MEETING MINUTES

13 March 2017

Location: Hyatt Regency Hotel
Orlando, FL

Committee Chair: Kord Wissmann
Committee Secretary: Antonio (Tony) Marinucci

This meeting was called to order by K. Wissmann at 1.00pm (local time)

Minutes of the Meeting

1. Meeting was started with a welcome by K. Wissmann, followed by a statement of thanks and gratitude to outgoing committee chair, Kyle Rollins, for all of his hard work and dedication to the committee
2. There was a self-introduction of meeting attendees, and an introduction of the leadership roles in the committee (K. Wissmann)
    - The officers of this committee are as follows:
        - Committee Chairman: K. Wissmann, Foundation Co.
        - Vice Chairman: Jie Han, University of Kansas
        - Secretary: Antonio Marinucci, V2C Strategists, LLC
    - Other non-officer positions for this committee are as follows:
        - Awards Subcommittee Chairman: Jie Huang, University of Texas-San Antonio
        - Technical Conference Papers Chair: José Clemente, Bechtel Corp.
        - Web master: Armin Stuedlein, Oregon State University

3. Awards for Ground Improvement - Jie Huang
    - J. Huang explained that there are 3 awards available: Peck Award, Wallace Hayward Baker Award, and technical paper awards (Middlebrooks Award, Norman/Croes Medals)
        - George Filz received Wallace Hayward Baker award at conference in 2016
        - Jim Hussin to receive the Wallace Hayward Baker award during GeoFrontiers 2017 conference
    - There is a small group that reviews the proposals and potential nominees, and then submits best choice(s) to Geo-Institute
        - In 2016, T. Siegel, J. Collin, and C. Woods volunteered to assist with effort and to serve on the Awards Subcommittee
    - J. Huang stated that the Soil Improvement Committee may join efforts with other committees if the other committee(s) wish to nominate someone who the SI committee approves and supports

4. Committee Structure – K. Wissmann
    - There was an active discussion about what constitutes an active / participatory member and who should be a correspondent-type of member → meetings attended, papers reviewed, activities undertaken within the operating year
    - Follow up will occur at next year's (2018) committee meeting

5. Update from GeoInstitute (GI) Board of Governors – K. Wissmann
    - K. Wissmann reiterated the 4 focus areas of GI 2014 Strategic Plan:
        1. Become more member-centric
        2. Become the source of knowledge (info) and value
        3. Bring better value to membership through better organization and collaboration
        4. Become more financially viable and more independent (enhance member delivery by bringing value to the members on a local/regional level)
    - The intent of the strategic plan is to deliver content locally and regionally to membership as most of members are not attending larger conferences and seminars
    - Ground Improvement Modules for Local/Regional Meetings
        - Committee received financial support of effort to develop presentation modules for regional/local GI Meetings
        - K. Wissmann – the technology being presented must be advanced enough to use (subject matter for where high level practitioners are working); need to unite the profession around the topic; material needs to be reviewed by committee and curated
        - Funds cover travel expenses only, but NOT personal time

6. Local / Regional Conference and Content Deliverables (3 ea) – K. Wissmann
    1. Soil Mixing Seminar – G. Filz
        - This is being delivered through the cross-country lecture series
        - G. Filz stated he has been delivering 2 lectures per location / visit – 1 at a chapter event and 1 at a nearby university
        - There are a total of 9 or 10 visits with 18 to 20 lectures that G. Filz will make
        - 2 possible topics will be presented during the visits – Deep Mixing or Column Stabilized Embankments. A 3rd topic could be Seepage, but the focus has been on the first two topics.
    2. Soil Improvement to Strengthen Lateral Capacity of Bridge Foundations subjected to Seismic Loading – K. Rollins
        - As part of the NCHRP study, K. Rollins will develop a powerpoint slide set for a 45 minute presentation on this topic
        - NCHRP Report 697 entitled "Design Guidelines for Increasing the Lateral Resistance of Highway Bridge Pile Foundations by Improving Weak Soils" was co-authored by K. Rollins and D. Brown is currently available at http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=729
        - When prepared, K. Rollins will ask for a review of the presentation from the committee
            - K. Rollins will send the presentation to K. Wissmann (A. Marinucci)
            - Subgroup to review presentation – A. Marinucci, A. Stuedlein, A. Sehn, M. Suleimann, J. Huang, J. Han
            - Subgroup will offer comments to K. Rollins for consideration and incorporation
        - There is a GI web conference in August 2017. K. Rollins will look to deliver this presentation as part of that web conference
    3. Soil Improvement and Acceptance Criteria – A. Sehn
        - 2 topics were discussed as possibilities – (1) Proper Selection of Soil Improvement Method and (2) Soil Improvement Acceptance Criteria
        - A. Sehn will develop an outline for Option 2
        - A small group will assist with the development and review – A. Marinucci, C. Woods, B. Metcalfe, F. Elsaid

- There was discussion about what other venues were available to deliver this presentation and content → local involvement, local seminars, etc. → BUT need good speakers who can deliver quality presentations; needed to be vetted by the SI committee
    - A. Sehn reiterated that this committee needs to keep within the practice-ready, vetted, and accepted methods – need to match the method with the need
    - [from last year's meeting → S. Nichols mentioned that FHWA/DOT issue is how to assure the requirement has been achieved in order for payment → How to get owners to understand what's happening and what the owner will get once the work is completed. Owners seem to understand traditional methods (e.g., driven piles) and use them with low acceptable / allowable strengths. The newer methods are not as easily understood, especially from QA and performance perspectives.]
    - Additional discussion to occur at a later meeting (full meeting or a teleconference)

7. Update on DFI Ground Improvement Committee – T. Blackburn
    - The two committees will act / operate separately, but will collaborate as much as possible to not duplicate efforts, expenses, messages, etc.
        - Should establish a liaison between the two committees
    - The GI Committee is working on updating the NAVFAC Specifications
    - DFI is establishing a speakers' bureau – developing a template for a database of vetted speakers and their areas of expertise and interest; this can be used for Geo-Institute local/regional events
    - There will be a DFI conference in August 2017 in Washington, D.C. covering non-piling techniques
    - DFI willing to share documents to disseminate information via the SI Committee's webpage: (1) Liquefaction Mitigation Guidance document, and (2) Ground Improvement Performance Specification Guidance document

8. Update on 2017 GeoCongress – J. Clemente
    - Two session proposals were submitted, one each by J. Clemente and J. Huang
        - J. Clemente submitted a general ground improvement proposal, which only received a few technical papers
        - J. Huang submitted a more specialized ground improvement proposal, and received considerable interest, so much so that two sessions were requested from the conference organizers (only one session provided)
    - The general ground improvement session at the conference was not sent or coordinated through the committee, and the papers contained therein were very broad in scope
    - There was a panel session (on the use of biologicals for ground improvement). This session, too, was not sent or coordinated through the committee
    - There was a session on column supported embankments and two other sessions pertaining to ground improvement using geosynthetics
    - There was discussion that the SI Committee should inform the GI Board that sessions for future conferences should be sent and coordinated through the respective technical committees, the earlier the better

9. Upcoming Geo-Institute Conferences and Events – K. Wissmann
    - 2017 - GeoRisk Denver, June
    - 2017 - Grouting Specialty Conference, Hawai'i, July (Sheraton)
    - 2017 - Performance Based Design III, Vancouver, BC July 16-19 - Ground Imp. Theme
        - Ground Improvement Committee is a co-sponsor

- 2017 – PanAmerica Conference - Unsaturated, Dallas, Texas, November
- 2018 – IFCEE GeoCongress (Broad Based-Case Histories), Orlando, March
    - Call for Abstracts / Papers is due 29 March
    - Call for Sessions / Panels – TBD; more information needed
        - J. Clemente and J. Hussin are proposing a panel session, and will send the proposal to the committee for information purposes
    - Moderators will be needed during the conference for the various sessions
        - C. Woods, A. Marinucci, J. Clemente, S. Mackiewicz, K. Rollins volunteered to moderate
    - Reviewers from the SI committee are needed to assist with reviews of papers
        - SI committee should send out to its members a spreadsheet (similar to that done by DFI) indicating areas of expertise and willingness for the reviews
- 2018 - Geotechnical Earthquake Engineering & Soil Dynamics, Austin, TX
- 2018 – GeoShanghai – May 27-30 (J. Han on Org Committee)
- 2019 – GeoCongress – Philadelphia (A. Cadden and S. Olson chairs) – focus on case histories
        - Shamsher Prakash Conference (Case Histories) - this conference will be turned over and managed by GI beginning in 2017
- 2019 - Numerical Modeling Specialty Conference – more details to come
- 2020 – Scour Conference – Washington, D.C.
- US – China Soil Improvement Workshop (every 10 years) – details to be provided at a later time

10. Discussion on Possible Soil Improvement Committee led Conference in 2020
    - B. Camp presented and expressed the sentiments from the Conference Organizing Committee that there are various unfilled or unclaimed spaces for hosting upcoming GI conferences. He also noted that it has been some time since the Soil Improvement Committee hosted a technical conference, and was soliciting interest to host an upcoming conference (as soon as 2020).
    - There was discussion about whether the committee's interests would be better served hosting a specialty conference or a larger GeoCongress.
    - B. Camp said the request was for the SI Committee to host a GeoCongress, as the specialty conferences are not as preferable with the GI. The larger GeoConference would need to include the wide array of areas under the GI umbrella…but there would be a heavy focus on Soil Improvement and Foundations. The next available conference would be in 2020.
    - A. Marinucci and C. Woods volunteered to be conference co-chairs for this event. B. Camp and K. Wissmann would look into what was required from the SI Committee (paperwork of formally requesting the conference).
    - Since the conference is quickly approaching, logistics and planning would need to commence as soon as the Committee is provided with guidance and the requirements.

11. Update on Web Site for Soil Improvement Committee – A. Stuedlein
    - A. Stuedlein solicited photos and technical content (papers, presentations, etc.) from the committee to populate and update the committee website (http://groups.engr.oregonstate.edu/soil-improvement/)
    - Send information to A. Stuedlein so he can upload and include on the website

12. Presentations
    - Two technical presentations were delivered during the committee meeting:
        1. Bio-inspired Soil Cementation by Dr. Nasser Hamden, Arizona State University

2. Lessons on Soil Liquefaction Remediation using Timber Piles – Dr. Armin Stuedlein, Oregon State University (*.pdf copy of presentation is included with electronic version of the minutes*)

13. Update on FHWA Activities – S. Nichols
    - This update is a quick snapshot of the FHWA geotechnical program during 2016 and a look at projects currently underway
    - Activities in research, development, guidance, technology transfer and training that will be accomplished are grouped into eight broadly-defined focus areas:
        - Extreme events, geohazards and sustainable geotechnics
        - Performance management
        - Reliability-based design and construction
        - Advanced geotechnical modeling
        - Alternative delivery methods
        - Design and construction optimization
        - Site characterization
        - Quality assurance
    - Currently active research, development and implementation funded by FHWA:
        - GRS/GRS abutments (FHWA has several active efforts supporting the design, construction and performance of GRS -IBS)
        - Dry cast block durability assessment
        - Strength characterization of open-graded and well-graded aggregates
        - Service limit state design and analysis of engineered fills for bridge support
        - Bearing resistance of large-diameter open-ended piles
        - High-performance concrete for geotechnical applications
        - Development of geohazards program framework
        - Post-grouting of drilled shaft foundations
        - Characterization of bridge foundations and remaining service life repair of bridge foundations
    - Development and/or update of FHWA Geotechnical Engineering Circulars (GECs). List of recently completed and currently active projects:
        - Recently completed (in 2016):
            - GEC 12 - Design and Construction of Driven Piles
            - GEC 14 - Assuring Quality in Geotechnical Reporting Documents
        - Soon to be released (in 2017):
            - GEC 5 - Geotechnical Site Characterization
            - GEC 9 - Design Lateral Load on Deep Foundations
            - GEC 13 - Ground Modification Methods
        - Once the GECs are published, the documents can be downloaded from the FHWA website at http://www.fhwa.dot.gov/engineering/geotech/library_listing.cfm.
    - Implementation of GeoTechTools is focused on changing the way that decision making occurs during project delivery. The outreach for the guidance and solution selection system is supported through training and workshops, presentations and continued development of the website. The web tool is located at www.GeoTechTools.org
    - Service Limit State Design for Bridges is focused on the calibration of the Load and Resistance Factor Design (LRFD) platform at the service limit state for bridge and structure design. The significance for the geotechnical discipline is that there will be a significant shift in how deformation is incorporated into the design process.

- National Highway Institute (NHI), training arm of the FHWA, is responsible for development and delivery of training to support the geotechnical program. In 2016, NHI completed two comprehensive instructor led training courses:
    - Course 132034 – Ground Modification Methods was completed as a three-day training course supporting GEC 13. In addition to the main course, two shorter versions (two days each) of the course were developed to better fit the needs of the target audience.
    - Course 132085 – Soil Nail Walls was completed as a two-day training course supporting GEC 7. In addition to the training course, the Soil Nail Analysis Program (SNAP-2) was updated and is demonstrated as part of the training course.

14. Other new business or topics?
    - No other new business was brought up

Meeting was adjourned at 3.05pm (local time)

Meeting Attendees

- Sign-in sheet is attached

Geo-Institute Soil Improvement Committee

Record of Attendance at Committee Meetings

First Name	Last Name	Organization	E-mail	Phone	Meeting Attendance						
					27-Mar-12	13-Mar-13	22-Feb-14	18-Mar-15	15-Feb-16	1/1/2017 - Comm. Mem.. Email Response	13-Mar-17
Kord	Wissmann	Geopier Foundation	KWissmann@geopier.com	704-439-1790	x	x	x	x	x	x	x
Jie	Han	Univ of Kansas	jiehan@ku.edu	785-864-3714	x	x		x	x	x	x
Antonio	Marinucci	V2C Strategists, LLC	antmarinucci@gmail.com	401-261-9102	x	x	x	x	x	x	x
José	Clemente	Bechtel	jlclemen@bechtel.com	703-429-6851	x	x	x	x	x	x	x
Jie	Huang	Univ Texas – San Antonio	Jie.huang@utsa.edu	210-458-7908	x	x			x	x	x
Armin	Stuedlein	Oregon State Univ	Armin.stuedlein@oregonstate.edu	541-737-3111	x	x	x	x	x	x	x
Kyle	Rollins	Brigham Young University	rollinsk@byu.edu	801-422-6334	x	x	x	x	x	x	x
Sharif	Abdelaziz	State Univ NY at Stony Brook	s.l.abdelaziz@gmail.com	540-467-4724				x			
Juan	Baez	AGI	jbaez@advgeosolutions.com	310-403-7751		x			x	x	
Tanner	Blackburn	Hayward Baker Inc.	jtblackburn@haywardbaker.com				x				x
Dennis	Boehm	Hayward Baker Inc.	dwboehm@haywardbaker.com			x		x			
Billy	Camp	S&ME, Inc	bcamp@smeinc.com	843-884-0005				x		x	x
Greg	Canivan	S&ME, Inc	gcanivan@smeinc.com	843-884-0005				x			
Matt	Caskey	Geopier Foundation	mcaskey@geopier.com	901-289-1414							x
Jim	Collin	The Collin Group	jim@thecollingroup.com	301-907-9501				x		x	x
Sam	Drumheller	Densification, Inc.	sam@densification.com	540-207-3900							x
Fathey	Elsaid	Mueser Rutledge Consulting Engineers	felsaid@mrce.com	914-316-3787						x	x
George	Filz	Virginia Tech	filz@vt.edu	540-231-7151		x	x				x
Jack	Franke	CB&I	jfranke@cbi.com	815-939-6192				x			
Ray	Franz	Hayward Baker Inc.	rjfranz@haywardbaker.com	630-339-4309					x	x	
Mahi	Galagoda	Bechtel	hgalagod@bechtel.com	713-235-2284					x		
Ehsan	Ghazanfari	University of Vermont	eghanzanf@uvm.edu	610-393-2161							x

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Angel	Gutierrez	U.S. Bureau of Reclamation	agutierrez@usbr.gov	928-919-4195							x
Nasser	Hamdan	Arizona State University	nasser.hamdan@asu.edu	480-965-2272							x
James	Hite	Geopier Foundation	jhite@geopier.com	704-439-1790							x
Jim	Hussin	Hayward Baker Inc.	jdhussin@haywardbaker.com	813-884-3441				x			x
Buddhima	Indararatna	Univ. of Wollgang (Australia)	indra@uow.edu.au		x					x	
Yan	Jiang	Terracon Consultants	yan.jiang@terracon.com	785-312-4335							x
Peter	Kelly	Univ of Portsmouth, UK	peter.kelly@port.ac.uk					x			
Prabir Kr	Kolay	Southern Illinois Univ. - Carbondale	pkolay@siu.edu		x					x	
Prabir	Kolay	SIUC	pkolay@siu.edu				x				
Mary Ellen	Large	DFI	mebruce@dfi.org		x	x	x	x			
Guoming	Lin	Terracon	Guoming.lin@terracon.com	912-629-4000	x				x		
Scott	Mackiewicz	Braun Intertec	smackiewicz@braunintertec.com	816-274-1499	x			x	x		x
Ali	Maher	Rutgers University	mmaher@rci.rutgers.edu		x	x				x	
Chris	Meehan	University of Delaware	cmeehan@udel.edu				x				
Brian	Metcalfe	Geopier Foundation	bmetcalfe@geopier.com	704-439-1790				x		x	x
Smith	Miriam	Geopier Foundation	msmith@geopier.com	925-999-5118							x
Kyle	Murrell	S&ME, Inc	kmurrell@smeinc.com	843-884-0005				x			
Silas	Nichols	FHWA	Silas.nichols@dot.gov	202-366-1554		x	x		x	x	x
Peter	Nicholson		peter.hawaii@gmai.com							x	
Angel	Palomino	University of Tennessee	apalomino@utk.edu		x						
Amin	Rahmani	AGI	arahmani@advgeosolutions.com	310-663-5298					x	x	
Sarah	Ramp	Menard	sramp@menardusa.com	412-620-6029					x		

Geo-Institute Soil Improvement Committee

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John	Rice	Utah State University	john.rice@usu.edu	540-808-8061				x			
Juan	Rodriguez	Geopier Foundation	jrodriguez@geopier.com	704-439-1790							x
Amr	Sallam	Terracon	Amr.sallam@terracon.com	407-618-8458					x	x	x
Zach	Scarboro	Geopier Foundation	zscaraboro@geopier.com	704-223-0068							x
Vern	Schaefer	Iowa State University	vern@iastate.edu		x	x	x	x		x	
Al	Sehn	Hayward Baker Inc.	AlSehn@haywardbaker.com	410-551-8200				x	x		x
Lisheng	Shao	Hayward Baker Inc.	LShao@haywardbaker.com	805-218-7314	x				x		
Rakshya	Shrestha	JAFEC USA	rshrestha@jafecusa.com	408-355-3456					x		
Tim	Siegel	Dan Brown and Associates	tim@dba.world	865-809-4883	x			x		x	
Mike	Simac	Earth Improvement Tech	mike@earthimprovement.com					x			
Greg	Simmons	Menard	gsimmons@menardusa.com	301-318-1719				x	x	x	
Lyle	Simonton	Subsurface Constructors	lsimonton@subsurfaceconstructors.com	314-568-3827				x		x	
Muhannad	Suleiman	Lehigh Univ	Mts210@lehigh.edu	610-758-2592	x		x	x	x	x	x
Amirata	Taghavi	Univ of Oklahoma	ata@ou.edu	405-795-2965				x		x	
Marty	Taube	Menard	mtaube@menardusa.com				x				
Gary	Taylor	Hayward Baker Inc.	getaylor@haywardbaker.com	805-933-1331				x			
Mark	Thompson	CH2M Hill	mark.thompson@ch2m.com		x						
Leon	van Paassen	Arizona State University	leon.vanpaassen@asu.edu	480-479-7116							x
Rimas	Veitas	Helical Drilling	rimas@helicaldrilling.com	617-212-8038				x			
Kevin	Wikar	Hayward Baker Inc.	kewikar@haywardbaker.com	440-551-8200							x
Chris	Woods	Densification, Inc.	chris@densification.com	203-823-8026					x	x	x
David	Yang	JAFEC USA	davidyang@jafecusa.com	408-605-2924		x			x		

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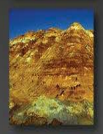


Biogeotechnologies for Mitigation of Earthquake-Induced Soil Liquefaction

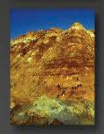
Nasser Hamdan, Ph.D.

Industrial Liaison Officer, CBBG

Geo-Institute Soil Improvement Committee Meeting

13 March 2017

CBBG
Center for Bio-mediated & Bio-inspired Geotechnics

Biogeotechnics

An emerging sub-discipline in geotechnical engineering

Learn from nature and harness natural biological processes to transform the engineering of geotechnical systems

CBBG: Seed funding provided by NSF

- Gen-3 Engineer Research Center (ERC)
- Research and education
- $18.5 million for 5 years

Academic institutions: ASU, G. Tech, NM State, UC Davis

ASU UCDAVIS Georgia Tech NM State biogeotechnics.org CBBG@asu.edu NSF

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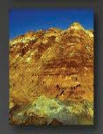

How can we prevent liquefaction?

Densify the soil

- Not beneath/around existing facilities
  - Exception: Compaction grouting (very expensive)

Cement the soil

- Difficult/ impossible beneath existing facilities

→ No cost-effective way beneath/around existing facilities

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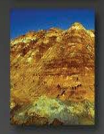

How can biogeotechnology help?

Three CBBG biogeotechnologies:

- Microbially induced carbonate precipitation (**MICP**) via ureolysis
- Enzyme induced carbonate precipitation (**EICP**) via ureolysis
- Microbially induced desaturation and precipitation (**MIDP**) via denitrification

All rely on carbonate precipitation

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Carbonate Precipitation

Very common mineral precipitation phenomenon

- $CaCO_3$ most common

  → $Ca^{2+} + CO_3^{2-} = CaCO_3$

Most studied biogeotechnical mechanism for soil improvement

- Increases strength, stiffness, dilatancy, cyclic resistance

MICP via Ureolysis

Most studied mechanism

- Western Australia, Delft, Cambridge, **UC Davis**
- Stimulate indigenous microbes, add urea and $CaCl_2$

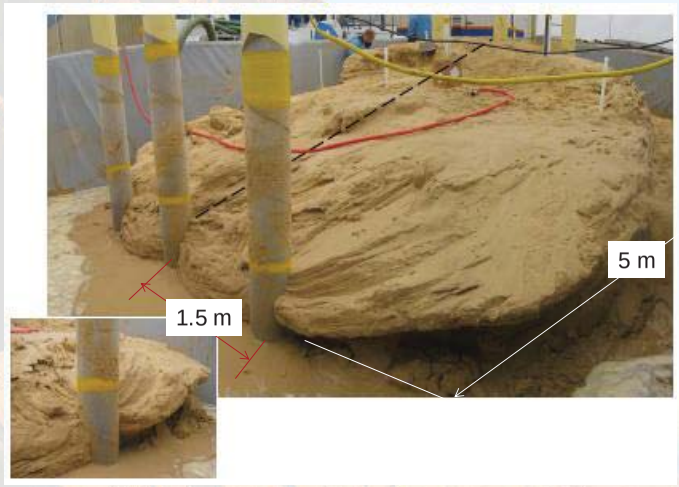
Advantage

- Rapid improvement

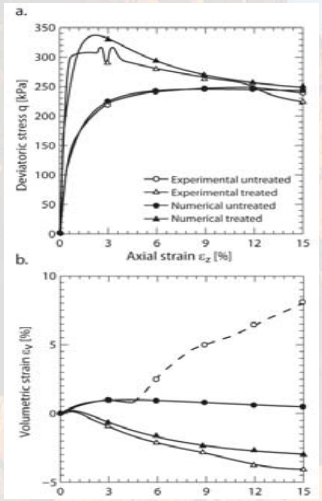
Limitations

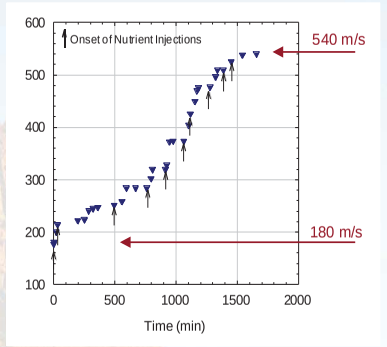
- Limited to fine sand or coarser soil (pore size)
- Ammonium (NH_4^+) by-product

TU Delft MICP Tank Test (van Paassen et al. 2010)



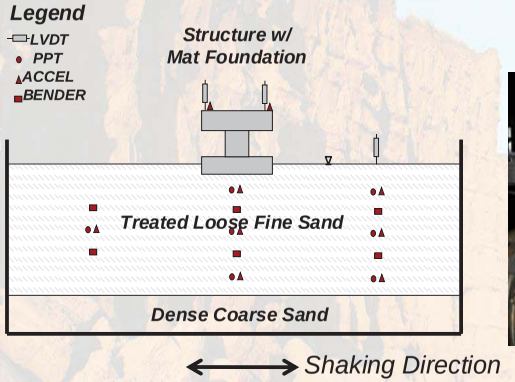
Ureolysis Research at UC Davis (DeJong and others)





Mitigation of Liquefaction via Ureolysis

UCD Centrifuge tests show increased **resistance to liquefaction triggering** and **reduced settlement**



Montoya, DeJong & Boulanger (2013)

Enzyme Induced Carbonate Precipitation (EICP)

Same chemical process as MICP via ureolysis

- Enzyme only
- Urease derived via agricultural sources (litter, seeds, etc.)
- Eliminates need to stimulate & sustain microbes
- Mitigates pore size constraints . . .

Challenges

- Cost of urease
- Speed of reaction

EICP Columns for Ground Improvement

Concept: Columns of cemented sand **and silt** for ground improvement (including liquefaction)

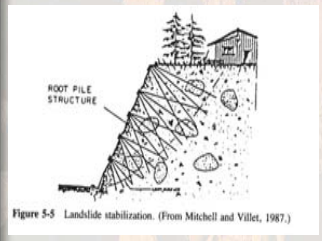
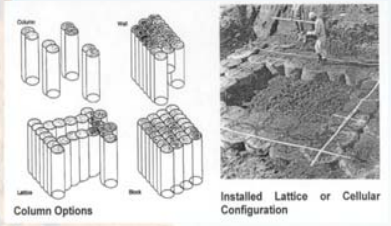
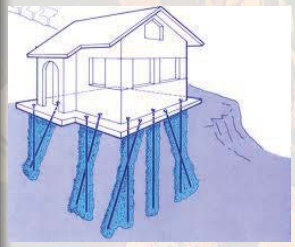
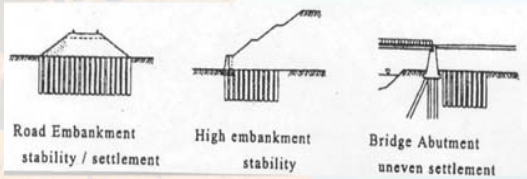


Figure 5-5 Landslide stabilization. (From Mitchell and Villet, 1987.)







5-Gallon Bucket Experiments

Hamdan 2014

Microbially Induced Desaturation and Precipitation (MIDP)

Relies upon dissimilatory reduction of nitrogen (denitrification)

- Still need nutrients, calcium source
- Uses indigenous microbes
- No NH_4^+

Two Stage Process

- Stage 1: Microbial desaturation
- Stage 2: Carbonate precipitation

Stage 1: Desaturation

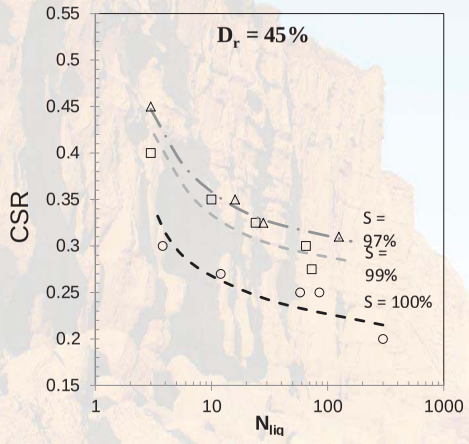
Measurement techniques / observations

- Observations – gas bubbles within columns
- Dialysis bags above columns – capture fluid, gas
- Measure Compressional (P) – wave velocity

O'Donnell 2016

Effect of Desaturation (20-30 Sand)

CyDSS testing on Ottawa 20-30 Sand



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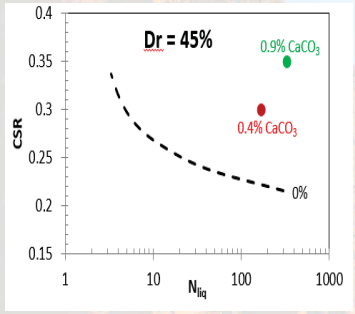
Stage 2: Carbonate Precipitation

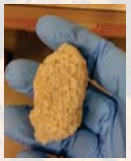
Biotic columns in split molds (for subsequent tests)

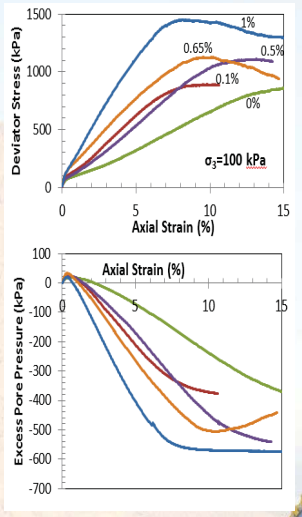
- Measure shear wave velocity with time
- Triaxial (TX) testing for strength, dilatancy, stiffness
- CyDSS testing cyclic resistance
- IC analysis & acid digestion for monitoring carbonate production
- SEM imaging

CyDSS and TX Testing (S = 100%)

Increase in stiffness, dilatancy, strength of treated columns







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MIDP Findings

Small amount of **desaturation** leads to significant ↑ in liquefaction resistance

- Desaturation occurs quickly

Small amount of **precipitation** leads to significant ↑ in dilatancy, stiffness, strength & cyclic resistance

- Some improvement remains after breaking cementation bonds

➡ Denitrification shows promise for mitigation of liquefaction potential as a 2-stage process

Conclusions

Three promising biogeotechnologies for mitigation of earthquake-induced liquefaction

- MICP via ureolysis
- MIDP via denitrification
- EICP via ureolysis

All can play a role in earthquake hazard mitigation

Questions?

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Ground Improvement and Liquefaction Mitigation using Driven Timber Piles

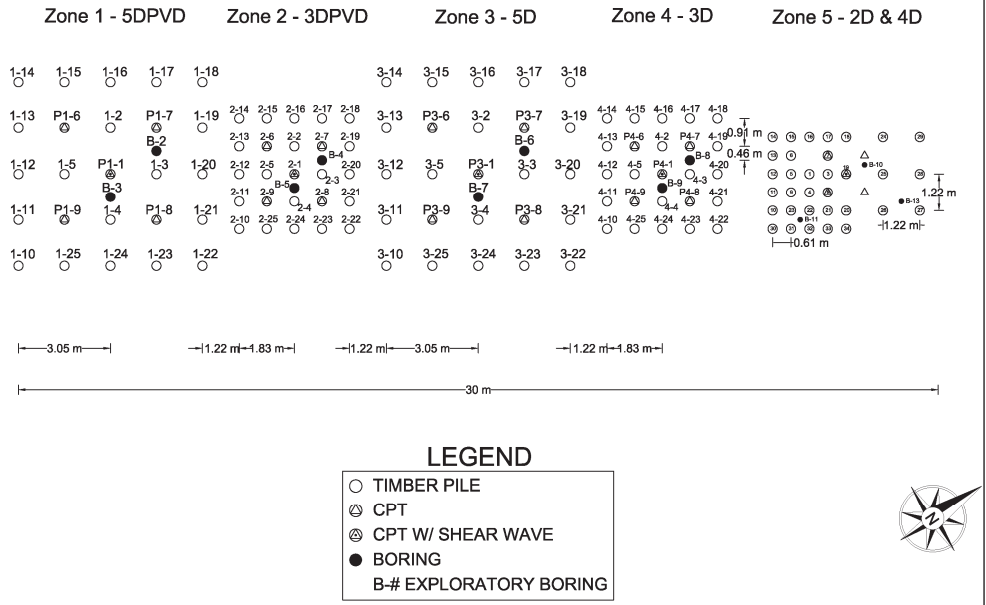
Armin W. Stuedlein, PhD, P.E.

Overview on the Research Program

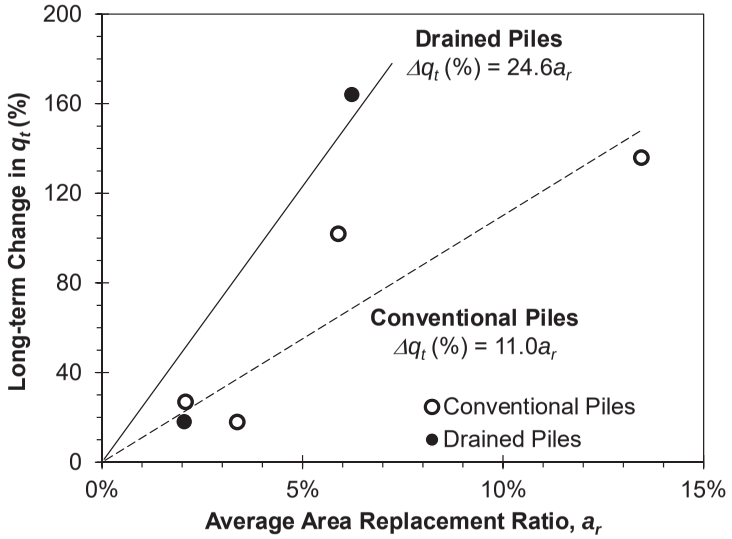
- Initial Effort:
  - 1st Sponsor: TRB IDEA Program NCHRP 180
  - 2nd Sponsor SC Chapter of the PDCA
  - In-situ tests to quantify variation in densification with pile spacing
  - Controlled blasting program to make one-to-one comparisons on the post-liquefaction response
- New Effort:
  - 3rd Sponsor: TallWood Design Institute
  - Numerical modeling program to assess shear strain compatibility, amplification, effect of working platforms, tensile strains, etc.
  - (Attempt to) Develop limit equilibrium-equivalent modeling methodology
- Pubs-to-date:

- Gianella, T.N., and Stuedlein, A.W. (2017) "Performance of Driven Displacement Pile-Improved Ground in Controlled Blasting Field Tests," Journal of Geotechnical and Geoenvironmental Engineering, In Press
- Stuedlein, A.W. and Gianella, T.N. (2016) "Observations on the Effect of Driving Sequence and Spacing on Displacement Pile Capacity," Journal of Geotechnical and Geoenvironmental Engineering, Vol. TBD, No. TBD, 06016026. In Press
- Stuedlein, A.W., Gianella, T.N., and Canivan, G. (2016) "Densification of Granular Soils using Conventional and Drained Timber Displacement Piles," J. of Geotech. Geoenv. Engrg., 142(12), 11 pp.
- Stuedlein, A.W. and Gianella, T.N. (2016) "Drained Timber Pile Ground Improvement for Liquefaction Mitigation," Final Report, NCHRP IDEA Project 180, Transportation Research Board, The National Academies, Washington, D.C., 66pp.

(Very Brief Overview of Findings): Densification

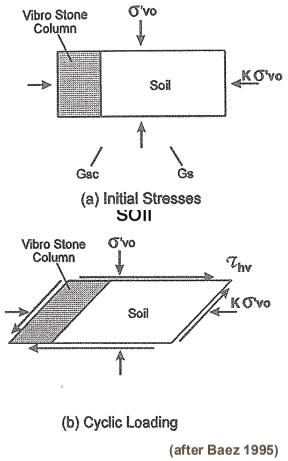


Summary: Average Improvement in CPT q_t



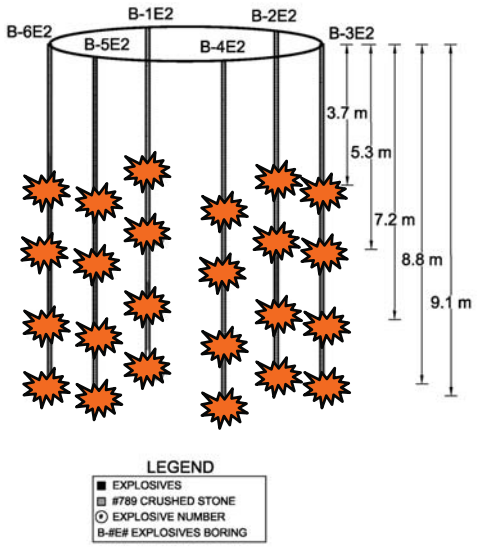
Outstanding Question: Reinforcement (?)

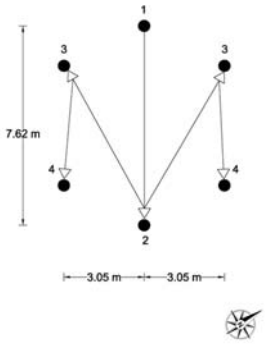
- Reinforcement effect – two modes
  - Vertical support and shear reinforcement: global stability
  - Stiffened elements divert the cyclic stresses away from soils, reduce u_e
- Baez (1995):
  - Introduced a theory of seismic shear stress redistribution for stone columns
  - Shear strain compatibility (**SSC**) assumption
- SHRP2: use **SSC** for CFA piles, deep mixing, jet grouting, vibro-concrete columns
- Olgun & Martin (2008); Rayamajhi et al. (2014):
  - Performed finite element modeling on columns
  - Showed that the shear strain compatibility assumption may not be valid…
- Does the reinforcement effect result in a reduction of excess pore pressures ?
- Is there an effect of gapping that further reduces efficiencie ?



[Controlled Blasting]

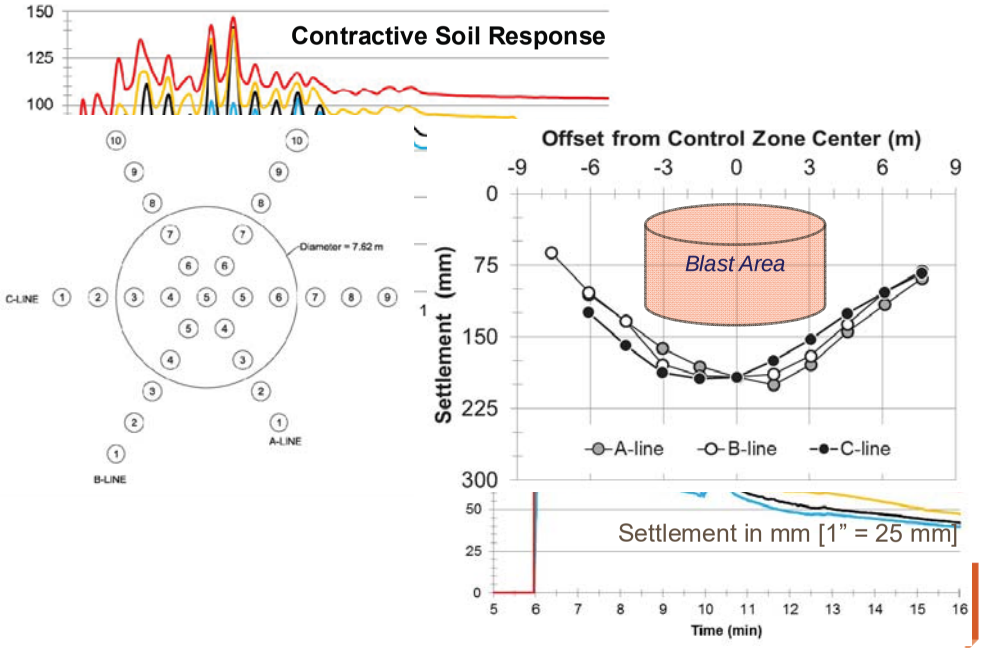
Controlled Blasting Program for the Control Zone





Controlled Blasting Program for the Control Zone

Controlled Blasting Program for the Control Zone



Controlled Blasting Program for the Treated Zones

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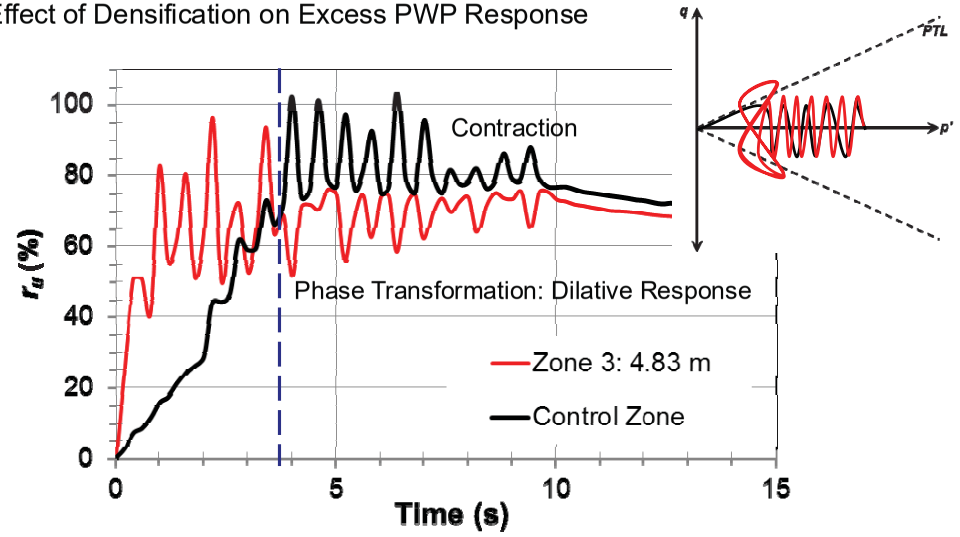
Controlled Blasting Program for the Treated Zones

Effect of Densification on Excess PWP Response



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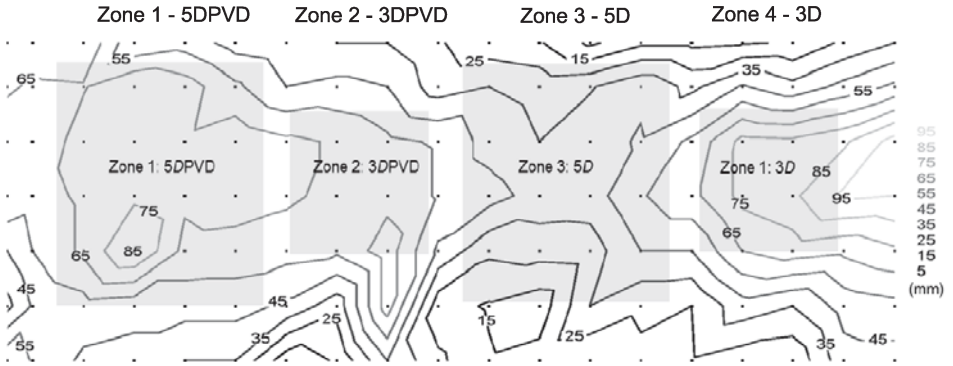
Controlled Blasting Program for the Treated Zones

Settlements = 1/6 to 1/3 that of control zone

These observations confirm the post-liquefaction ε_v measurements from the mid-70's

Median settlement of piles tipped in Dense Sand: 20 mm (3/4")



Settlement in mm [1" = 25 mm]

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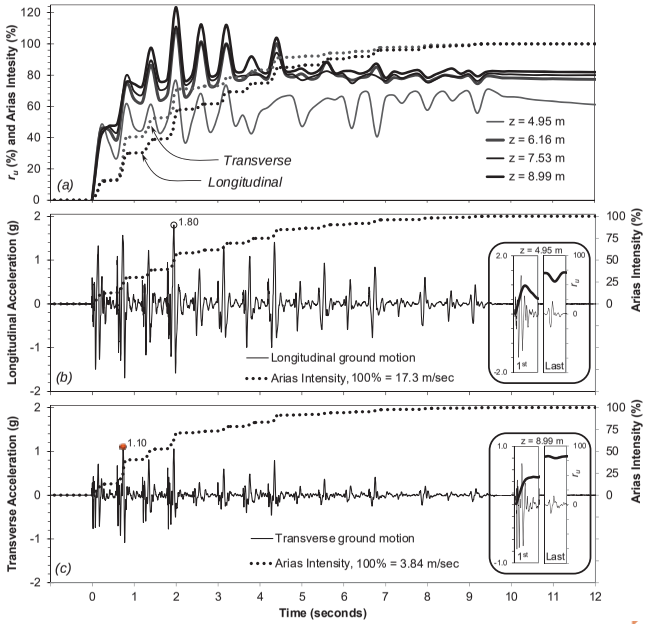
Blast-induced Ground Motions and Energy

- Compared to EQ ground motions, blasting motions have higher frequencies (8 Hz vs. ~1 Hz)
- Blasting motions are much stronger; peak transverse (shear) motions: 1.1*g*
- Energy in these motions equivalent to M = 7.0 at distance of ~5 km, or a M = 8.5 at 100 km



[Assessment of Reinforcement]

Reinforcement effect – Baez (1995) Approach

Baez (1995) shear strain compatibility (SSC) approach:
assuming the "simplified" method for liquefaction triggering

$$CSR = \frac{\tau}{\sigma'_{v0}} = 0.65 \cdot \frac{a_{max}}{g} \frac{\sigma_{v0}}{\sigma'_{v0}} \cdot r_d \cdot MSF$$

substitute $\tau = \gamma G$ and rearrange for shear strain:

Note that MSF disappears for assessments of blast-induced shaking

$$\gamma_{SSC} = 0.65 \cdot \frac{a_{max}}{g} \frac{\sigma_{v0}}{G_{comp}} \cdot r_d$$

$$G_{comp} = G_{soil}(1 - A_{rr}) + G_{pile} A_{rr}$$

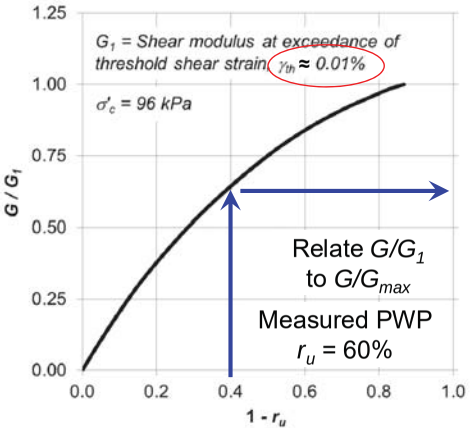
G_{comp} = shear modulus of composite ground

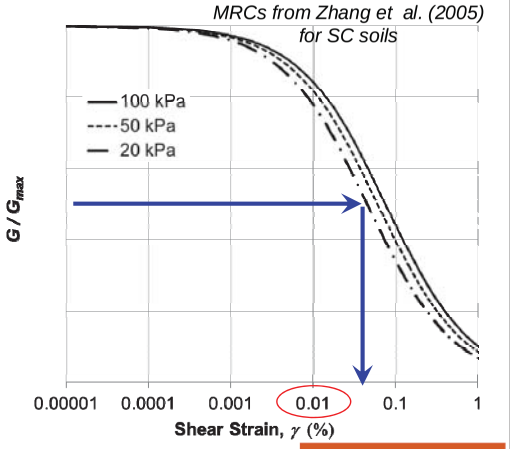
A_{rr} = area replacement ratio

since $\mathbf{G_{pile}} >> \mathbf{G_{soil}}$, *small* $\mathbf{A_{rr}}$ *still provides high* $\mathbf{G_{comp}}$, *and theoretically small strains* γ_{SCC}… *If* **SSC** *assumption is appropriate….*

Reinforcement Effect – Estimation of Shear Strains

If we can estimate shear strains…we can make some observations on the reinforcement effect and the shear strain compatibility (**SSC**) assumption for reinforcement-type ground improvement





Curve based on Data by Dobry et al. (1982)

Reinforcement effect – Results of Assessment