the wall due to the preload increased the stiffness of the soil when it responded to the second loading process associated with the backside surcharge. The other was that the shear strength of the soil behind the wall was enhanced due to the increased confinement stress associated with the elastic deflection of the wall.
Main students	:	Gongyan Gao and Glyn Stevens
Related publications	:	Gao, G., 2014. Comparing performance of different sheet pile walls. M.Eng. Project Report, Cambridge University Department of Engineering, 50p.

Ishihara, Y., Ogawa, N., Okada, K. and Kitamura, A., 2015. Implant Preload Wall: a novel self-retaining wall with high performance against backside surcharge. Proceedings of the 5th IPA International Workshop in Ho Chi Minh, Press-in Engineering 2015, pp. 68-82.

Ogawa, N., Ishihara, Y. and Kitamura, A., 2017. Experimental study on deformation of self-retaining sheet pile wall due to excavation and backside surcharge. Journal of Japan Society of Civil Engineers, Division C: Geotechnics, pp. 62-75. (in Japanese)

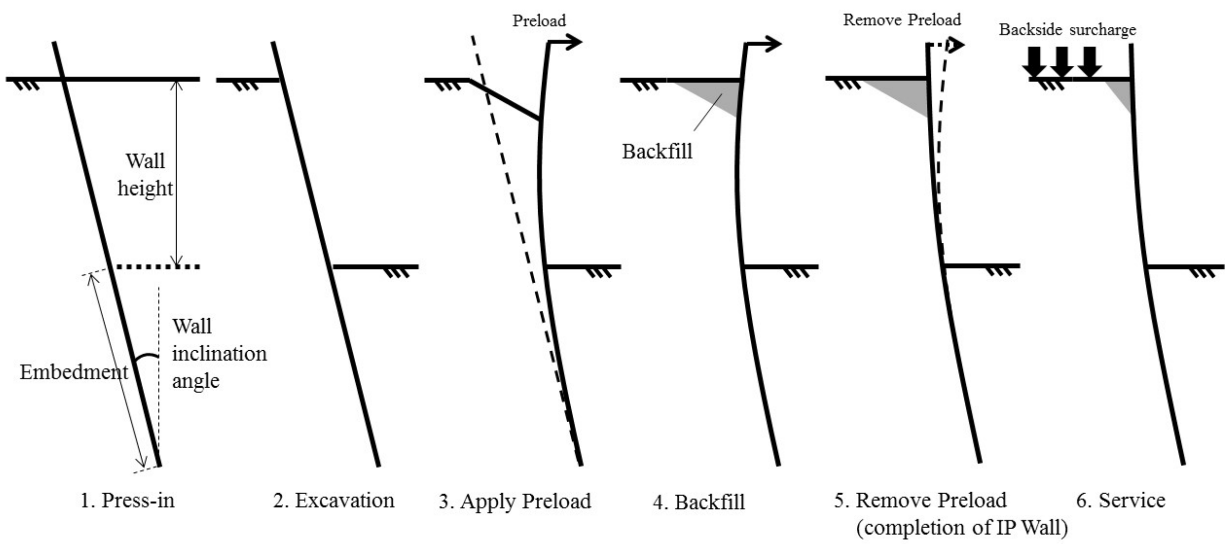


Figure 2

[2014-2015]

Project title	:	Mechanism of water-binding during rotary press-in in dense sand
Outline of tests in Kochi	:	Water-binding is a phenomena that is sometimes encountered when installing a pile in sand assisted with water injection. Muddy water coming up to the ground surface along the pile shaft, which will be observed when a pile is being installed smoothly, is lost and the penetration resistance suddenly increases. To investigate into the mechanism of water-binding, a circular and a semi-circular model piles with the outside diameter of 48.6mm and a soil tank with the width and the horizontal depth of 1000mm and the depth of 1200mm were used in this project. The soil tank had an acrylic plate on one of its four sides, and a saturated model ground was prepared inside the soil tank by mixing a saturated silica sand #7 using a stirring bar. The semi-circular pile was pressed-in assisted by water injection against the acrylic plate, so that the penetration process can be visualized. The circular pile was installed by rotary press-in assisted by water injection at the center of the model ground, with different penetration rates, rotational rates and flowrates to confirm the conditions on which the water-binding is triggered. From the tests using the semi-circular piles, the process of the creation of 'interface liquefaction' and the disappearance of it (i.e. water-binding) was observed, and the three parameters were identified as critical for sustaining the interface liquefaction: the water pressure at the pile shoulder, the water pressure required to sustain the interface liquefaction and the flowrate available for interface liquefaction. An analytical model was proposed by assuming that the cause of water-binding is the sufficient pressure in the liquefied region to transmit all water though the pores, and was confirmed to be able to predict the depth of water-binding correctly for saturated sand.
Main students	:	Glyn Stevens and Andrei Dobrisan
Related publications	:	Stevens, G., 2015. Mechanism of water binding during press-in in sand. M.Eng. Project Report, Cambridge University Department of Engineering, 50p.

[2015-2016]

Project title : Verification of the resilience of Implant levees against tsunami

Outline of tests in Kochi : Two sets of experiments were carried out in this project. One was to investigate the horizontal load imposed by tsunami on a wall in an overflowing condition, by means of model tests using an experimental facility called the Tsunami Simulator, as shown in Figure 3. The other was a static horizontal load tests on two piles with the same outside diameter of 1000mm and different thicknesses of 12mm and 24mm, to observe the deformation characteristics of piles embedded in dense sand beyond its elastic limit. The results of the model tests showed that the tsunami load in an overflowing condition can be safely estimated by an existing estimation method, excluding instantaneous loads measured when the model tsunami hit the wall. Based on the results of the load tests, it was confirmed that the stiffness and bending moment profile of the pile were well estimated by DNV (1992). On the other hand, the horizontal capacity of the pile was confirmed to be underestimated by a factor of 2 by the p-y method, which has been pointed out by many researchers.

Main students : Andrei Dobrisan and Yan Zhuang

Related publications : Dobrisan, A., 2016. Suitability of jacked-in steel piles as tsunami defences. M.Eng. Project Report, Cambridge University Department of Engineering, 48p.

Dobrisan, A., Haigh, S. K. and Ishihara, Y. 2018. Evaluating the efficiency of jacked-in piles as tsunami defences. Proceedings of the First International Conference on Press-in Engineering.

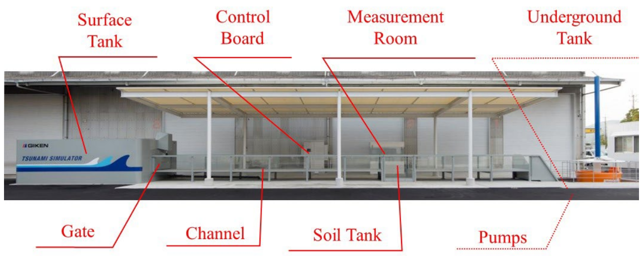


Figure 3

[2016-2017]

Project title : Design and construction of sheet pile retaining wall with and without the stabilization of excavation base

Outline of tests in Kochi : Two types of sheet pile pits were designed and constructed One was a square pit No.1 with a horizontal length of 8.4m, an embedment depth of 10m and an excavated depth of 5m. The other was a rectangular pit No.2 with a horizontal length of 8.4m and 6m, an embedment depth of 16.5m and an excavated depth of 9.5m. The excavation base in the pit No.2 was stabilized by a number of concrete columns before the excavation, as shown in Figure 4. The deformation of the wall due to the stabilization and the excavation was measured manually by an inclinometer. The wall was pushed outwards due to the stabilization and then pushed inwards due to the excavation. Together with the results of FEM analysis in which the stabilization process was modelled by thermal expansion, the effectiveness of the stabilization was discussed qualitatively.

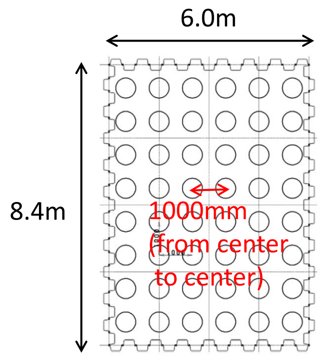


Figure 4

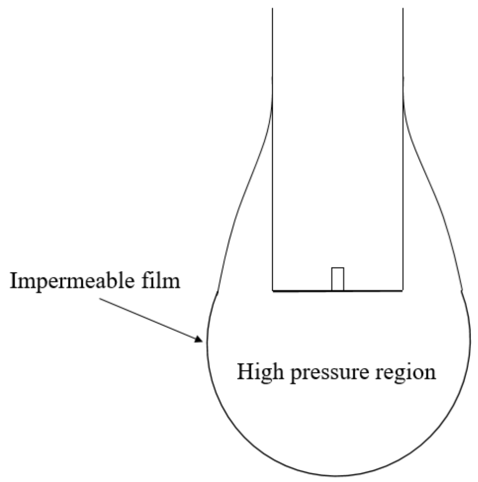
Main students : Yan Zhuang and Marla Gillow

Related publications : Zhuang, Y., 2017. The effect of bottom stabilisation on sheet pile pit. M.Eng. Project Report, Cambridge University Department of Engineering, 46p.

[2017-2018]

Project title : Mechanism of water jetting

Outline of tests in Kochi : Two sets of sheet piles equipped with pore pressure transducers were used in this project. One pile was installed prior to the installation of another, so that the pore water pressure not only on the shaft of the pile being installed but also in the ground at a certain distance from the pile being installed can be measured. Results of detailed analysis of the data suggested that a high stress region near the base of the sheet pile caused a build-up of base resistance, preventing further penetration of the pile, until enough water pressure was built up at the pile base to reduce the stress of the high stress region. The high water pressure was able to be built-up around the pile base even in relatively permeable soils, presumably because the repeated penetration and extraction at a constant depth range caused crushing of sand particles, forming an impermeable film in the pile base as shown in Figure 5.



Fiure 5 (from Gillow (2018))

Main students : Marla Gillow, Jennifer Chambers

Related publications :

Gillow, M. 2018. Water jetting for sheet piling in sandy soils. M.Eng. Project Report, Cambridge University Department of Engineering, 49p.

Gillow, M., Haigh, S. K., Ishihara, Y., Ogawa, N. and Okada, K. 2018. Water jetting for sheet piling. Proceedings of the First International Conference on Press-in Engineering.