COLLABORATIONS IN GEOTECHNICAL ENGINEERING: LESSONS FROM THE BALLINA BYPASS AND THE NATIONAL SOFT SOIL FIELD TESTING FACILITY

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ABSTRACT

Collaboration assists both academics and industry partners to achieve innovations, scientific advancement, and maintain technical competencies. The Ballina Bypass is used here to demonstrate collaboration via an Australian Research Council (ARC) Linkage project on vacuum consolidation, and to discuss how the lessons learned from the Ballina Bypass led to establishing a national facility in Ballina to field test soft soils. The outcomes of the work at the field testing facility have been transferred back to the industry via an international numerical prediction symposium. The project background, roles, and responsibilities of researchers and industry members are discussed and explained, as are the innovative outcomes, stakeholder benefits, and cultural impacts.

1 INTRODUCTION

The Ballina Bypass is part of the Pacific Highway Upgrade. The challenging ground conditions at this site, consisting of highly compressible saturated estuarine and alluvial clays up to 30m thick, enabled innovative ground improvement techniques such as lightweight fill, surcharge with prefabricated vertical drains (PVDs), vacuum consolidation, dry soil mixing, stone columns, and dynamic replacement to be utilised. Vacuum consolidation was used in the early works package to stabilize soft ground at the southern approach to Emigrant Creek, even though it had not been applied at any site in Australia before the collaborative project was initiated in 2007. To increase confidence in the works, an ARC Linkage collaboration was established with the University of Wollongong in partnership with the NSW Roads and Traffic Authority (NSW RTA, currently Transport for NSW), Queensland Department of Main Roads (currently Queensland Transport of Main Roads), Coffey Geotechnics, and Douglas Partners. This project took place in parallel with the design and construction of the early works. This research helped to establish design principles and lead to the development of design procedures, which were then applied to vacuum consolidation works at the Port of Brisbane.

The Ballina Bypass had an Alliance delivery model between the NSW RTA, Leighton Contractors, SMEC, AECOM, and Coffey Geotechnics. One of the elements of these Alliances was the development of key result areas for the project, one of which was Legacy. Since there were many challenges during the design and construction of the Ballina Bypass, it was felt that establishing a research site for soft soil would be a valuable legacy for technical and broader communities. While some land adjacent to the Ballina Bypass alignment was deemed to be suitable for this project, none of the alliance partners was in a position to fund the proposed research. However, the Centre of Excellence for Geotechnical Science and Engineering (CGSE) for ARC funding was being bid at the same time so the concept of a testing facility for soft soil was included in the bid. The CGSE was a collaboration between the universities of Newcastle, Western Australia, and Wollongong, supported by Coffey, Douglas Partners, and Advanced Geomechanics (now Fugro). The CGSE bid was successful, which led to a research-level geotechnical investigation, construction of trial embankments, and an international numerical prediction symposium. The numerical prediction symposium brought asset owners, academics, and practitioners together, which enabled the current state of practice in soft ground engineering to be greatly improved.

2 OUTCOMES OF COLLABORATION

2.1 Vacuum Consolidation

During 2009-2012, the team proactively engaged with all the partners to initiate research and provide some input into the theoretical development deemed necessary to better understand the performance of vacuum consolidation systems. The industry partners increased understanding of and updates about vacuum consolidation technology were then applied to a future project, the Port of Brisbane Reclamation Project (POB). The employees who attended the progress meeting gained considerable knowledge and skills in this field and its application while networking through a PhD student involved in the project helped with personal development and recruitment of future employees. The research team and industry partners were in regular communication throughout these 4 years, while the first Author became an active consultant at the POB when vacuum consolidation was applied. The research team's seminal contributions in the fields of soft clay improvement by vertical drains and vacuum consolidation fulfilled the project aims and objectives beyond the initial expectations, and with a significant impact on the industry. Some of the major highlights are described below.

- For the first time in Australia, a combined vacuum preloading with surcharge was successfully applied at a project to increase embankment stability and reduce consolidation time (Fig.1, Indraratna et al., 2010).
- A revised theory of vacuum preloading via PVDs for two distinct vacuum systems under large strain conditions was incorporated into finite element computer codes that were used as a predictive tool for evaluating settlements, excess pore pressures, and lateral displacements in the field, especially for embankments built on soft clays (Fig.2, Geng et al. 2012, Indraratna et al. 2006).
- A method to determine the optimum length of PVDs and when to remove vacuum application (Fig. 3, Geng et al. 2010; Kianfar et al., 2015)
- Comprehensive design charts proposed by the first Author and his co-workers (e.g. AS8700-2011, Indraratna et al., 2011; Rujikiatkamjorn & Indraratna, 2007) are being used by the Australian industry for the Port of Brisbane and Ballina Bypass development work.
- A Rowe cell was modified to measure excess pore pressures measured laterally at various points and use larger samples to reduce the effects of size (Kianfar et al. 2013).
- The validation of proposed new concepts of non-Darcian consolidation and the effects of unsaturated drain interfaces via field measurement (Sathananthan & Indraratna, 2006; Kianfar et al. 2013).
- The 1st research-based volume "Ground Improvement-Case Histories", edited by Indraratna & Chu (2005) and published by Elsevier (UK) contained 38 comprehensive Chapters. It was considered to be the leading reference for practitioners involved with the design and planning stages of projects for improving the soft ground. This book has subsequently been expanded into a 3-volume series that covers physical, chemical, electrokinetic, and bioengineering concepts, and applications covering over 90 Chapters; it was launched by Elsevier in September 2015 (Indraratna et al.2015).

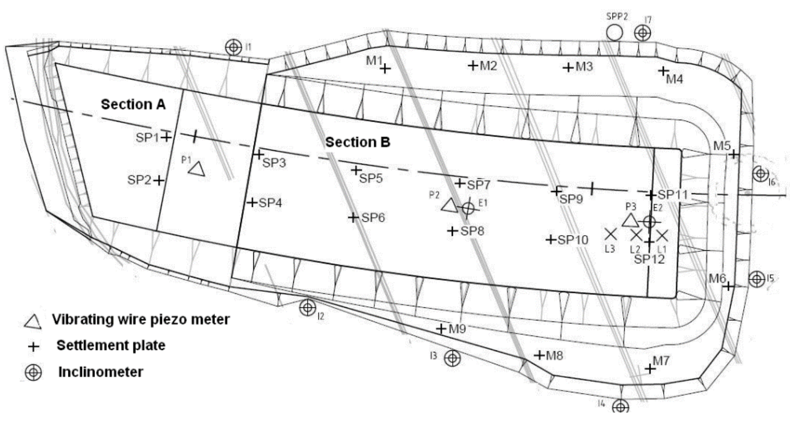


Fig. 1. Layout of instrumentation for the test embankments at Ballina Bypass (Reproduced from Indraratna et al., 2010 with permission)

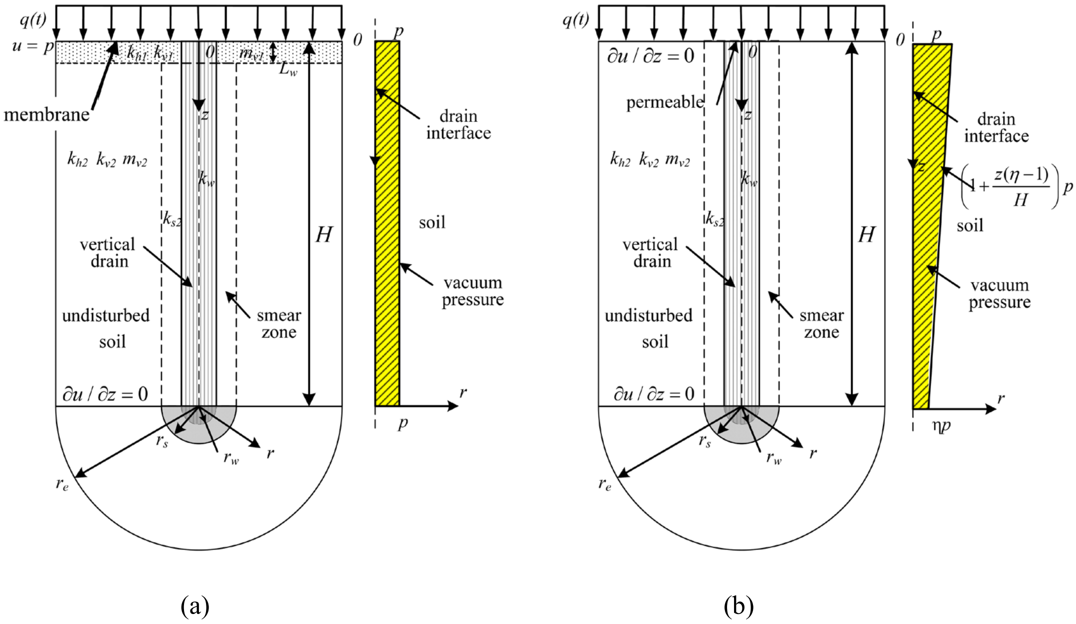


Fig. 2. Analysis schemes of unit cell with vertical drain: (a) membrane system and (b) membraneless system (Reproduced from Geng et al., 2010 with permission) Note: *r*= the radial direction in the unit cell from the center of the drain

2.2 Ballina Field Test Facility

The Ballina Field Test Facility (Fig. 4) concept arose as a Legacy output from the Ballina Bypass Alliance. The many geotechnical challenges encountered during the design and construction of the Bypass demonstrated the construction risks and long-term performance risks. These risks included the characterisation of soft clays and the accurate prediction of soft soil behaviour beneath an embankment. Under the support of Road and Maritime Services (RMS, currently Transport for NSW), CGSE, and industry partners in general, the Ballina Field Test Facility was established and acted as a proving ground prior to adopting the technology in practice. The salient outcomes are briefly described below:

Site characterization: In-situ tests (piezocone penetration test (CPTu), seismic dilatometer testing (SDMT), field vane, BAT® permeability tests, etc.) and laboratory tests (oedometer and triaxial tests, scanning electron microscope) were carried out on high-quality undisturbed samples to establish site stratigraphy, groundwater levels, in situ stresses, soil parameters (Pineda et al. 2016, Kelly et al, 2017). Using geophysical and geotechnical datasets, Huang et al. (2017) proposed a probabilistic site characterization based on Bayesian statistical methods to reduce the uncertainty of the soil profile at the site. A Bayesian analysis of monitoring data was carried out to understand how the embankment would perform and thus allow timely decisions to be made with confidence (Huang et al. 2017). Back analyses were also carried out for the Teven Road trial embankment from the Ballina Bypass (Huang et al. 2019) and the trial embankment at the national soft soil field testing facility (Zheng et al, 2018).

Extent of smear zone: The effects of installing vertical drains on the permeability and compressibility of the soil in the smear zone were assessed in the field for the first time at the Ballina Field Test Facility (Indraratna et al. 2014). In previous years, the smear zone was often characterised using constituted soil samples or back-calculated using time settlement curves. These time settlement curves showed that the radius of the smear zone was about 6.3 times the equivalent mandrel radius, which was larger than that observed in the laboratory using reconstituted specimens. These findings gave the industry partners a realistic characterisation of the smear zone which they could then utilise in their design.

International collaboration: A partnership between the CGSE, National Jute Board of India, and Soilwicks was initiated. For the first time, Biodegradeable jute drains were installed beneath a trial embankment in Australia. This project revealed that the performance of jute drains (Fig. 4b) as on par with conventional drains, as found using field and laboratory studies over the first 2 years (Kelly et al 2018).

Prediction Symposium: The objective of the Symposium was to understand the current state of practice by inviting practicing engineers and academia to predict the settlement, lateral deformation, and excess pore pressure at key locations under a full-scale test embankment. The results obtained from laboratory and field measurements were made available before the participants submitted their predictions. The outcomes of their numerical predictions are summarised in Kelly et al (2018) in a special issue of Computers and Geotechnics. Recommendations for improving site characterisation practice and numerical predictions of embankment performance were also made.

Vacuum consolidation: This was the first time that vertical drains with vacuum had been used below a circular embankment to demonstrate the advantages of an axisymmetric condition induced by a circular embankment where the corner effect is minimized (Fig. 4c). The field trial showcased the construction techniques, the methods used to prevent vacuum loss, the treatment of extracted acidic groundwater before being discharged into a nearby creek, and the measurement of non-Darcian flow behaviour during consolidation (Baral et al. 2021).

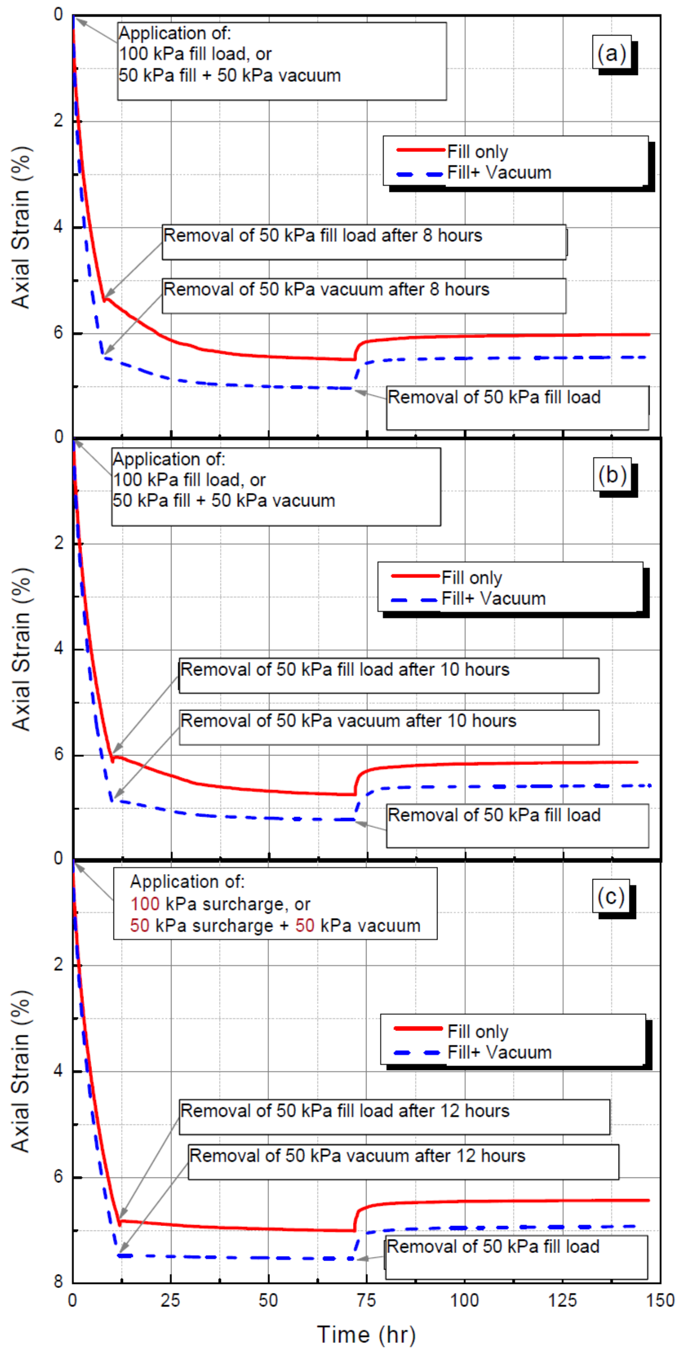
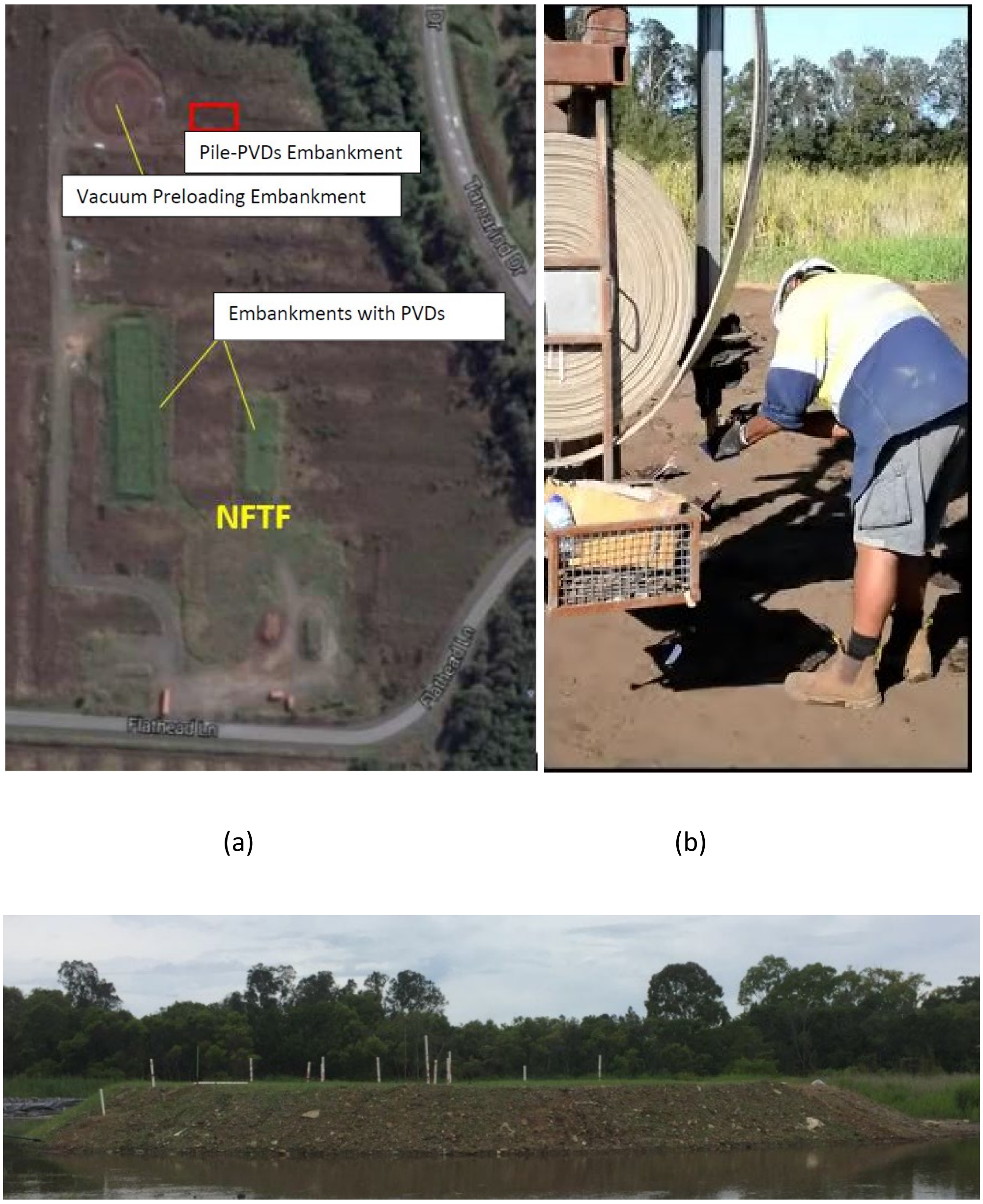


Fig. 3. Effect of vacuum removal at different times (Reproduced from Kianfar et al., 2015 with permission)



(a) (b)

(c)

Fig. 4: Ballina Field Test Facility (a) Locations of various embnakments, (b) Installation of jute vertical drains and (c) circular embankment stabilised with vacuum consolidation

3 BENEFITS OF COLLABORATION

Industry Partners: Collaboration benefits companies, universities, and the wider community through asset owners such as the NSW RTA. In principle, companies can obtain a commercial benefit as their expertise increases, this enables them to win work by having early access to procedures developed from the vacuum linkage project (Indraratna 2017), and the development of software or other tangible deliverables. Academic expertise leads to an increase in confidence that the desired outcomes will be achieved when adopting new technology such as vacuum consolidation. Building networks with academia can also be useful for future projects, for example, the connections made during the Ballina vacuum consolidation study were subsequently used for Inland Rail, and the connections made at the CGSE were used on unsaturated soil projects, the behaviour of soft rock, advanced laboratory and in-situ testing, and stochastic analysis for the Western Sydney Airport tender, and various solar farms and tunnel projects. Collaboration also allows research students to be hired by a business, for example, the fourth author on this paper completed a PhD at the University of Wollongong and many other post-graduate students have also been hired over time. Many of the post-graduate students from the University of Western Australia are now working in the offshore industry. Collaboration with universities helps to disseminate knowledge and provide opportunities for practitioners to raise their profile and the profile of their companies. Other opportunities include participation in technical journal editorial panels and the review of technical papers which creates international networks.

Universities: Universities benefit from collaboration by being exposed to current industry challenges, this enables their research to be relevant to current issues. Collaboration also provides access to non-government sources of funding, industry feedback and guidance, and allows universities to demonstrate industry impact. Students can then be mentored by industry partners and academics and thus develop their skills for future job placement. The university faculty gains a reputation through increased external research funds, publications, and awards. The relationship helps universities to improve their facility e.g. a conventional Rowe cell was modified to study flow behaviour under vacuum consolidation; this resulted in optimising the time for removing the vacuum and allows industry partners to decide on the duration of a vacuum application.

Awards and Recognitions: The valuable contributions made by the research team are reflected by national and international awards, e.g. the first Author was honoured at the 2010 EH Davis Memorial Lecture of the Australian Geomechanics Society (AGS), the Engineers Australia Transport Medal in 2011, ISSMGE's prestigious awards the 1st Ralph Proctor Lecture in Transport Geotechnics (2016) and the 4th Louis Menard Lecture in Ground Improvement (2017), and the 2015 Thomas Telford Premium of ICE (UK). the second Author received the 2012 Trollope Medal by AGS, 2013 and Young Engineer Award from ISSMGE. Dr Richard Kelly won the 2012 Shamsher Prakash Award for Excellence in Geotechnical Practice and the 2019 Ray Fisher award from roads Australia for establishing the soft soil testing facility. All three received the 2012 Robert Quigley Award from the Canadian Geotechnical Society. The PhD students attached to this project, the fourth Author shortlisted for 2013 AGS Research award, the fifth Author was elected a Fellow of the Royal Society (FRS) in 2015 and was made an Officer of the Order of Australia in 2018. In 2021, the third Author was invited to be the State-of-the-Art Lecturer for the ICSMGE 2022 in Sydney, with the first Author as a co-author for Transportation Geotechnics.

Community: The community also benefits from collaboration because the outcomes of the numerical prediction symposium led to changes in practice which should improve the outcomes of infrastructure constructed on soft clay. The east coast of Australia is under increasing pressure from the demands of a rising population for capital investment in commercial buildings, transport links, and other infrastructure. The soft and compressible clays along this coast present major challenges in the design, construction, and longevity of transport and port infrastructure. In Australia, millions of dollars are spent annually on road and rail maintenance. In NSW alone, this figure is around $39 million/year (Source: Regional Roads Funding Assistance to Local Government 2010/11). This national focus of building infrastructure on soft ground is obvious given the major projects currently being constructed, such as the $6.6B Pacific Highway upgrade and the Port of Brisbane reclamation. The application of PVDs and vacuum pressure (VP) to improve the stability of soft ground should help to reduce the construction and maintenance costs, and the construction time, while enhancing productivity through a better supply chain that integrates coastal road-rail-port links with regional mining and agriculture. This collaborative project enhanced our fundamental understanding of the mechanics of VP-based soil stabilisation, and hence contribute to the scientific advancement and reliability of emerging vacuum consolidation systems in Australia and elsewhere.

4 HOW TO COLLABORATE

Collaboration begins with people talking to each other. Communication between academia and practitioners can be difficult because everyone is busy and focused on their particular activities. However, in the authors' experience, if an effort is made to reach out to academia and to industry, then people are willing to take the time to discuss each other's needs and capabilities. Connections between people can be made at conferences, presentations, personal contacts, or various forms of electronic media.

Government funding through Australian Research Council Linkage projects, Centres of Excellence, and Training Hubs provide mechanisms that enable collaboration and partnership among academia, industry, and asset owners. This funding has played a dominant role in creating a critical mass to transfer and commercialise academic outcomes to industries. The programs boost the transfer of skills, knowledge, and ideas as a basis for securing commercial and other benefits of research. This assists the university in the purchase or use of research equipment in the laboratory and for field research, and when hiring research personnel for innovative technological activities.

The governance of these research projects is an important aspect of successful delivery. The progress of this research was steered by committees with an industry chair. The participants came to an agreement about overall objectives as well as results that are relevant to academics and industry partners. During the vacuum consolidation project, the consortium was dynamic and provided a forum for all the participants to present their results, network, and discuss new problems and directions that can be changed over time. A constructive conflict resolution process was adopted to achieve results that would benefit the partnership. The members subsequently developed trust and a feeling of mutual respect and commitment. The steering committee meetings were held at the University every 3-6 months to discuss progress and share new insights.

Knowledge transfer can occur via reports, papers, and presentations, as well as by direct involvement in the research. For the vacuum consolidation linkage project, extensive annual reports and papers were written by the researchers to disseminate information for feedback from industry colleagues. A lot of research information was uploaded to a website that can be accessed by all the research participants. The main technology transfer was through research forums (usually held at the University, but occasionally at a venue in Sydney, and the Industry partner's offices), journal articles, as well as national and international Conference papers co-authored by academics and industry partners. The third author spent an industry sabbatical at the University of Newcastle to set up the national soft soil field testing facility and organise the international numerical prediction symposium. This enabled two-way knowledge transfer between academia and practice, created connections with academia that have been subsequently used in practice, and allowed the third author to refresh technical skills and become more acquainted with the current state of the art. This industry sabbatical was by far the most successful method of transferring knowledge between academia and industry experienced by the third author. Embedding industry staff in research projects is the best way to transfer knowledge and increase the value of the investment made, but is often difficult to achieve due to wage pressures and family commitments.

Other forms of collaboration that can be adopted with limited financial and time commitment include 4th-year research projects, guest lectures, connecting academics and staff, sponsorships, and through the ISSMGE Corporate Associates Presidential Group (CAPG).

5 OVERCOMING BARRIERS TO COLLABORATION

Due to lack of time and resources, industry partners have often committed to acquire their in-depth knowledge through intense cooperation, R&D outcomes, and innovative processes in vacuum consolidation from specialised researchers in academia led by the first Author. There were three factors in this project which strongly influenced the success of this collaboration, namely, trust, familiarity, and interaction. Trust at the personal and institutional levels was formed during the initial meetings by providing clarity to all members regarding the geotechnical processes, the research and knowledge sharing arrangements, and aligning the expectations of the outcomes at the level of conceptual understanding and practical applicability. Regular structured meetings with presentations by researchers and PhD students were scheduled for continuous information dissemination and subsequent feedback. These meetings facilitated increased familiarity with the outcomes and helped to acquire technical know-how. Face-to-face interaction through meetings was an essential mechanism for transferring the research findings and thus instilling an enhanced level of trust and confidence in the research process and the quality of deliverables.

6 CULTURAL IMPACT

In the authors' opinion, the tangible research outcomes and the impact they made on vacuum consolidation technology and soft soil engineering has changed the culture of the practitioners involved, they are now more appreciative of the need for research and development and the need to be pro-active in pursuing new knowledge with University research and development collaborations.

Collaboration has led to significant student training as many of them have been employed by the industry. This helps reinforce cultural cross-pollination between academia and industry. Several of these students now occupy senior positions in the industry and help drive continuing research collaborations.

For example, over the past 10 years, former PhD students of the first author, Dr. Ni Jing, Dr. Darshana Perrera, Dr Kourosh Kianfar, and Dr. Pankaj Baral have won numerous national and international research awards from the Australian

Geomechanics Society, International Geosynthetics Society, and Canadian Geotechnical Journal for their innovative research that has transformed design culture and practices. Evidence that this collaboration is still developing world-class researchers who will become future leaders in this field include Prof Geng Xueyu who has already developed a new design approach for a large strain consolidation analysis. These students left the University, not only with a well-recognised body of published research and awards, but a strong culture of industry engagement and collaboration.

7 CONCLUSIONS

Significant benefits for research partners and the community can arise through collaboration between academia and industry. The development of scientific fundamentals (conceptual and computational) by the researchers helped to rejuvenate existing design procedures.

Active communication through regular steering meetings and brainstorming sessions instilled a greater understanding of the research directions between the academics, PhD students, and industry partners through the sharing of ideas, and by achieving the milestones and timely outcomes. This philosophy has led to successful ARC Linkage projects, Centre of Excellence, Industrial Transformation Hubs (Training and Research) among other collaborative Centres.

Some of the key barriers in these collaborative projects were the contrasting expectations for the advancement of science in academia and the swifter expectations of applied R & D outcomes in the industry, neither of which necessarily reflect innovation or originality. The authors' experience shows that a middle path that upholds the best of both worlds can only evolve through close collaboration and effective communication, tactical planning, and aspiring for realistic goals in a timely manner. In essence, a pathway that helps university researchers better understand the requirements of industry and commerce, and in return, an appreciation of academic standards for higher research degrees and high-quality publications by industry need to merge in order to achieve optimal success in collaborative research projects.

The transfer and dissemination of technology through these research projects is best achieved through a mix of technical reports to industry, design aids, guidelines, and scholarly publications, especially those journals which uphold a practical flavour that is popular among practitioners. Active participation by industry colleagues in research projects facilitates the best outlets for transferring technology through national forums, and seminars and workshops that focus on the topic at hand.

The R & D outputs through these studies have been numerous. They include direct influences on design and construction practices, thus leading to new technical standards (e.g. AS8700 – Execution of Vertical Drains), and user-friendly software developed by HDR students and research associates. Under strong leadership with a clear vision for the project, the tangible outcomes include (a) the successful application of vacuum at Ballina Bypass and Port of Brisbane development project, (b) the subsequent ARC Centre of Excellence for Geotechnical Science and Engineering, (c) comprehensive design guides for determining drain length and vacuum removal, (d) training and guidance for future leaders, and (e) numerous publications in reputable journals. The partnership continues to grow and repeat collaboration in other subsequent projects shows great indicators of success.

It is this partnership that has made a significant change in the culture of transport engineering that has remained relatively static over a very long period. In this project, early-career researchers (Prof Geng Xueyu, University of Warwick, UK; Dr Mojtaba Kan, South Australia Water) and four PhD graduates (Dr Kourosh Kianfar, SMEC; Dr Ni Jing, Shanghai Uni. of Science & Technology, China; Dr. Darshana Perrera, AURECON; Dr. Pankaj Baral, Geotesta) directly contributed to the scientific advancement of Australian Roads.

8 ACKNOWLEDGEMENT

We acknowledge the Australian Research Council, Queensland Transport and Main Roads, Port of Brisbane Corporation, Transport for NSW (previously Road and Maritime Services), Coffey Geotechnics, Douglas Partners, SMEC, Menard Bachy, SoilWicks and National Jute Board (India) for their continuous support in terms of research funding and technical assistance during numerous R&D projects over the past two decades. The support and cooperation received at various times from many colleagues are gratefully appreciated. Special thanks are conveyed to Prof. Harry Poulos, Prof. (Bala) Balasubramaniam, Vasantha Wijeyakulasuriya, Geoff McIntosh, Daniel Berthier, Patrick Wong, Henk Buys, Prof. Serge Leroueil, and Phillipe Vincent among others.

9 REFERENCES

AS 8700-2011 (2011), Australian Standards- Execution of prefabricated vertical drains.

Baral. P., Indraratna, B., Rujikiatkamjorn, C., Kelly, R. and Vincent, P. (2021). A Case study: Consolidation by Vertical Drains beneath a Circular Embankment under Surcharge and Vacuum Preloading. J. of Geotechnical & Geoenvironmental Engineering, ASCE, 10.1061/(ASCE)GT.1943-5606.0002576.

Geng, X. Y., Indraratna, B. and Rujikiatkamjorn, C. (2011). The effectiveness of partially penetrating vertical drains under a combined surcharge and vacuum preloading, Canadian Geotechnical Journal, 48(6), pp. 970-983. **Robert M. Quigley Honourable Mention award from the Canadian Geotech. Society.**

Geng, X. Y., Indraratna, B. and Rujikiatkamjorn, C. (2012). Analytical solutions for a single vertical drain with vacuum and time-dependent surcharge preloading in membrane and membraneless systems. Int. Journal of Geomechanics, ASCE, 12(1), pp. 27-42.

Huang J, Zeng C, Kelly R (2019) Back analysis of settlement of Teven Road trial embankment using Bayesian updating. Georisk, 13, 320-325.

Indraratna, B. (2017). Recent Advances in Vertical Drains and Vacuum Preloading for Soft Ground Stabilisation, Proceedings of 19th ICSMGE, Seoul, Korea, pp.141-166.

Indraratna, B. and Chu, J. (2005). Ground Improvement – Case Histories. Elsevier Scientific (UK). 38 Edited Chapters, 1115p.

Indraratna, B., Rujikiatkamjorn, C., Kelly, R. and Buys, H. (2010) Environmentally Sustainable Soft Soil Improvement via Vacuum and Surcharge Preloading. Ground Improvement 163 (1), pp. 31-42.

Indraratna, B., Rujikiatkamjorn, C., Ameratunga, J., and Boyle, P. (2011) Performance and Prediction of Vacuum Combined Surcharge Consolidation at Port of Brisbane. J. of Geotechnical & Geoenvironmental Engineering, ASCE, 137 (11), pp. 1009-1018.

Indraratna, B., Perera, D., Rujikiatkamjorn, C. and Kelly, R. (2014). Soil Disturbance Analysis due to Vertical Drain Installation. Geotechnical Engineering, ICE, 168 (3), pp. 236-246

Indraratna, B. Chu, J. and Rujikiatkamjorn, C. (2015). Embankments with Special Reference to Consolidation and Other Physical Methods. Elsevier Scientific (UK). 26 Edited Chapters, 817p.

Indraratna, B., Zhong, R., Fox, P. J., Rujikiatkamjorn, C. (2016). Large-Strain Vacuum-assisted Consolidation with Non-Darcian Radial Flow incorporating Varying Permeability and Compressibility, Geotech. Geoenviron. Eng. ASCE. 10.1061/(ASCE)GT.1943-5606.0001599, pp. 1-9.

Kelly, R. B., Pineda, J. A., Bates, L., Suwal, L. P. & Fitzallen, A. (2017). Site characterisation for the Ballina field testing facility. Geotechnique 67 (4), 279-300.

Kelly, R. B.; Sloan, S. W.; Pineda, J. A.; Kouretzis, G.; Huang, J. (2018). Outcomes of the Newcastle symposium for the prediction of embankment behaviour on soft soil. Computers and Geotechnics Vol. 93, p. 9-41.

Kianfar, K., Indraratna, B., and Rujikiatkamjorn, C. (2013). Radial Consolidation Model Incorporating the Effects of Vacuum Preloading and Non-Darcian Flow. Géotechnique. 63(12), pp. 1060-1073.

Kianfar. K., Indraratna, B., Rujikiatkamjorn, C. and Leroueil, S. (2015). Radial consolidation response upon the application and removal of vacuum and fill loading. Canadian Geotechnical Journal 52 (12), pp. 2156-2162.

Pineda, J. A., Suwal, L., Kelly, R. B., Bates, L. & Sloan, S. W. (2016a). Characterization of the Ballina clay.Géotechnique, No. 7, 556–577, http://dx.doi.org/10.1680/jgeot.15.P.181.

Rujikiatkamjorn C. and Indraratna, B. (2007). Analytical solutions and design curves for vacuum-assisted consolidation with both vertical and horizontal drainage. Canadian Geotechnical Journal, 44, pp. 188-200.

Sathananthan, I. and Indraratna, B. (2006). Plane Strain Lateral Consolidation with Non-Darcian Flow. Can. Geotech. J., 43, pp.119-133. **Robert M. Quigley Honourable Mention award, Canadian Geotech. Society.**

Zheng D, Huang J, Li D.Q, Kelly R, Sloan S.W (2018) Embankment prediction using testing data and monitored behaviour: A Bayesian updating approach. Computers and Geotechnics, 93, 150-162.