

NEESR-II: Mechanisms and Implications of Time-Dependent Changes in the State and Properties of the Recently Liquefied Sands

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ABSTRACT: The IREE supplemental grant added an international component to the grant "NEESR II: Mechanisms and Implications of Time-Dependent Changes in the State and Properties of Recently Liquefied Sands." The IREE grant was significant both from a technical and a cultural perspective. The contacts that researchers made with geotechnical engineering firms working in Dubai will provide a mechanism for us to collect data that would otherwise be unavailable to the research community. The data being collected is important in that the quantity of the data will ensure any observed trends in the state and properties of the densified sands are statistically significant. Also, the IREE grant allowed a strong research collaboration between the American University in Dubai and the University of Michigan to be established that otherwise would not have.

INTRODUCTION

The goal of the IREE project is to collect and analyze vibrocompaction data for "aging" effects from several of the mega land reclamation projects on-going in Dubai and neighboring emirates. "Sand aging" refers to the time-dependent strength gain that often occurs in recently deposited, densified, and/or liquefied granular soils well after increases in soil density have ceased. The IREE project is a supplement to the already funded National Science Foundation project "NEESR II: Mechanisms and Implications of Time-Dependent Changes in the State and Properties of Recently Liquefied Sands." The Principal Investigator of the project is Dr. Russell A. Green, who is an Associate Professor in the Department of Civil and Environmental Engineering at the University of Michigan. The doctoral student working on the IREE project is Ms. Kathryn A. Gunberg,

and Dr. Alaa K. Ashmawy, Dean of the School of Engineering, American University in Dubai, is the international host and collaborator on the IREE project.

The field work for the NEESR project is being carried out in a sand quarry located in Griffin, Indiana, and utilizes the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) large-scale mobile shaker or vibroseis. The field investigation entails the inducement of liquefaction by explosives, vibrocompaction (using a vibroflot), and vibroseis at adjacent locations in the same deposit. It is anticipated that vibrocompaction will be performed at a total of ten compaction points at the site. The state and properties of the sand at the Griffin site will be monitored with time after inducement of liquefaction to better understand the aging phenomenon. Synergistic laboratory tests will be performed to better discern the underlying mechanisms of the sand aging phenomenon.

To supplement the data collected from the Griffin, IN field study, Ms. Gunberg traveled to Dubai, United Arab Emirates (UAE) between January 10 and May 4, 2007. The focus of Ms. Gunberg's stay in Dubai was to work with Dr. Ashmawy to collect vibrocompaction data from the large-scale construction projects in the region and to develop contacts with local geotechnical engineering firms, with the latter providing a mechanism for Ms. Gunberg to continue to obtain data from on-going and future projects in the UAE (e.g., Palm Island projects, which are the 3 largest land reclamation projects in the world). To aid in establishing initial contacts with engineering firms in the UAE, Dr. Green accompanied Ms. Gunberg to Dubai for the first two weeks.

During her stay in Dubai, Ms. Gunberg was hosted by The American University in Dubai (AUD). Dr. Alaa Ashmawy, Dean of the School of Engineering at AUD, assisted Ms. Gunberg in finding housing, provided her with an office, and aided with her research. Because the majority of the work was a field study, no laboratory space was needed at AUD. Ms. Gunberg continues to analyze the data she collected while in Dubai.

RESEARCH ACTIVITIES AND ACCOMPLISHMENTS OF THE INTERNATIONAL COOPERATION

The IREE proposal planned for Ms. Gunberg to be hosted by the American University of Sharjah (AUS). However, AUS no longer had a geotechnical engineering faculty member with whom to collaborate. Fortunately, shortly before the scheduled trip to UAE, Dr. Green received word that Dr. Alaa Ashmawy, previously a geotechnical engineering professor at the University of South Florida, had recently assumed the deanship of the School of Engineering at the American University in Dubai (AUD). Because of this development, Dr. Green and Ms. Gunberg decided to pursue a collaboration with Dr. Ashmawy at AUD instead of the collaboration with AUS.

As opposed to laboratory work, Ms. Gunberg's efforts in Dubai focused on making contacts with local geotechnical engineering firms in order to gain access to data that would be beneficial to the research project. Several contacts with firms working in the region had been established prior to submitting the proposal and others were being pursued. However, upon arrival in Dubai, both Dr. Green and Ms. Gunberg quickly learned about intellectual rights and other privacy issues raised by the owner that prevented the release of the field data, as well as regional business politics. One of the

main contractors performing vibrocompaction on the palm islands that Dr. Green had contacted well in advance of writing the proposal was Soletanche-Bachy's Vibroflotation Group. The engineers for Soletanche-Bachy and their consultants were very excited about our research and had assembled data for our study. However, the developer of the Palm Islands decided not to allow us access to the project data. Fortunately, Soletanche-Bachy had vibrocompaction data from other projects that they shared with us.

In addition to Soletanche-Bachy, Ms. Gunberg and Dr. Ashmawy made contact with Mr. Shad Khan, General Manager at Keller-Grundbau's Dubai office. Mr. Khan was very helpful and more than willing to do what he could to help with the research project. Ms. Gunberg traveled to Keller-Grundbau's office on numerous occasions to collect data from a number of land reclamation projects and to visit project sites in the nearby areas.

The data collected through Keller-Grundbau includes pre- and post-vibrocompaction CPT logs and vibrocompaction records (which includes items such as date and time of compaction, depth, and location) from the Palm Jumeirah Project. This data is currently being compiled and will be presented in a form similar to that of Figure 1 which shows the results from the Jebba Dam site on the Niger River in Nigeria. The Jebba Dam project was the first well documented study where the aging effects were both significant and widespread (Mitchell and Solymar 1984, Solymar 1984).

One significant difference between the Griffin, IN field study and the data being collected in Dubai is the type of the sand at the respective sites. The sand at the Griffin, IN site is silica sand. In contrast, the land reclamation projects in Dubai are using sands being dredged from the bottom of the Arabian Gulf. Thus, the Dubai sand is calcareous due to the high content of crushed shells (Figure 2). This difference will allow us discern the significance of sand type on aging effects.

The data is still being analyzed, but the expected results from Ms. Gunberg's efforts in Dubai will add substantial information to the Griffin, IN field study.

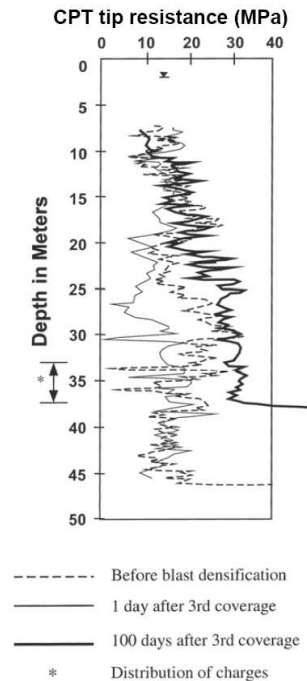


Figure 1. Effect of time on the cone penetration resistance of sand following blast densification at the Jebba Dam site. (after Solymar, 1984)



Figure 2. Photo of calcareous sand being used in the land reclamation projects in the UAE.

BROADER IMPACTS OF THE INTERNATIONAL TRAVEL

The research performed by Ms. Gunberg in Dubai helped greatly to promote diversity in the region. At Keller-Grundbau, Ms. Gunberg was the only American and the only female working on the project. The majority of the Keller-Grundbau employees were male and Pakistani. Although she stood out, Ms. Gunberg did not feel looked-down-upon but instead felt welcomed in the office and in the field. Additionally, the amount of data Ms. Gunberg collected while in Dubai will add significantly to the overall sand aging study. One concern with any field study is that whether observed trends in data are real or are the result of limited data that is anomalous; the addition of the Dubai data will any observed trends are indeed real.

Regarding the cultural component of the IREE supplement, during her stay in Dubai, Ms. Gunberg taught two courses at AUD. The first was the laboratory for Physics I, where Ms. Gunberg guided the students through experiments involving particle position, velocity and acceleration, projectile motion, Atwood's machine, Newton's second law, et cetera. The second class was an SAT review course. Both of these classes were filled with students from around the region, including Sudan, Egypt, Lebanon, Syria, Iran, Afghanistan, and India. The experience gained by Ms. Gunberg during these classes was invaluable.

Ms. Gunberg was also approached by Sareh Khoshi, an Iranian student, who requested a tutor to help maximize her score on the GMAT exam so she could attend graduate school at AUD. Ms. Gunberg tutored Ms. Khoshi twice a week throughout the semester. This was an amazing experience for Ms. Gunberg because she was exposed directly to another culture on a personal level. Both Ms. Khoshi and Ms. Gunberg learned much about the other's culture and enjoyed sharing traditions and stories from their homelands. Ms. Gunberg learned first hand that the Middle Easterners were very welcoming and friendly.

Living in Dubai allowed Ms. Gunberg to enjoy visiting museums and historic areas of town in order to learn about the local culture. The local people were more than happy to explain and show their local and ancient customs and traditions. One of the most rewarding experiences was attending a cultural breakfast put on by the Sheikh Mohammed Center for Cultural Understanding. There, AUD students were able to try local food and talk to local women about their culture and customs. After learning more about some of the Middle Eastern cultures, customs and beliefs, Ms. Gunberg is excited to share what she learned about the region with others in the US.

Finally, the IREE grant allowed a strong research collaboration between the American University in Dubai and the University of Michigan to be established. Dr. Green will be making a second visit to AUD to discuss with Dr. Ashmawy future research collaborations.

DISCUSSION AND SUMMARY

The IREE grant was significant both from a technical and a cultural perspective. The contacts that Ms. Gunberg and Dr. Ashmawy made with geotechnical engineering firms

working in the UAE will provide a mechanism for us to collect data that would otherwise be unavailable to the research community. The data being collected is important in that the quantity of the data will ensure any observed trends are statistically significant. To put it in perspective, the cumulative equipment hours per year for all vibrocompaction projects in the entire US is less than the annual hours on the smallest of the Palm Islands alone, let alone the other two Palm Islands. Additionally, the data collected from this project will allow the influence of soil type (i.e., silica vs. calcareous sand) on aging effects to be studied. Finally, the IREE grant allowed a research collaboration between two universities located in different regions of the world to be established that would not likely have been established otherwise.

The cultural aspects of the project are also significant. Ms. Gunberg and Dr. Green learned a lot about the Middle East and Islamic culture as a direct result of this project. The authors applaud the National Science Foundation for fostering such international collaborations. Modern technology has effectively reduced the size of the world and programs such as IREE are essential for the international community to learn from each other and to develop respect for each others cultures. The authors have no recommendations for "Best Practices" in future operation of the IREE Program.

ACKNOWLEDGEMENTS

Support for the research presented herein came from the NSF NEESR grant CMMI 0530378 and NSF IREE grant CMMI 0636710; this support is gratefully acknowledged. Also, the authors thank Mr. Shad Khan, General Manager at Keller-Grundbau's Dubai office, for providing access to vibrocompaction data from a large number of projects in the UAE.

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BRIEF BIOGRAPHIES OF RESEARCHERS

Kathryn A. Gunberg received her B.S.E. and M.S. degrees in Civil Engineering from the University of Michigan in 2005 and 2006, respectively, and is currently pursuing a Ph.D. degree in Civil Engineering. Ms. Gunberg worked as a Technician Aide II for the City of Ann Arbor, Ann Arbor, MI from May to November 2005 and as a Geotechnical Engineer in Training for Soils & Structures in Western Michigan from May to August 2006.

Russell A. Green received a B.S. in Civil Engineering from Rensselaer Polytechnic Institute in 1992. He received a M.S. in Civil Engineering from the University of Illinois at Urbana-Champaign in 1994, and a Ph.D. in Civil Engineering from Virginia Polytechnic Institute and State University in 2001.

Dr. Green worked as a Staff Engineer for the US Defense Nuclear Facilities Safety Board in Washington, DC and was a Visiting Research Engineer at the US Army Engineer Waterways Experiment Station in Vicksburg, MS. Since 2001, Dr. Green has been an Assistant Professor of Civil and Environmental Engineering at the University of Michigan. Research Interests include geotechnical earthquake engineering issues in the central-eastern US.

Alaa K. Ashmawy received his BS in Civil Engineering from Alexandria University in Egypt in 1989, and both his MS and Ph.D. from Purdue University in 2003 and 2005, respectively. Before joining the American University in Dubai, he had been a faculty member at the University of South Florida in Tampa for 10 years. Dr. Ashmawy has consulted for numerous companies and organizations in the fields of foundation engineering and soil improvement. His academic research interests are in the areas of micromechanical modeling and geoenvironmental engineering.