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A decade of R&D in press-in technology: Bridging the gap between academia-industry in Malaysia

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ABSTRACT: The vibrant relationship between academia and industry are needed in fostering an applied research especially for a developing countries, such as Malaysia. This paper will highlight a decade of joint activities between Universiti Tun Hussein Onn Malaysia (UTHM) and several industrial stakeholders in adapting sustainable technology such as Press-in Technology in Malaysia. The technological transfer had been carried out since the establishment of a press-in pile research in 2007 at The University of Sheffield, United Kingdom. In general, conventional teaching and learning sessions, undergraduate and post graduate research and development activities and industrial attachments are the common activities. In addition, industrial sharing sessions and technology showcases are also the common activities initiated to bridge the gap between academia and industry. The activities allow dissemination of latest Press-in technology to both academia-industry by establishing R&D collaborations with local and international stakeholders in the Malaysia construction industry.

1 GENERAL INTRODUCTION

1.1 *Preface*

The vibrant relationship between academia and industry needs to be strengthened to meet the strategic needs of research and development in the developing countries, such as Malaysia.

The relationship may allow both the academician and the industry to capitalize on the strength of the other. Progressive construction activities in Malaysia worth some RM150 billion last year demand sustainable solution in minimizing the negative impact on the environment. When it comes to substructure construction, conventional dynamic piling methods are ill-suited to urban development because of the emissions of deafening noise and vibrations. These methods may no longer be the best options in certain conditions especially when subjected to the construction of a structure in a busy city such as Kuala Lumpur.

The silent piling technology offers an alternative sustainable solution by using a relatively small press-in machine, so called the "Silent Piler". The technology was developed to satisfy five construction principles consisting of Environmental Protection, Safety, Speed, Economy and Aesthetics. Based on the reaction principle of press-in piling method, pre-fabricated piles are hydraulically jacked-in with minimum noise and vibration. However, the technology can be considered as new and not commonly used in a country such as Malaysia.

1.2 *Objectives of review*

This paper will highlight a decade of research and development activities between Universiti Tun Hussein Onn Malaysia (UTHM) and several industrial

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stakeholders in adapting a sustainable technology such as Press-in Technology in Malaysia. In general, a conventional teaching and learning sessions, industrial sharing sessions, industrial attachments, technology showcases, undergraduate and post graduate research and development activities are among the common activities initiated to bridge the gap between academia and industry.

2 EARLY RESEARCH

2.1 *PhD study at the University of Sheffield*

The PhD research journey started in 2007 under The International Press-in Association International Grant awarded to Professor Adrian Hyde. During that time, The University of Sheffield received the grant in exploring the potential rate effect of press-in pile.

Press-in pile installation techniques have highlighted the need for a better understanding of rate effects in clays. In order to gain an insight to the problem, a new Rowe Cell-Vane Shear Test (RCVST) apparatus has been developed for this project with a single phase electric servo motor and torque transducer to drive the shear vanes over a wide range of angular velocities. The apparatus as shown in Figure 1 allowed four vanes of different dimensions to be consolidated in a single clay bed.

2.2 *Development of Rowe Cell-Vane Shear Test (RCVST) apparatus*

The main reason which lead to the development of this apparatus is the existing laboratory apparatus (i.e.: triaxial and direct shear apparatus) have a limited range of strain rate and often cover at a slower rate of loading (strain rate is usually 0.5 % to 1 % per minute). For this study, it was justified that the research interest is to investigate the rate effect at a faster speed as compared to the ordinary laboratory application.

It is hoped that the research finding will be reflected to the similar industrial application in a point of rate of strain. For example, in-situ vane shear tests are normally conducted around 0.03 to 0.13 mm/s, a press-in piling operation is approximately about 25 to 592 mm/s, in-situ cone penetration tests is about 10 to 20 mm/s and direct shear tests are conducted at about 0.02 mm/s.

Figure 1. Early setting of Rowe Cell-Vane Shear Test apparatus at the University of Sheffield.

The apparatus consisted of a modified triaxial test frame, a double Rowe cell consolidometer connected to a pressure unit, a laboratory vanes with servo motor and a gear head connected to a motion controller and a data logging device. (Figure 2).

The test rig is very similar to that used by Srishaktivel (2003) and Hird & Srishaktivel (2005) but with a cross head designed to accommodate a servo motor with a gear head. The test cell, similar to the one used by Srishaktivel (2003) and Emmett (2007) was formed by bolting together with two Rowe consolidation cell bodies, 254 mm in diameter and 126 mm high, while the aluminium cell base was modified in order to accommodate four vanes during consolidation.

In total, it took slightly over two years to complete the development, fabrication and commissioning of the apparatus at the Department of Civil and Structural Engineering laboratory.

2.3 *Rate effects from RCVST apparatus*

The developed apparatus is capable in conducting both rate effect studies for undisturbed and disturbed soil sample from slurry consolidation. Figure 3 and 4 show the results for undisturbed and disturbed sandy clay specimens using undrained shear strength tests. The vane length ranges from

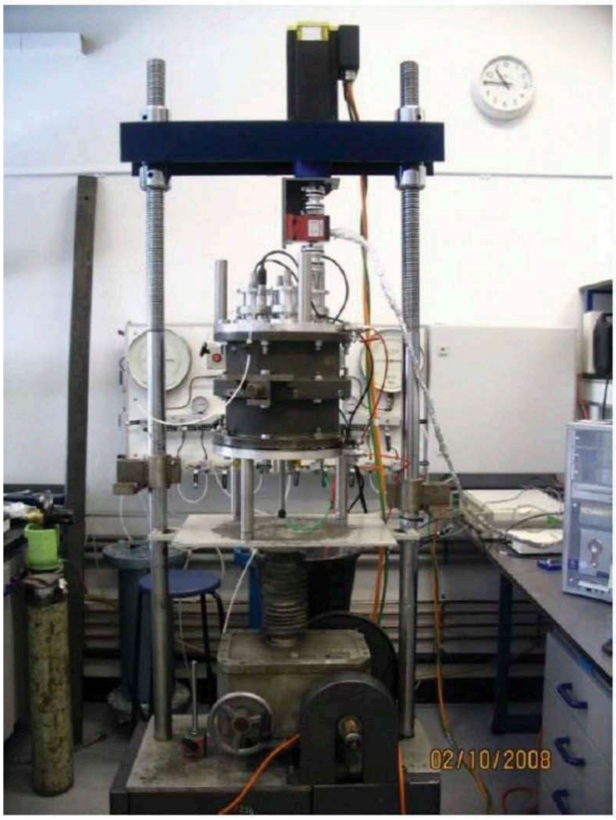

Figure 2. Rowe Cell Vane Shear Apparatus.

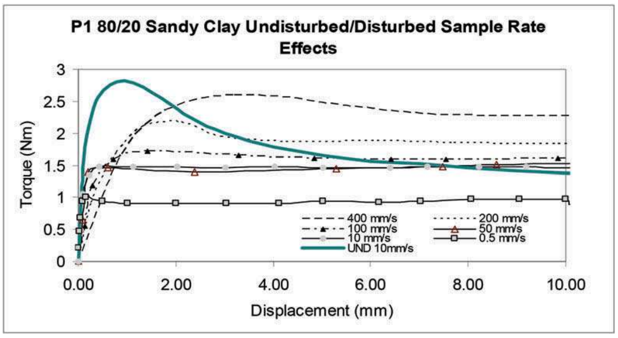

Figure 3. Peak and residual torque for sandy clays by using 80/20 vanes (Plasticity index, PI=22).

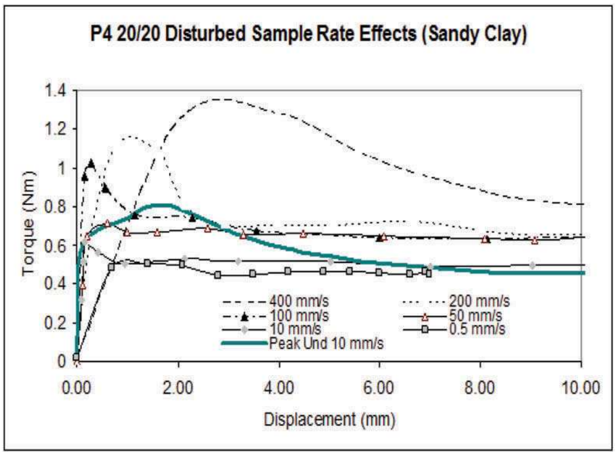

Figure 4. Influence of peripheral velocity on peak and residual torque for sandy clays by using 20/20 vanes (Plasticity index, PI=22).

20mm and 80mm long with 20 mm diameter. The available rate of shearing for this apparatus is in the range from 0.5 m/s to 400 mm/s. Some results are shown in figure below.

3 RESEARCH ACTIVITIES AT UNIVERSITI TUN HUSSEIN ONN MALAYSIA

3.1 *Method 1: Statistical studies*

Currently, there is still very limited application of press-in technology in Malaysia. This indicates a need to understand the various perceptions of the practitioners in accepting the technology. A qualitative review has been conducted in order to investigate the acceptance of silent piling technology among designers (civil engineering consultants) in Malaysia.

For this reason, sets of questionnaires were distributed to 43 companies from civil engineering consultants registered with Association Consultancy Engineering Malaysia (ACEM). These respondents were given 4 weeks to return the questionnaires. In theory, the response rate from respondents may be vary. 20% response can be considered adequate and 80% can be considered to be high. For this study, the sample size for data analysis was 52%. Therefore, the data set was adequate and can be considered as valid.

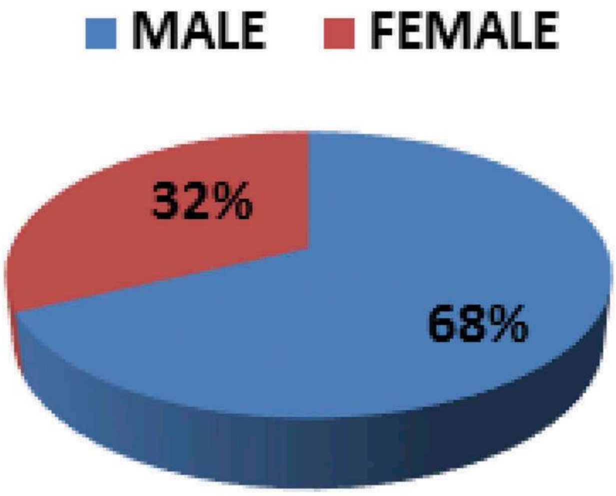

Figure 5. Gender of the respondents (Ibrahim, *et. al*, 2015).

Figure 5 Shows that 68% are male respondents and 32% are female. In addition, in terms of the age of the respondents, 36% of the respondents are in the range of 31 to 40 years old. On the other hand, 32% respondents in the range of 20 to 30 years old and 40 years old and above respectively.

In terms of design experience obtained from the respondents, 50% of the respondents have less than 5 year experience in this sector. The respondents with 5 to 10 year experience represent 14% of the respondents & those with more than 10 year experience are about 36%. The distribution is as shown in Figure 6.

In general, respondents were given several scenarios such as conducting piling work in a sensitive area, which method produce the lowest noise and

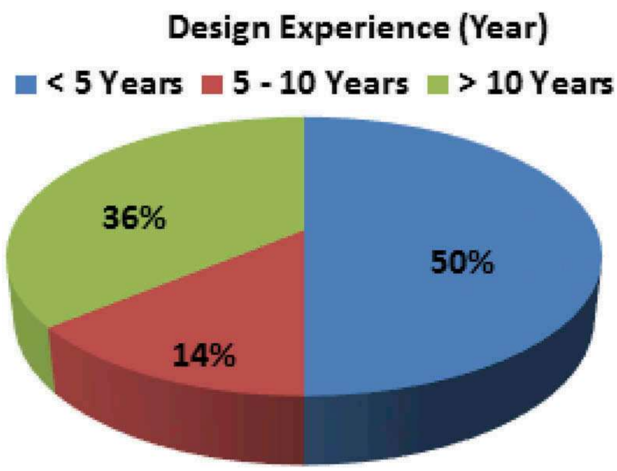

Figure 6. Respondent's experience in particular engineering design (Ibrahim, *et. al*, 2015).

vibration, extension of a railway track without halting the train operation, narrow access site and development above water. The findings show that they are in favor with press-in piling method as compared to other approaches. These show that the respondents agreed that this technology may have a great potential in dealing with a related problems on site in Malaysia.

Figure 7 shows that even though it was observed that most of the respondents were able to recognize the benefits of applying this technology, it was found that 82% of respondents were not familiar and had never used the press-in piling method before. In addition, only 5% were very familiar and often used it. Therefore, it can be concluded that the press-in piling method provides a very positive future for foundation engineering construction but this new technology has not yet widely used in Malaysia.

In order to accelerate the application of this sustainable technology, the respondents advised that some technical support should be provided to the designers. Their recommendation is as shown in Figure 8. In summary, they believed that the designer

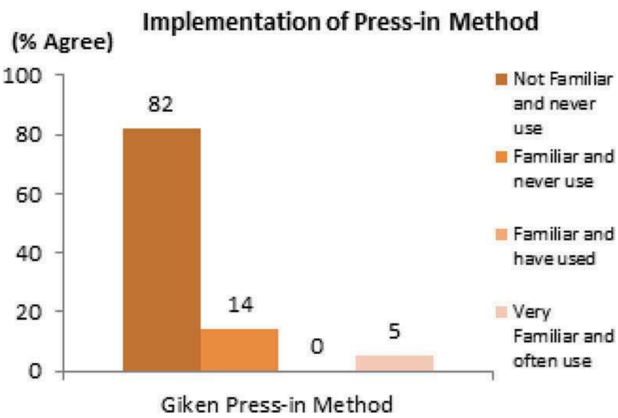

Figure 7. Implementation of press-in method in Malaysia (Ibrahim, *et. al*, 2015).

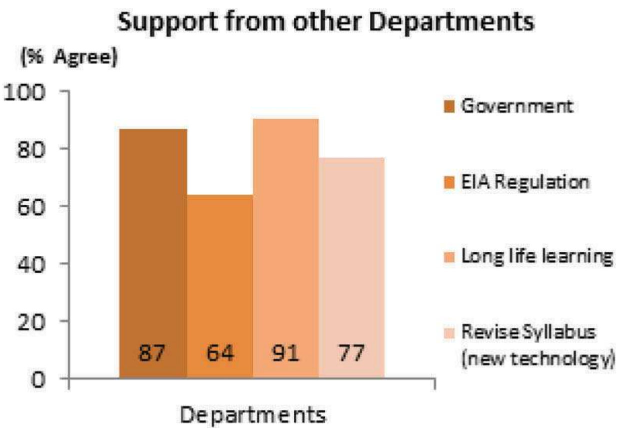

Figure 8. Implementation of press-in method in Malaysia (Ibrahim, *et. al*, 2015).

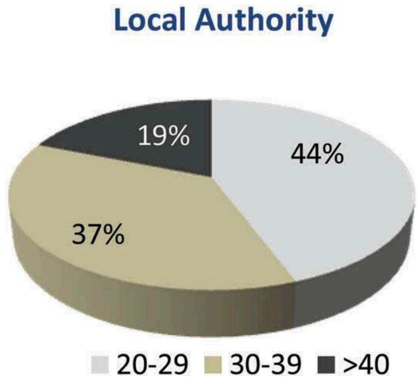

Figure 9. Age of respondent.

should emphasize more on their time towards lifelong learning. Majority of them also believed that the government may play a very important role in promoting this kind of technology. At the university level, it was recommended that the current engineering syllabus should be revisited in order to make room for this latest technology (Ibrahim, *et. al*, 2015).

Based on the finding of the survey, a similar survey had been conducted to the group of engineers working with the local authorities or the government bodies (Azhar, 2018). The findings are as shown in Figure 9 to 11. 43.6% of the respondents are in the range of 20 and 29 years old, 41% in the 30-39 years age group and the rest are 40 years old and above. In respect to gender distribution, 69.2% are male respondents and the rest 30.8% are female. Majority of the respondents are having more than 5 years working experience.

Most of the respondents believe that inadequate skill among the local authorities are the main factors why press-in technology is still not commonly used in Malaysia. The second factor is related to the financial consideration. The result also suggested that incentives should be imply to promote the application of sustainable technology. In addition, the finding also suggesting that mandatory sustainable regulations should be enforced in accelerating the application of this technology. Therefore, further research and development are needed in addressing the issues.

3.2 *Method 2: Case study*

The application of statistical and survey methods will be helpful in recognizing the general needs of the country in understanding the beauty of press-in technology. However, most of the construction companies in Malaysia do not familiar with the existence of silent piling method as an alternative technique for the pile installation. At present, the availability of press-in machine is also very limited. In order to bridge the needs and current limitations, a case study method is one of the possible options. By having a case study method, deeper understanding of the actual application

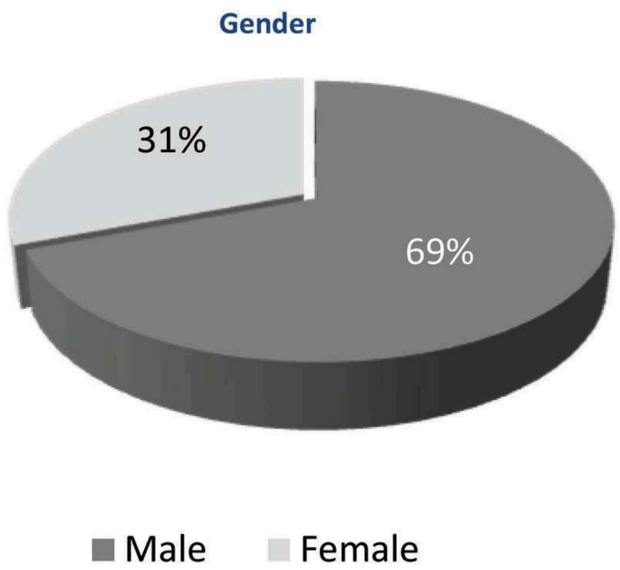

Figure 10. Gender of respondent.

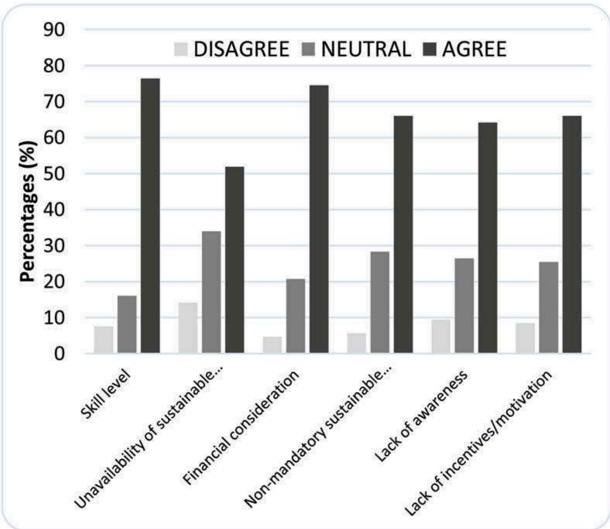

Figure 11. Limitation for the sustainable construction practices with piling construction.

Figure 12. One of the construction site for mass railway Transit in Kuala Lumpur (Yun, 2020).

Figure 13. Student spending their time at the actual construction site (Yun, 2020).

Figure 14. Overall view of one of the construction site in Kuala Lumpur.

on the ground could be written and shared. Hopefully it will be able to facilitate the lifelong learning activities among engineers in order to enhance their awareness such as shown in Figure 12 to Figure 14.

In order to conduct the case study method, several students had been attached at certain period of time at the relevant companies. For example, several engagements with the local contractors such as KOYE (Malaysia) Pte. Ltd. had been initiated in developing the existing case study for press-in application in Malaysia.

In order to develop a case study, important information such as the project background, ground geological properties, surrounding environment of project site, structural type, piling information, structural and pile type, piling method and productivity is needed. In addition, having a real job experience is also a very important element in a student experiential learning process. In addition, the student also indirectly learn other things too. For example, they were exposed to various factors that might cause delays on construction works throughout the project life cycle due to several reasons including the weather, communication and coordination, planning, construction materials, project finance, construction equipment, experience and qualification, construction labour and site management (Durdyev & Hosseini, 2019). However, due to a commercial restriction of the project information, only general information is shareable for this paper.

3.2.1 *Case Study 1: KLCC East Station, MRT 2 (SSP Line), Kuala Lumpur*

The construction project was located at Mass Rapid Transit (MRT) Line 2 - Sungai Buloh - Serdang - Putrajaya (SSP Line), KLCC East station (SSP21), Kuala Lumpur. The purpose of the project was to conduct the temporary sheet piling works by using the Super Crush Piler for cooling tower at KLCC East station.

According to the published geological maps of Kuala Lumpur area, Kuala Lumpur Limestone Formation underlies in most of the area in Kuala Lumpur. Besides that, KLCC and Bukit Bintang areas are occupied with the Kenny Hill Formation (Tan, 2005). Kenny Hill Formation occupied the depth up to 10 meters below the existing ground level in Kuala Lumpur area with the SPT value greater than 50 which is considered as hard ground. Therefore, hard ground press-in method which known as Super Crush Piler SCU-400M was adopted for this project.

Figure 15 to Figure 17 show the operation of the super crush piler at the construction site. Other equipment and apparatus which assisted the crush piler such as power unit, reaction stand, counter weight, pile auger, crane machine and radio controller were introduced (Yun, 2020).

Figure 15. Super crush piler are working on site (Yun, 2020).

Figure 16. Lifting and transferring sheet pile to the crush piler by using crane machine (Yun, 2020).

Figure 17. Photo taken with Koye (M) Sdn. Bhd. Project Manager, Mr. Alvin Low (Yun, 2020).

Based on the case study, the silent piling technology was recommended to be adopted and applied in the urban and densely populated area. This noise and ground vibration free technology is a more suitable sustainable construction practice as compared to the conventional piling installation method. Therefore, silent piling method can minimize and avoid the risk of destroying the massive underground systems in the urban city such as underground cable system, underground drainage and sewer system and tunnel (Yun, 2020).

3.3 *Method 3: Laboratory study*

During this period, several laboratory studied related to the press-in technology had been initiated. One of the studies that is worth to share here is the study related to time dependent effect to certain selected soil. This simple undergraduate laboratory study was conducted in order to recognize the understanding related to recovery of pile skin friction concept (Aliff, 2014). Based on Nozaki (2013) site experience as shown in Figure 18 and Figure 19, it was observed that the extraction static force significantly increased after 30 days for sandy gravel. The scenario may trigger a need to establish further understanding especially to estimate the extraction force and the appropriate machinery for pile extraction procedure.

For this study, a model pile with a 450mm length and 25.4mm in diameter had been considered. The study was conducted on a test bed by using a sandy material at the Research Centre for Soft Soil (RECESS). The extraction force was monitored in a sequence of 1, 5, 7, 10 and 25 days after pile installation. Due to a very limited budget, a self-fabricated pile extraction mechanism and a portable scale had been utilized to monitor the extraction force.

Due to the limited depth of test bed and capability of the portable scale, the model pile could only be installed up to 200 mm depth. For reference, a theoretical surface force was estimated based on Meyerhof's Method (1976). In general, the average extraction force after one day installation was approximately double than the theoretical force. It is apparent from this figure that the average extraction force were steadily increased as the numbers of day increased. After 7 days of installation, more than four times force was needed to extract the pile as compared to

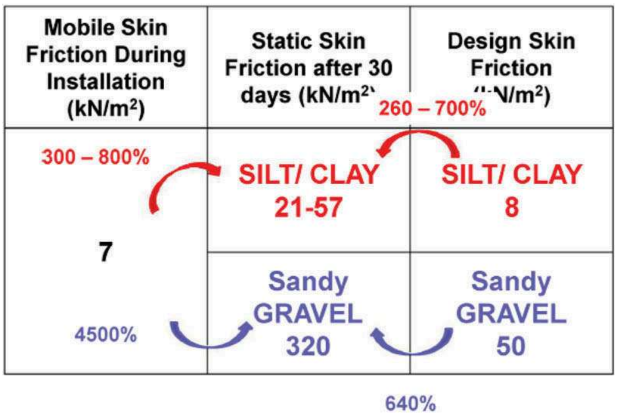

Figure 18. Recovery of skin friction for some selected soil samples (Nozaki, 2013).

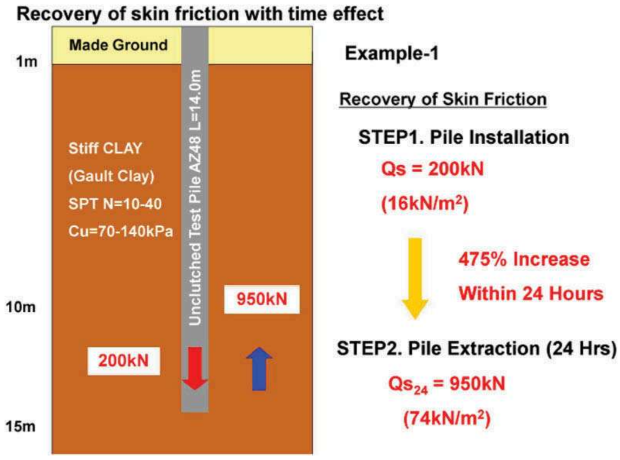

Figure 19. Recovery of skin friction after 24 hours after installation (Nozaki, 2013).

Figure 20. Circular model pipe piles.

Figure 21. A self-fabricated pile extraction mechanism and test bed.

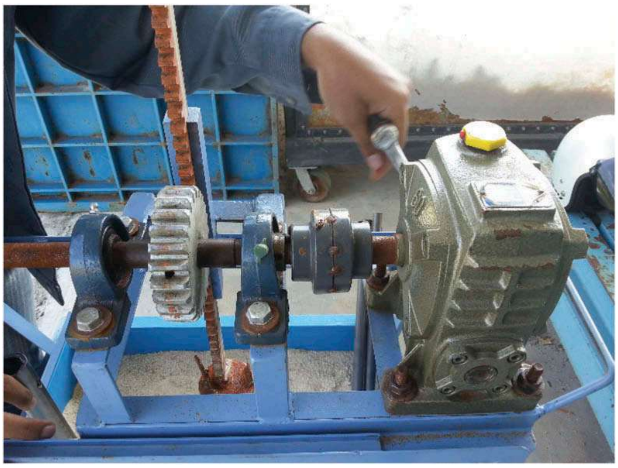

Figure 22. A self-fabricated pile extraction mechanism.

Figure 23. Pile installation force monitoring setup.

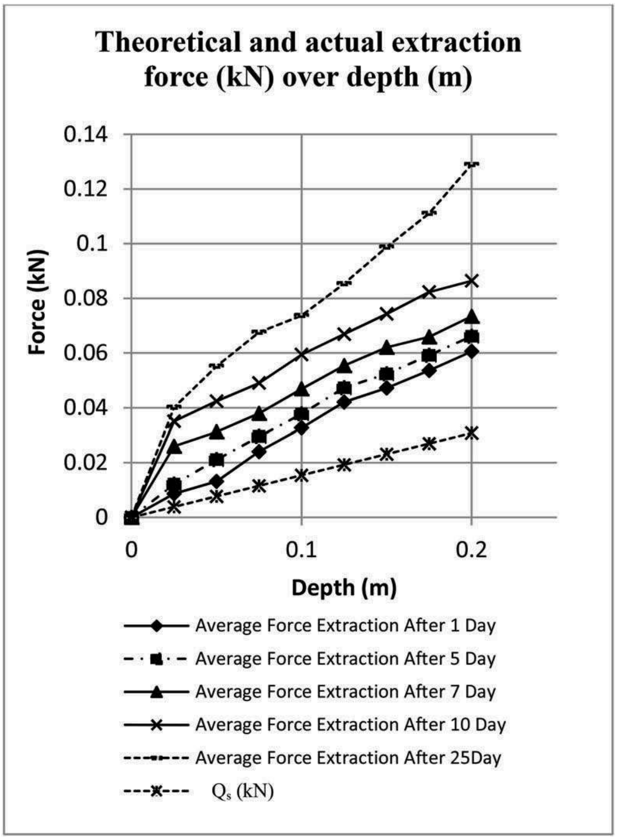

Figure 24. Theoretical and actual extraction force over depth after 1, 5, 7, 10 and 25 days.

the theoretical force. Some of these laboratory setup has been shown in Figure 20, 21, 22 and 23.

In summary, this simple research shows a similarity with the general trend of the recovery of skin friction due to time effect by Nozaki (2013). It is also useful to help the young engineering students to appreciate their knowledge on this particular topic. However, a better data and results could be established if a proper monitoring device and more appropriate testing programme are established in the near future.

In respect to the economic perspective of the study, this could be among the cheapest option to facilitate the engineering students in appreciating the technology and at the same time to be realistic with the financial readiness of the project.

4 INDUSTRY RELATED INITIATIVES

In general, several industrial sharing sessions, industrial attachment, seminar, conference, technology showcase and development activities are among the common activities initiated to bridge the gap between academia and industry. The activities allow dissemination of the latest Press-in technology to both academia-industry by establishing R&D collaborations with local and international stakeholders in Malaysia construction industry. In addition, the activities triggered more industrial adaptation of this technology in this country.

4.1 *Method 4: Industrial related activities at the UTHM campus*

UTHM is one of the technical universities in Malaysia. Currently, the university has slightly over than 1000 academic staffs and more than 17000 active students. The industrial awareness among the students is one of the primary concern of the university. Therefore, the university always welcome any activities to bridge the students with the industry. Several activities were initiated in Malaysia to widespread the concept of Press-in engineering and to disperse this sustainable agenda to this country.

"Steel Sheet-pile Symposium,, was one of the initiative. The symposium was organized by Technical Committee 3, International Press in Association and RECESS, UTHM on 6th December 2018 at Al-Jazari Auditorium, Tunku Tun Aminah Library, Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, Batu Pahat, Malaysia. Close to 100 participants joined this symposium. They were consisted of academicians and students from Universiti Tun Hussein Onn Malaysia (UTHM), Universiti Teknologi Malaysia (UTM), Universiti Malaysia Pahang

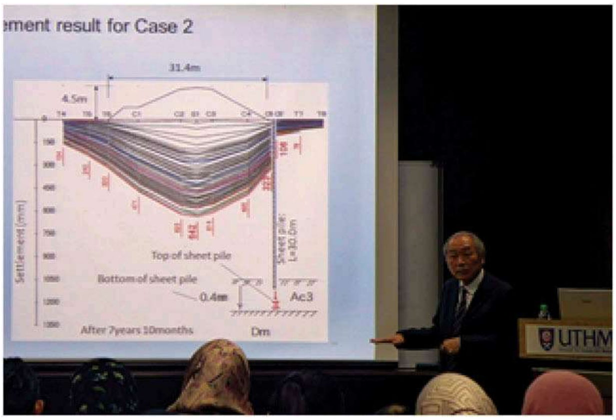

Figure 25. Prof. Jun Otani introducing partially floating sheet-pile concept.

Figure 26. Dr. Nor Azizi wrap up the symposium with his closing speech.

Figure 27. A group photo of the participants after the symposium.

Figure 28. Mr. Heng Li presented press-in technology to the honorable Deputy Minister and UTHM Vice Chancellor.

Figure 29. Mr. Syahri Fuddin explaining the concept of tsunami protection.

Figure 30. Undergraduate student, Nur Liyana bte Mohd Nor with Mr. Alvin at the KOYE office.

Figure 31. Nur Liyana operating the Standard Press-In machine for the first time.

Figure 32. A site visit at MRT construction in early 2013 utilizing a crush piler machine for the first time.

Figure 33. Conduction a presentation for a group of civil engineering consultant.

(UMP), Kolej Komuniti Batu Pahat, Kolej Kemahiran Tinggi MARA Sri Gading and RECESS. Several local companies also participated in this symposium. The speaker for the symposium involved Prof. Jun Otani, Mr. Yukihiro Ishihara and Prof. Katsutoshi Ueno from IPA. In addition, the local geotechnical expert, Prof. Ramli Nazir from Universiti Teknologi Malaysia and Dr. Nor Azizi Yusoff are also presented their related topics.

Figure 34. Mr. Takata from Giken Asia (Singapore) presented a Press-in technology to CREAM CEO.

In 2019, the Eid Gathering was initiated on the 13th June 2019 by Research Centre for Soft Soils (RECESS), Universiti Tun Hussein Onn Malaysia. The gathering were attended by our guest of honour YB. Datuk Dr. Shahruddin bin Mohd Salleh (The Deputy Minister of Federal Territories of Malaysia), Datuk Ir. Hj. Abdullah Isnin (Director General, Department of Irrigation and Drainage Malaysia) and Universiti Tun Hussein Onn Malaysia (UTHM) Vice Chancellor, Professor Datuk Ts. Dr. Wahid Razzaly. RECESS fellow researchers and students, UTHM top management and staff also attended the gathering. During the gathering, Mr. Heng Li and Mr. Takata from Giken Sesisakusho Asia (Singapore) Pte. Ltd. delivered a simple explanation of this technology to the guest of honour.

The concept of Press-in technology are also disseminated thru an exhibition. For example, the International Language Exhibition was organized to expose the UTHM students with the Japanese language, culture and some associated technology related to this country. In that exhibition, 'Silent Piling' applications were introduced by GIKEN to the visitors and fellow students.

Each group was assigned and given an ample time to create two replicas of tidal and tsunami defense system using straws and polystyrenes. Then, the presentation were made in Japanese language. Based on the activity, the students found that this technology is interesting and may potentially applicable for Malaysia scenario.

4.2 *Method 5: Other industrial related activities outside UTHM campus*

Several activities outside the UTHM campus have also been initiated to bridge the gap between the industry and the academia.

For example, a number of students had been attached to the real construction site for their final year project. The activity is needed in order to enhance their real experience on the technology. For that reason, a smart partnership with Press-in piling contractor (Koye (M) Pte. Ltd.) and many more industrial players were initiated several years ago. The partnership may potentially benefit both parties. For students, they could learn and experience themselves the technology. On the other hand, the industry will be able to get a helping hand to highlight their achievement on the ground.

In addition, many site visits have also been established since 2012 especially when there are new established sites using the technology. For now, most of the projects using this technology are more concentrated at Kuala Lumpur area. Normally the site visits are restricted only for a small groups. It is also bound with the regulations by the project owners. The site visit ends in approximately less than two hours. However, during this short period of time, the attendees are able to observe the real application of this technology in Malaysia. In addition, it is also useful as a networking sessions for all the parties.

In addition, many industrial sharing sessions and technology showcases were also initiated. Most of the time, the activity will involve UTHM, Giken Asia and the local press-in piling contractor. The idea is to make sure that the explanation will be able to accommodate the appropriate theoretical, practical and technological needs of the customer. For example, a technical talk was delivered at The Institution of Engineers Malaysia (IEM) Terengganu branch. The very similar presentation was also conducted at Construction Research Institute of Malaysia (CREAM). The event demonstrated RECESS commitment in facilitating CREAM with the cutting edge technology such as Press-in piling technology implementation in Malaysia.

5 CONCLUSIONS

In summary, the activities demonstrated a vibrant relationship and a decade of efforts between academia and industry in Malaysia in order to promote this sustainable technology. The relationship may allow both the academicians and the industry to capitalize on the strength of all. Since the establishment of a research related to the rate effect of press-in pile in 2007 at The University of Sheffield, United Kingdom, many technological transfer practices have been carried out until today. The activities allow dissemination of latest Press-in technology to both academia-industry by establishing R&D collaborations with local and international stakeholders in the Malaysia construction industry.

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REFERENCES

Azhar, Nur Abidah (2018). Acceptance of Silent Piling Technology Among Local Authorities in Malaysia. Masters thesis, Universiti Tun Hussein Onn Malaysia.

Durdyev, S., & Hosseini, M. R. (2019). Causes of delays on construction projects: a comprehensive list. *International Journal of Managing Projects in Business*. 13(1): 20–46.

Emmett, K. (2007). Movement of Soil and Groundwater Around Piles in Layered Ground. The University of Sheffield: Ph.D thesis.

Hird, C.C. & Srishaktivel, S. (2005). Lasboratory Investigation of Permeability Measurement in Clay Using Outflow from Unsupported Cavities. Geotechnique, Vol. 55, No. 5, pp. 393–402.

Ibrahim, Z, Yusoff, N.A., Sufahani, S.F. and Azhar, n.a. (2015). A Quantitative Review On Acceptance Of Silent Piling Technology Among Designers In Malaysia. Applied Mechanics and Materials. ISSN: 1662-7482, Vols. 773-774, pp 1471–1475.

Meyerhof, G.G., (1976). Bearing Capacity and Settlement of Piles Foundations. Journal of the Geotechnical Engineering Division, ASCE, Vol. 102, No. GT, Mar., 1976, pp.197–288.

Mohd Aliff bin Mohd (2014). Recovery of Skin Friction with Time Effect in Sand. Universiti Tun Hussein Onn Malaysia (UTHM). Final year dissertation.

Nozaki (2013). Proposed Research for Each Country or Institutions. The 1st International Research Seminar for Research Works in ASEAN Countries. 10th July 2013. Kochi, Japan.

Srishaktivel, S. (2003). Laboratory Measurement of the Permeability of Clay Soils Assisted by a Self-Boring Device. The University of Sheffield: Ph.D thesis.

Tan, S. M. (2005). *Karstic Features of Kuala Lumpur Limestone*. Retrieved on April 20, 2020, from https://nrmt.files.wordpress.com/2011/04/kl-limestone-paper.pdf

Yun, Lew Wei(2020). The Press-in Method Assisted with Augering for Urban Transportation System Work in Malaysia. Case study: Mass Rapid Transit 2 (SSP Line). Universiti Tun Hussein Onn Malaysia (UTHM). Final year dissertation.

Yusoff, N.A. (2011). Effect of Rate of Shearing on Resistance in Fine Grained Soil. The University of Sheffield: Ph.D thesis.