OKLAHOMA TRANSPORTATION CENTER

ECONOMIC ENHANCEMENT THROUGH INFRASTRUCTURE STEWARDSHIP

GRADUATE STUDENT RECRUITING INTO CRITICAL TRANSPORTATION INFRASTRUCTURE AREAS OF INTEREST

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16. ABSTRACT

This report presents the results of a three-year, intensive recruiting and mentoring program in the University of Oklahoma's (OU) College of Engineering (CoE). Highly qualified and diverse graduate students were sought to pursue degrees in transportation related engineering fields, spanning the disciplines of Civil Engineering, Computer Science, Electrical and Computer Engineering, Industrial Engineering and Mechanical Engineering. The purpose of the project was to explore innovative ways in which to recruit, educate, retain and mentor the next generation of transportation engineers to fill both Oklahoma's and the United State's critical need for qualified engineers to help our aging infrastructure. The graduate students recruited to these programs became Oklahoma Transportation Center (OkTC) Fellows, gaining significant experience in transportation research and industry. All OkTC Fellows were gainfully employed in the transportation industry after graduation or currently pursuing advanced degrees.

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SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.40	millimeters	mm
ft	feet	0.3048	meters	m
yd	yards	0.9144	meters	m
mi	miles	1.609	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm
ft^2	square feet	0.0929	square meters	m^2
yd^2	square yards	0.8361	square meters	m^2
ac	acres	0.4047	hectares	ha
mi^2	square miles	2.590	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0283	cubic meters	m^3
yd^3	cubic yards	0.7645	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.4536	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.448	Newtons	N
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa

Approximate Conversions from SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.0394	inches	in
m	meters	3.281	feet	ft
m	meters	1.094	yards	yd
km	kilometers	0.6214	miles	mi
		AREA		
mm^2	square millimeters	0.00155	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.196	square yards	yd^2
ha	hectares	2.471	acres	ac
km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME		
mL	milliliters	0.0338	fluid ounces	fl oz
L	liters	0.2642	gallons	gal
m^3	cubic meters	35.315	cubic feet	ft^3
m^3	cubic meters	1.308	cubic yards	yd^3
		MASS		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	degrees Celsius	9/5+32	degrees Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	Newtons	0.2248	poundforce	lbf
kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

Graduate Student Recruiting into Critical Transportation Infrastructure Areas of Interest

Final Report

January 2013

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Executive Summary

The University of Oklahoma (OU) College of Engineering (CoE) continually seeks to recruit and retain highly qualified and diverse graduate students to pursue degrees in transportation related engineering fields. This project helped to recruit seven highly qualified graduate students over a three year period, to pursue transportation research. The graduate students recruited through this Oklahoma Transportation Center (OkTC) Program became OkTC Fellows, gaining significant experience in transportation research and industry. This experience helps foster technological competitiveness in the future transportation workforce and sets a standard for continued student recruitment. The OkTC Fellows program helped to educate the next generation of transportation engineers to fill both Oklahoma's and the United State's critical need for qualified engineers to help our aging infrastructure.

The CoE recruiting staff, in collaboration with transportation faculty, identified highly qualified graduate applicants from diverse backgrounds that had interest in transportation fields. Not only were undergraduate students from our own institutions aggressively targeted through a transportation engineering activity series in the existing ENGR 1410 Engineering Seminar and an undergraduate research program, but national societies were used to find domestic applicants, including, American Indian Society of Engineering and Science, National Society of Black Engineers, Society of Hispanic Professional Engineers, and Society of Women Engineers. OU has active chapters of each of these societies, and used these as well as each society's national conference to search for applicants. We also utilized the Graduate Records Examination (GRE) score search to identify excellent students within our geographic location.

OkTC funding for this project allowed us to augment successful, existing undergraduate research programs at our institutions and provide a competitive level of financial support to graduate students. This funding not only helped with the *recruitment*, but perhaps more importantly, the *retention* of prospects. OkTC

supplemental funding combined with research funding was a competitive recruitment and retention tool.

Introduction

The purpose of this project was to recruit diverse individuals to graduate programs in transportation engineering fields. The graduate students recruited to the programs with the stipend augmentation funded by this proposal were Oklahoma Transportation Center (OkTC) Fellows, and remained fellows for three years, provided they remained in good academic standing and productively contributed to research. The OkTC Fellows selected were all pursuing transportation related research within Civil Engineering at the University of Oklahoma (OU).

This project helped OU align their recruiting efforts with the OkTC strategic plan, which states that "Students attending transportation-related education today, through degree programs and experiential learning, will become the transportation workforce and leaders of tomorrow. The OkTC will maintain and enhance its human resources through transportation research and education that are compatible with the Center's theme." Transportation workers of the future will need a wider skill set and more training than the current workforce (Transportation Report 275, Transportation Research Board of the National Academies, 2003). More students need to pursue graduate level studies to gain the knowledge and skills needed to address complex transportation problems. Additionally, changing population demographics indicate a need to diversify student recruitment, retention, and career placement programs. Diversity positively impacts the workplace, increases competitiveness of corporations, and improves higher education (Carnevale and Fry, 2000). The minority labor force is an important source of labor in the 21st century, especially for the transportation industry.

Increasing minority recruitment and retention in higher education to meet industry needs also brings benefits to the classroom and increases the quality of learning. Diversity on college campuses creates an atmosphere that cultivates scholarly debate by exposing students to a variety of perspectives. Also, diversifying higher education allows students the opportunity to interact closely prior to entering the workforce, thus increasing their tolerance of differences (Taylor and Olswang, 1997).

Several issues create challenges in recruiting diverse students to engineering graduate programs. These include lack of early engagement in STEM studies, poor preparation in math and sciences prior to college, and the high costs of graduate education (Carnevale, 1999). These issues are beginning to be addressed on a national level by a variety of constituents. Many universities, including OU, have K-12 outreach programs providing STEM enrichment programs to engage students at an early age. The University of Oklahoma also has a Multicultural Engineering Program to provide financial, educational, and social support to diverse students to ensure educational success and foster their transition into the workforce.

OU recognizes the need to actively recruit and retain a diverse cohort of students to graduate programs. In fact, an aggressive graduate recruiting program has been in place since 2006 that has resulted in an increased number of Oklahoma students continuing to graduate school, as well as a more diverse graduate population. Additionally, we recognize the critical need for technologically sound engineers for the transportation labor force not only nationwide, but especially in Oklahoma. OU is dedicated to research and education in the transportation engineering arena, with many faculty members participating in the OkTC.

Recruiting and Retention Program

The University of Oklahoma (OU) College of Engineering (CoE) continually seeks to recruit and retain highly qualified and diverse graduate students to pursue degrees in transportation related engineering fields. OU's CoE has ongoing research projects within a variety of transportation issues that span the disciplines of Civil Engineering, Computer Science, Electrical and Computer Engineering, Industrial Engineering and Mechanical Engineering. OU is poised to educate the next generation of transportation engineers to fill both Oklahoma's and the United State's critical need for qualified engineers to help our aging infrastructure. The graduate students recruited to these programs became OkTC Fellows, gaining significant experience in transportation research and industry.

Complex transportation issues demand increased education in a variety of disciplines. Recruiting highly qualified diverse graduate students each year to pursue transportation research, fosters technological competitiveness in the future transportation workforce and sets a standard for continued diverse student recruitment. As the OkTC and the OU College of Engineering continue to put more resources into transportation projects and diversity, they raise awareness not only in the state, but nationwide.

The CoE recruiting staff, in collaboration with transportation faculty, identified highly qualified graduate applicants from diverse backgrounds that had interest in transportation fields. Not only were undergraduate students from our own institution aggressively targeted through a transportation engineering activity series in the existing ENGR 1410 Engineering Seminar and an undergraduate research program, but national societies were used to find domestic applicants, including, American Indian Society of Engineering and Science, National Society of Black Engineers, Society of Hispanic Professional Engineers, and Society of Women Engineers. OU has active chapters of each of these societies, and used these, as well as each society's national conference, to search for applicants. We also utilized the Graduate Records Examination (GRE) score search to identify excellent students within our geographic location.

OkTC funding for this project allowed us to augment successful, existing undergraduate research programs at our institutions and provide a competitive level of financial support to graduate students. This funding not only helped with the *recruitment*, but perhaps more importantly, the *retention* of prospects. OkTC supplemental funding combined with research funding proved to be a competitive recruitment and retention tool.

Recruitment Plan

Recruitment Programs for Undergraduate Students at OU

Less than half the freshmen who start in engineering graduate in the field, and at least half of this attrition occurs during the freshman year (Besterfield-Sacre et al., 1997, Wankat & Oreovicz 2005, Hartman & Hartman 2006). Even more disheartening is that the retention rate of female engineering students is consistently about 20 % or more below that of males, even when the female students have as high or higher academic achievements as males (Adelman 1998). Teaching methods based on active learning play a role in retention of all students by increasing involvement (Wankat & Oreovicz 2005). Therefore real-world experiences, such as undergraduate research, internships or cooperative group learning through case-histories must be integrated into programs during the students' first few semesters. These interactive "social" learning settings are especially important for the retention of female students (i.e., Etzkowitz et al. 2000, Loftus 2005)

In order to implement design and real-world experience into the civil engineering curriculum as early as the freshman year, CEES at OU implemented an innovative design across the curriculum project entitled "Sooner City: Design Across the Curriculum," (Kolar et al. 2000). Sooner City unifies the CEES undergraduate curriculum by weaving a common design theme (infrastructure) throughout. Sooner City has proven to be a sustainable paradigm: the project has continued after funding expired and is still readily utilized at every level within our curriculum. Even though this program has been widely successful, it does not specifically address low interest in transportation engineering among undergraduate students at OU because students receive no formal exposure to transportation engineering prior to the 4th year of undergraduate education, which is later than most other engineering subdisciplines. This late exposure impacts recruiting efforts into graduate programs.

Therefore, to provide early transportation engineering exposure to students already in their engineering curriculum, we completed the following tasks: 1) Implemented a transportation engineering activity series in the existing ENGR 1410 Engineering Seminar, a first-semester, required course designed to expose students to all aspects of the engineering profession, and 2) Recruited and mentored several freshman, sophomore and junior level students to work on various research projects throughout the CoE and strove to retain the most qualified students for graduate school.

The transportation engineering activity series included case studies and fantastic failures (and successes) to describe the role that transportation engineers play in society by bringing in dynamic outside speakers from industry and academia (Table 1). The students actively participated in the reenactment of the site preparation and design process and discussed the mistakes or successes in interpreting existing subsurface conditions, traffic loading, and/or seismic loads. The CoE transportation undergraduate research program engaged students early in their college career and introduced them to exciting research and the advantages of obtaining an advanced degree.

Table 1. Interactive Seminars presented at OU.

Date	Seminar Speaker	Company/University	Topic
4/30/2010	Ning Lu	Colorado School of Mines	Unified Effective Stress Concept for Variably-Saturated Soil
9/17/2010	Thomas Oommen	Michigan Tech	Pre- and Post-Earthquake Induced Liquefaction: Characterization Using Pattern Recognition and Satellite Remote Sensing
1/18/2011	Jacques Huyghe	Eindhoven University of Technology	Synergies Between Geo and Biomechanics: Hydraulic Fracturing and Herniation of the Disc
2/25/2011	Melissa Landon	University of Maine	The challenges of site characterizations and geotechnics for offshore renewable energy: A case study from the Gulf of Maine
4/8/2011	Priyantha Jayawickrama	Texas Tech University	Recent Advances in Earth Retaining Structures for Transportation Applications
9/23/2011	Usama El Shamy	Southern Methodist University	A Microscale Framework for the Seismic Response of Soil-Foundation-Structure Systems
11/7/2011	Arul K. Arulmoli	Earth Mechanics, Inc.	Seismic Design of Port Facilities
9/24/2012	Yoga Chandran	CH2M Hill	Geotechnical Engineering for Transportation Projects through the Case History of the Golden Ears Bridge Project
11/5/2012	Liz Smith	Terracon	Global Stability: Case histories and lessons learned

Approximately 90% of all undergraduate students in the College of Engineering at the University of Oklahoma leave school after graduation for the workforce. Some are first generation college students with families to support and others just don’t know that engineering students can get their graduate degree fully funded. With increasing technological requirements and complexity within the transportation industry, advanced schooling is becoming necessary. We need to entice the excellent students to stay in school and get an advanced degree in order for Oklahoma and the U.S. to stay technologically competitive. The implementation of an undergraduate research program is helping to retain our best and brightest.

The CoE undergraduate transportation research program is run mainly during the academic semesters, with students working approximately 10 hours/week on a segment of a larger research project under the tutelage of graduate students and their advisor. The research experience exposes them to aspects of transportation engineering they would not see in the required curriculum and hopefully motivates them to attend graduate school, increasing the applicant pool and eventually the education of the workforce and society at large. In the past five years, the PI has recruited FIVE undergraduate students into her graduate program utilizing the undergraduate research assistant approach. Of the FIVE undergraduate students she recruited, there were 4 minority students; 1 Black Male (Texas), 2 White Women (Oklahoma) and 1 Native American Male (Oklahoma). This type of recruitment works; students love the one-on-one contact with the graduate students and professors and they feel like their work benefits society, which is very important for engaging minority students. A list of students who have participated in undergraduate research in from 2006-2012 with the PI is provided in Table 2.

The institutional support for undergraduate research is phenomenal at the University of Oklahoma and also within the College of Engineering. The University of Oklahoma also has a fantastic Honors Research Assistant Program (HRAP) and the University Research Opportunities Program (UROP). Faculty researcher's also routinely write undergraduate research assistantship (URA) funding into research proposals (i.e., I currently support 2 URA's on externally funded projects). Therefore, this CoE undergraduate transportation research program is sustainable; continuing after the OkTC funding is over. One of the primary reasons that these educational components have succeeded is that they are integrated into the existing curriculum and on-going undergraduate research programs. Institutional inertia often prevents more "radical" reforms from having long-lasting impacts.

Table 2. Undergraduate Students involved in research.

2006 to 2012			What transportation related career activity did they pursue after their project participation?		
Participant Name	OkTC Project Participant(s)	Other Project Participant(s)	Undergrad. school	Graduate school	Employment or university (where)
Colin Osborne	X	X	OU	OU, MS	ODOT
Jacob Grasmick	X	X	OU	Co. Sch. of Mines, MS	?
Eric Holderby	X	X	OU	OU, MS	Halliburton, TX
Michael McLean	X	X	Citadel	N/A	US Military (Army)
Jessie Cunningham		X	Clarkson Univ.	N/A	?
Janessa Rosales		X	CA St. Univ.-Bakersfield	N/A	?
Ondra Dukes	X		Old Dominion Univ.	N/A	?
Michaela Campbell	X		OU	OU, MS	Engineering Analytics, Fort Collins, CO
Youssef Elfakih		X	Clermont-Ferrand, FR	N/A	?
Abbo Mbacke		X	Clermont-Ferrand, FR	N/A	?
Wassim Tabet	X		OU	OU, MS	PhD Cand., OU
Mark Emde		X	OU	OU, MS	PhD Cand., Co. Sch. of Mines
Russell Buhler		X	OU	OU, MS	Exxon-Mobil, TX
Marty Farris		X	OU	OU, MS	ODOT
Carlos Guzman		X	OU	UTAustin, MS	?
Rory Victor		X	OU	OU, MS	Exxon-Mobil, TX
Amanda Adams	X		OU	OU, MS	Johnson and Associates, OK
Paul Romero		X	OU	N/A	ODOT
Richard Starks		X	OU	N/A	ODOT

Recruitment Program for Students outside OU

While OkTC funding was utilized to bolster OU's solid undergraduate student recruitment and retention programs in the form of undergraduate research assistant stipends, the majority of the requested funds paid for graduate student stipends to help entice excellent undergraduate students to attend graduate school in Oklahoma within transportation related fields. The stipend supplements requested through this transportation fellows program provided the means necessary to recruit the best and brightest, as well as retain them throughout their program. OU recognizes the need to actively seek highly qualified domestic graduate students to our programs.

Most of our recent successes in recruitment to our graduate programs have taken place within our undergraduate research programs, since it is more likely that a student who attends OU would simply stay for graduate school; a local student doesn't have to find housing or adjust to a new city. However, it is also important to recruit undergraduates from colleges and universities other than OU that have undergraduate engineering degrees to increase the diversity of students and enhance the graduate experience. Our graduate program consists of Native Oklahomans as well as Texans, Notre Dame and New Mexico Tech graduates, and a multitude of international students. The diversity within the group breeds creativity and collegiality and the working dynamic is phenomenal. We would like to continue that trend.

We recruited at local colleges and universities such as Rose State, Oklahoma Christian University (OCU), University of Central Oklahoma, Oklahoma State University, etc., that have approved undergraduate engineering degrees and we made contacts in schools in Kansas, Missouri, Arkansas, Texas and New Mexico, for example, to try and recruit excellent students that have all the pre-requisites necessary for an advanced degree and would integrate directly into a graduate degree at OU. We focused on the schools in the mid-west/south because previous recruiting efforts performed by the PI has shown that we have a much higher likelihood of recruiting a student from the center of the country then if we try to recruit from the coasts. Our money is better spent on students who have a higher chance of choosing Oklahoma as a state in which to pursue their advanced degree.

For the local Oklahoma schools, we sent a College of Engineering recruiter to their career fairs to get the word out. We also purchased the national GRE score list through the graduate college and targeted only those students who live in the center of the country. This approach has been performed successfully by the PI and the following sections detail the plan used and commitment to recruit quality graduate students.

Creating a Qualified Applicant Pool

Increasing the number of qualified applications submitted to, and the number of graduate students enrolling in, the CoE has been the primary focus of our recruiting program instituted during the Fall of 2006. The CoE recruiting plan was developed out of necessity to provide quality graduate students for recently hired junior faculty members. Graduate students are essential in fulfilling obligations on externally funded research grants and contracts and, as of 2005, there were not enough graduate applications to meet those obligations.

The CoE has identified several criteria to use in identifying competitive students. Nationally competitive students can be identified using a minimum of four pieces of information including: source of BS and/or MS degree, grade point average for BS and/or MS degree, GRE scores, and quality of recommendation letters. A nationally competitive student according to CoE is one who meets the criteria in Table 3. Other criteria that may be considered are the quality of writing, work experience, participation in other extracurricular activities, publication record, and impressions from on-campus interviews.

Table 3: Criteria for Nationally Competitive Students

Criteria	Minimum Qualification
Academic Origin	BS or MS obtained from schools in the top 2 quartiles of comparator institutions or from Big 12 schools; or BS or MS from top ranked international school (A rating).
Academic Performance	Minimum cumulative GPA of 3.5 for BS and 3.5 for MS work.
Performance on GRE	Score above the 75^{th} percentile (Quantitative).
Recommendation Letters	Exceptional recommendations from past mentors and teachers. Students should rank in the top 20% among their peers, have a strong work ethic, solid academics, and work well with others.

In addition to aggressively pursuing graduate students through GRE scores, there are at least four major annual national diversity conferences that the CoE targets as prospect mining events and to publicize OU engineering programs. The CoE travels regionally to graduate and professional school fairs within the mid-west, and coordinates faculty recruitment efforts at the professional conferences they attend. The CoE has access to a national database of McNair Scholars, and the GEM Fellowship Consortium, which is addressing the critical shortfall in the production of American engineering and scientific talent, and focuses on diversity.

All of these recruiting events and multi-contacts, along with our undergraduate research assistantship program, are used to create a pool of exceptional candidates. Once the candidates have completed their graduate applications they are invited to visit the campus for an Engineering Visitation Weekend, typically held in March or April. The Engineering Visitation Weekend is a collaborative effort of faculty, staff, and our own graduate students serving as ambassadors to the College of Engineering. Planning efforts were managed by the Graduate College and the Graduate Liaisons and Graduate Assistants from each school.

The main objective for the program is to welcome students to the College of Engineering, introduce them to our outstanding faculty and research opportunities, and allow them to meet our students and learn about their experiences, and become familiar with Norman/Stillwater and the surrounding area.

Converting Applications to Enrollments

Attracting the top M.S. and Ph.D. candidates is very costly. OU CoE stipends average about $1,400/month ($16,800/year) with a range of $1,080-$2,000/month ($12,960-$24,000/year), which is low compared to other schools in the region. However, what makes the stipends even lower at OU than at competitor institutions, is that OU graduate student fees are $1,100/semester, and schools like UTAustin, UCLA, etc., have NO fees for their students because they are included within the research assistantship. These extra fees that a graduate student must pay reduce their CoE stipend to an average of $12,500/year, which is one of the lowest stipends among the typical packages offered by our competition. We continue to focus on increasing our stipends in order to recruit and retain the best and brightest students. Stipend augmentations, such as that provided by the OkTC, were very successful in enrolling students to our programs.

Retention of Recruits

While recruiting a diverse group of graduate students in and of itself is a daunting task given the limited resources and financial incentives for students to continue to graduate school, retaining these students from matriculation to graduation can be even more challenging. Within the framework of the proposed recruiting program, however, retention becomes a relatively easy task. Creating an extended group of students who all work on transportation related research projects and providing forums for their interaction with each other and with faculty members forms tight knit groups of support and promotes collegiality. In fact, over the past five years, the PI has had a 100% retention rate from the undergraduate research assistant program to her graduate research program (6 for 6!). Within that group of diverse undergraduates there was 1 Black male, 1 Native American male and 2 White women. This type of program is fantastic for minority students who often feel outnumbered in traditional engineering forums, which the PI can attest to first hand. We help foster a collegial environment by sitting students in multi-disciplinary offices, hosting monthly lunchtime seminars, involving our students in the annual recruiting campus visit activities and hosting social events throughout the year. We have several graduate student organizations that host these types of events (e.g., ASCE GeoInstitute Student Chapter), and we coordinate our efforts within the existing graduate student social networks. Not only did this OkTC funding touch OkTC Fellows (4 augmented stipends/year), but it also affected all graduate students involved in transportation research.

Mentoring can't be forced; it must evolve and be self-selected in order to work long-term. By providing informal settings with which to explore various avenues of transportation research and availability of expertise in scheduling, coursework and graduation requirements, we create a safe-haven for our students and they feel included and valued. As a result, they strive to do excellent work and be excellent stewards of transportation engineering throughout their student and professional lives.

Selection of Students

Applications were sent out to all faculty in the College of Engineering in January of each of the three years. Faculty were encouraged to have their current students apply, as well as to identify new student recruits that they would like to see matriculate at OU. Applications were received in April of each year and the fellows were chosen. To receive an OkTC Fellowship, all applicants had to provide proof that they were funded on a Research Assistantship within the College of Engineering ($13,000/Fellow/2010). This was the **minimum** that the student could be paid from a state research grant. The OkTC fellowship could have been renewed for up to three years, however, in each year, the applicant had to reapply and compete with the new batch of applications. In year one (2010), five graduate students were selected and received a $5,000 supplement. In year two (2011), four graduate students were selected (two renewed) and received a $6,000 supplement. In year three (2012), four graduate students were selected (four renewals) and received a $6,000 supplement (Table 4).

The selected OkTC Fellows were as follows:

Table 4. Information about OkTC Fellows.

Name	OkTC Fellow. Year	Degree/ Grad. Date	School	Research Topic	Current Employment
Parnaz Boodagh	2010	MS/2011	CEES	Resilient Modulus of Stabilized Soils	PhD Candidate, Univ. of Colorado
Karim Saadeddine	2010	MS/2012	CEES	Resilient Modulus of Stabilized Soils	Field Engineer, Terracon, OKC
Zac Thompson	2010	MS/2011	CEES	Improving bridge pile behavior using CDSM	Engineer, Terracon, Tulsa
Wassim Tabet	2010-12	MS/2011	CEES	Clod size influence on shear behavior in clays	PhD Cand., OU
Botao Lin	2010-12	PhD/2012	CEES	Predicting Expansive soil behavior for infrastructure applications	Post-Doc., OU
Lei Zhang	2011-12	PhD	CEES	Slope Stability in Transportation Corridors	PhD Cand., OU
Colin Osborne	2011-12	MS/2012	CEES	Bridge Embankment Collapse	E.I., ODOT, OKC

Student Research

Each student selected was successful in their chosen research topics and either gained employment directly in the transportation field, or are currently pursuing advanced degrees, as noted in Table XX. The research topics of the OkTC Fellows are briefly explained here.

Parnaz Boodagh was a Master of Science student in the OU School of Civil Engineering and Environmental Science (CEES) from 2009-2011. She graduated in the summer of 2011 and is currently a PhD candidate at the University of Boulder, CO. While at OU, her research focused on the influence of curing time on laboratory and field stiffness of chemically stabilized subgrade soils. The resilient modulus (M_R) of pavement materials is currently considered the most reliable characteristic used in pavement design for assigning structural coefficients to both untreated and chemically treated soil layers. Therefore, there was interest in determining what effect curing time had on the stiffness gain of chemically stabilized soil and the magnitude of improvement of M_R of subgrade soil collected from five construction sites in Oklahoma. Also, the stiffness improvement response of a field subgrade layer after pavement construction may be different from predicted laboratory stiffness gains due to the dissimilar field and laboratory conditions. It was of interest to evaluate how well lab and field values compare to examine possible correlations between field and laboratory stiffness that may allow pavement designers ability to validate stiffness gains of stabilized subgrades.

The testing included two parts: field testing using Portable Falling Weight Deflectometer (PFWD), and M_R testing of laboratory specimens made to simulate the field soil conditions. The M_R testing performed in the lab and field testing involved curing times of 1 to 28 days. The effects of curing time on stabilized stiffness gains of soils using Class C fly ash (CFA) and lime were studied.

Regression equations for laboratory M_R data were developed so that improved M_R values could be predicted as a function of curing time. Another regression analysis was performed to relate field stiffness and laboratory M_R values in attempt to develop a useful correlation for evaluating the effectiveness of chemical treatment of soil in the field. Comparing the stiffness data obtained from laboratory and field at corresponding curing times revealed that field stiffness (E_{vd}) measured with the PFWD is considerably lower than obtained from laboratory (M_R) tests. While the comparison of field and lab data involved significant scatter, an obvious and significant trend did emerge for the five sites investigated.

Karim Saadeddine was a Master of Science student in the OU School of Civil Engineering and Environmental Science (CEES) from 2009-2012. He graduated in the fall of 2012 and is currently a field engineer for Terracon in OKC. While at OU, his research focused on the influence of additive content on resilient modulus of chemically stabilized soils. His research studied the effect of soil stabilization additives on the Resilient Modulus (M_R) of subgrade soils after 14 days of curing. M_R is defined as the ratio of the repeated cyclic axial deviator stress divided by the recovered axial strain. This study was motivated by the fact that the M_R of stabilized soils is not well documented and by the interest in determining the strength and stiffness properties of three soil series from Oklahoma.

Soil stabilization improves some engineering properties of soil such as plasticity and swell reduction and improved stability for better pavement conditions. Various percentages of stabilizers were used. Soils were collected at three different sites in Oklahoma; Woodward, Ardmore and Idabel. Approximately one hundred M_R tests were performed including duplicates. Results were used to develop an empirical model to predict M_R of the stabilized soils based on stress states and soil physical properties. The various percentages of stabilizers used included: 1, 2, 3, 4, and 5% by weight for hydrated lime and 6, 7, 8, 9, 12, and 15% for cement kiln dust (CKD), Muskogee fly ash (M-FA) and Red Rock fly ash

(RR-FA). The three test soils included Hollywood clay (CH, A-7-6 (45)), Heiden clay (CH, A-7-6 (39)), and Devol soil (ML, A-4 (0)).

The additives react with the subgrade soil in the presence of water to improve the strength and stiffness properties. Cylindrical specimens (4’’ by 8’’) of stabilized soil were compacted in the laboratory at optimum moisture content (OMC) and 98% of the maximum dry density (MDD) and cured for 14 days in a humidity room at 100% humidity and at temperature of 75°F. After 14-day curing, M_R test was conducted according to ASSHTO T-307-99. Results demonstrate improvements in stiffness properties of the tested stabilized soil specimens as a function of additive content. It is found that the average M_R values of Hollywood, Heiden and Devol soils were improved by all four additives compared to the untreated values of M_R. However, the degree of improvement differs by the type of soil, additive and additive content. Lime showed the highest enhancement in average M_R values for Hollywood and Heiden soils at an additive percentage of 3% compared to 6% of CKD and fly ash. At additive percentages of 10 to 15%, CKD provided maximum improvements among all four additives. It was statistically found that the best model for predicting M_R is a function of soil and additive properties, the parameters include: additive percentage, OMC (%) of the stabilized soil, conductivity (ms) of the stabilized soil and, CaO (% by weight), LOI (% by weight) and SAF (% by weight)of the additive. This study also enhanced the database of M_R test results for stabilized subgrade soils in Oklahoma.

Botao Lin was a Doctoral student in the OU School of Civil Engineering and Environmental Science (CEES) from 2007-2012. He graduated in the Fall of 2012 and is currently a post-doctoral research associate at OU. During his PhD work, his research focused on predicting expansive soil behavior using micro-scale soil properties. Understanding the complicated behavior of expansive soil requires in-depth exploration of microscopic phenomena under varying situations, especially when the soil stays unsaturated and experiences swell-shrink cycles. His research was dedicated to a comprehensive investigation of eleven micro-scale properties that function as revealing factors of these electrophysico-chemical mechanisms and the associated surface forces. These microscale properties include: specific surface area (S_a), cation exchange capacity (CEC), surface conductance (λ_{ddl}), soil acidity (pH), diffraction pattern (from X-ray diffraction), micrograph (from scanning electron microscopy), elemental spectrum (from energy-dispersive X-ray spectrometry), diffuse double layer thickness (t), real relative permittivity (κ'), effective conductivity (σ) and suction (s).

Four naturally collected and two laboratory stabilized expansive soils were selected as the study objects. The roles of some microscale properties in determining the macroscopic behavior of volume change and shear strength have been thoroughly examined through experimental work including three dimensional water content-volume-suction studies and a triaxial test program on unsaturated specimens along three capillary paths. The effects of chemical stabilization by fly ash have also been extensively evaluated from a microscopic point of view.

Some innovative testing and analysis approaches were proposed; highlights include (1) constructing a two-terminal electrode system integrated in conventional oedometer equipment and performing dielectric measurements on natural expansive soils at various hydromechanical stages; (2) quantifying diffused double layer (DDL) in terms of thickness and surface conductance; (3) establishing an unsaturated triaxial test program based on the predetermined HSWCCs and the chilled mirror hygrometer tests after shear. Additional newly developed approaches were applied in the studies of soil mineralogy, structure and pore fluid (e.g., assessment of the degree of interfacial polarization and the electrical anisotropy).

This research established a comprehensive framework of expansive soil behavior based on experimental efforts and analysis founded in geology, geochemistry, electronics and geomechanics. The outcome will not only help field engineers explain and find solutions for natural threats on civil infrastructure caused by expansive soils, but also provide evidence and a database for verification or improvement of the present geophysical and mechanical constitutive models. Some potential research efforts, especially the imaging of intact soil structure and the adoption of dielectric testing as a common geotechnical practice, are suggested based on the findings of this study.

Zac Thompson was a Master of Science student in the OU School of Civil Engineering and Environmental Science (CEES) from 2009-2011. He graduated in the Spring of 2011 and is currently an engineer with Terracon in Tulsa, OK. While at OU, his research focused on stress-strain behavior of unimproved and cement-improved soft clays. Soft clays are common around the world, and can be problematic for buildings, bridges, retaining walls and many other engineering structures, especially in seismic prone regions. Weak soils are often improved using chemical additives such as Fly Ash, Cement Kiln Dust, Lime, and Portland cement. Cement Deep Soil Mixing (CDSM) is a ground improvement technique that uses a hollow shaft and paddle to penetrate and mix cement slurry with a native soil. As this method becomes more popular it is important to understand the stress-strain behavior of unimproved and cement-improved soft clays.

Laboratory testing is an effective way to study the stress-strain behavior of soils. The behavior of soft clays has been extensively studied and various constitutive models have been developed to capture their behavior. Limited experimental data and constitutive models are, however, available for cement-improved soft clays. The primary focus of his study was to perform monotonic and cyclic triaxial tests, determine the mechanical properties, and calibrate and validate a bounding surface elastoplastic constitutive model for unimproved and cement- improved soft clays.

Oedometer and triaxial tests were performed on laboratory prepared samples to calibrate the bounding surface elastoplastic constitutive model. The model was calibrated using the observed experimental behavior during the triaxial compression tests on unimproved and cement-improved soft clays for normally, lightly, and heavily overconsolidated samples. Once the model parameters were calibrated, the model was used to predict the observed experimental behavior during extension and cyclic tests.

The model predicted the unimproved soft clay behavior in compression and extension very well. The model was, however, unable to capture the behavior of cement-improved clay and both improved and unimproved cyclic tests accurately, pointing to a need for better models.

Wassim Tabet was a Master of Science candidate in the OU School of Civil Engineering and Environmental Sciences (CEES) from 2009-2011. He graduated in the Spring of 2011 and is currently a PhD Candidate at OU. While a MS student, his research focused on the influence of clod size on the shearing behavior of compacted soil. Laboratory tests used to predict the shearing behavior of compacted soils (e.g. compacted fills or embankments) may not properly model the actual behavior of soil compacted under field conditions. One reason for this is that soil clods compacted in the laboratory are smaller than soil clods compacted in the field. Previous studies have shown that the structure of a soil affects its behavior. The soil structure is influenced by several factors including soil composition, compaction method, clod sizes, initial moisture condition of clods, dry density or void ratio, and compaction moisture content.

The purpose of his research was to study the influence of clod size and initial moisture condition (which affects the moisture distribution within clods) on the shearing behavior of a moderately plastic clayey soil with a plasticity index (PI) of 22. Two initial moisture conditions were achieved by using two different moisture curing times of 0 and 14 days. For the 0-day curing time, samples were directly compacted after the addition of water. As for the 14-day samples, the soil was mixed with water, cured for two weeks, and then compaction occurred at the end of the curing time. The clods were divided into categories each having a range of different nominal diameters, and then two groups of samples were prepared; samples with large clods (LC = clod size less than 38 mm) and samples with small clods (SC = clod size less than 4.75 mm). All samples, however, were compacted at constant volume using the same specifications (95 percent of maximum dry density and 2 percent dry of optimum moisture content). Triaxial compression tests, including constant water content unsaturated tests and back pressure saturated isotropically consolidated undrained and drained compression tests (CIUC and CIDC) were performed at three different confining pressures in order to compute the shear strength parameters.

The results of this study suggest that the shearing behavior of compacted soils is significantly influenced by the size of the clods as well as their moisture conditions. At 0-days curing time, samples prepared using large clods were found to be stiffer and stronger than those prepared using small clods. However, at 14-days curing time, the strength of both LC and SC samples were similar. The effective stress failure envelopes from saturated tests for both LC and SC samples were non-linear; the friction angle was higher at low confining pressures, and decreased with increasing confining pressures. The difference in friction angle between LC and SC samples decreased by as much as half with increasing effective mean normal stress and the friction angle seemed to approach a constant value.

Colin Osborne was a Master of Science student in the OU School of Civil Engineering and Environmental Sciences (CEES) from 2011-2012. He graduated in the Spring of 2012 and is currently an Engineer in Training at ODOT in OKC. While a MS student, his research focused on applied bridge approach settlement. A bump may develop in a bridge at the interface between the bridge deck and the approach slab or between the approach slab and the road pavement. This occurs because the approach slab settles more than the bridge and abutment, which are supported by deep foundations. This bump can cause discomfort, dangerous driving conditions and damage to bridges. It can require expensive repairs. Major causes of the bump include settlement of foundation soil, compression of fill material and erosion of the backfill. Various remedies have been studied to address these issues, including reinforcing the foundation or embankment soil, improving drainage and improving construction practices.

The purpose of this research is to investigate bridges in the state of Oklahoma to determine the leading causes of bump development and provide recommendations for alleviating the problem. In order to achieve these goals, the inspection team conducted Level I investigations on 30 bridges at 22 locations. These observations were analyzed to investigate trends between bridge design and construction and bridge approach settlement issues. In addition to Level I investigations, the scope of this research project included choosing specific bridges based on a number of criteria to perform subsurface investigations. Level II investigations were conducted in order to better determine the cause of the noted problems, namely embankment collapse, erosion and foundation soil issues. Nine bridges were identified and selected for subsurface investigations.

His research detailed the creation of a database containing all the collected bridge information, how the database was used to analyze possible trends in Oklahoma bridge approach problems and to further select specific bridges for subsurface investigations. Analysis of the Level I investigations found that erosion and drainage issues were a major factor in Oklahoma bridge bump problems. Surface drainage was often compromised, which allowed water into the backfill beneath the approach slabs. Many underdrain designs used allow water to bypass the underdrain and flow beneath the abutment instead, leading to erosion. Other underdrain issues improper filtering and blocked outlets. Nine bridges were recommended for Level II investigations, based on the analysis of the database. These bridges represent a wide variety of bump severity, issues, designs and site conditions. Preliminary recommendations include improving existing underdrain designs to prevent flow under the abutment and improving joint design to prevent water infiltration from the surface, as well as preventing soil to flow through the abutment.

Lei Zhang is currently a PhD student in the OU School of Civil Engineering and Environmental Sciences (CEES). His research is on slope stability in transportation corridors. In the U.S. in 2001, landslides caused approximately $3.5 billion in damage (USGS 2004). While the majority of the newsworthy landslides in the United States occur in California, Oregon, and Washington, landslides occur on a smaller scale in all 50 states. In fact, Oklahoma experiences approximately 20 reported landslides per year (Reidenbach, ODOT Materials Division, 2011, personal communication) that damage homes, roadways and infrastructure and quietly cost the taxpayers substantial amounts of money. In fact, two relatively recent slides (Route 20 Keatonville and Route 82 Red Oak) cost taxpayers well into the millions of dollars. Many times, the slide recurs seasonally and roadways must be continually cleared of debris, or physically moved to avoid the sliding soil. This problem is particularly expensive and perplexing in the southeastern corner of Oklahoma (ODOT Division 2), where many roads are annually damaged or destroyed by landslides.

His research aims to characterize and assess landslides in eastern Oklahoma in order to determine indicators revealing why particular areas continue to slide year after year. This characterization will be performed using a combination of historical data from ODOT project files, laboratory testing, in situ testing and analysis of high resolution satellite images, including hydro-climatology data. Coupling high-quality ground reconnaissance and testing with high tech satellite images will produce a refined regional landslide hazard map and a comprehensive model for Oklahoma transportation officials to use to keep transportation corridors open and commerce moving. While the scope of this study is focused on eastern Oklahoma, the information gleaned from this research project will be applicable across the state and nation. The goals of this research are to not only create a functional landslide hazard map as a deliverable for this project that may be used by ODOT and others when building and maintaining infrastructure, but to work toward a real-time monitoring and prediction program that uses real-time dynamic data, like precipitation, to create a reliable warning system for unstable embankments and slopes in the future.

Student Accomplishments

Engaging in cutting edge research to help solve the current infrastructure and transportation issues and being able to offer solutions in a timely manner is imperative if we intend to keep moving forward and not repeat the mistakes of the past. Peer-reviewed publications and national awards are an indication of the quality of work being performed and are a good way to present the results of a research study to the profession and to society. As can be seen, the OkTC Fellows were highly productive and engaged in high quality, timely, transportation related research and producing publishable results early in their research tenure that will help move our profession forward.

- **Zac Thompson** was awarded the prestigious International Drilling Association (ADSC) Graduate Scholarship in 2010.
- **Zac Thompson** was a collaborator on a publication regarding the behavior of bridge pile foundations in soft clay during earthquake loading. .

Kirupakaran, K., Cerato, A. B., Liu, C., Miller, G. A., Muraleetharan, K. K., Pinilla, J. D., Price, S. and **Thompson, Z. M.** (2010). Simulation of a Centrifuge Model Test of Pile Foundations in CDSM Improved Soft Clays. *GeoFlorida 2010: GSP 199, Advances in Analysis, Modeling and Design.* West Palm Beach, Florida, February 20-24, 2010. pp. 1583-1591.

- **Botao Lin** has published and/or submitted several conference and journal papers from his work on predicting expansive soil behavior using microscale properties.

Journal Papers (Peer-Reviewed)

Cerato, A.B. and **Lin, B.** (2012). Dielectric Measurement of Soil-electrolyte Mixtures in a Modified Oedometer Cell Using 400 kHz to 20 MHz Electromagnetic Waves. ASTM Geotechnical Testing Journal (GTJ). Vol. 35, No. 2. pp. 261-269.

Lin, B. and Cerato, A.B. (2012). Prediction of Expansive Soil Swelling Based on Four Micro-scale Properties. Bulletin of Engineering Geology and the Environment. Volume 71, No. 1, pp. 71-78.

Lin, B. and Cerato, A.B. (2012). Investigation on Soil-Water Characteristic Curves of Untreated and Stabilized Highly Clayey Expansive Soils. Geotechnical and Geological Engineering. Vol. 30, No. 4, pp. 803-812.

Lin, B., Cerato, A.B., Madden, A.S. and Elwood Madden, M. (2013). Effect of Fly Ash on the Behavior of Expansive Soils: Microscopic Analysis. Environmental & Engineering Geoscience. *In Press.*

Lin, B. and Cerato, A.B. Electromagnetic Properties of Expansive Soils under One-dimensional Deformation. (2013). *Acta Geotechnica*. In Press. DOI: 10.1007/s11440-012-0198-z

Lin, B. and Cerato, A.B. (2013) Hysteretic Soil Water Characteristics and Cyclic Swell-shrink Paths of Compacted Expansive Soils. *Bulletin of Engineering Geology and the Environment (BEGE).* In Press. DOI: 10.1007/s10064-012-0450-7

Conference Papers (Peer-Reviewed)

Lin, B. and Cerato, A.B. (2012). Hysteretic Soil-Water Characteristic Curves of Highly Clayey Expansive Soils. *GeoCongress 2012. GSP 225. State of the Art and Practice in Geotechnical Engineering.* Oakland, CA, March 25-29, 2012. pp. 1205-1212.

Lin, B. and Cerato, A.B. (2011). The Role of Micro-scale Properties in the Study of Expansive Soils. *GeoFrontiers 2011: GSP 211, Advances in Geotechnical Engineering.* Dallas, Texas, March 13-16, 2011. pp. 4129-4136.

Lin, B. and Cerato, A.B. (2010). Study of Expansive Soil Behavior Using Low to Medium Frequency Electromagnetic Waves. *GeoFlorida 2010: GSP 199, Advances in Analysis, Modeling and Design.* West Palm Beach, Florida, February 20-24, 2010. pp. 708-716.

I*n-Review Manuscripts*

Lin, B. and Cerato, A.B. (2013). Osmotic Suction of Two Highly Clayey Expansive Soils. *Submitted to Geotechnical and Geological Engineering.*

- **Wassim Tabet** has worked on many different projects and been co-author on several conference papers.

Tabet, W., Cerato, A.B. and Miller, G.A. (2012). The Influence of Clod Size and Moisture Condition on the Shearing Behavior of Compacted Soils. *GeoCongress 2012. GSP 225. State of the Art and Practice in Geotechnical Engineering.* Oakland, CA, March 25-29, 2012. pp. 1156-1164.

Hussey, N., Cerato, A.B., Grasmick, J., Holderby, E., **Tabet, W.** and Miller, G.A. (2010). Validation and Refinement of Chemical Stabilization Procedures for Pavement Subgrade Soils. *GeoFlorida 2010: GSP 199, Advances in Analysis, Modeling and Design.* West Palm Beach, Florida, February 20-24, 2010. pp. 2702-2711.

Evaluation of OkTC Fellows Program

Both the OkTC Fellows and the Faculty Advisors were very pleased with the program. In one particular case, the OkTC Fellowship was the deciding factor for the student to remain at OU for a PhD. He was being recruited by the top schools across the country and internationally. By using the OkTC Fellowship as a stipend augmentation, as well as leveraging another research assistantship in Industrial Engineering for his fiancée, OU was able to retain him. Providing a livable wage and a comfortable environment for our graduate students, makes everyone involved much more happy and therefore, productive.

Plans to continue recruiting program

Embarking on an intensive, quality recruiting program is expensive and without a central OU graduate recruiting office or staff, the burden still remains on each individual college and Schools within the college. As was detailed in this report, however, successful recruiting practices have been implemented since 2006 that have significantly increased the quantity and quality of our applicant pool. Thankfully, the OU Graduate College has recently implemented an online admissions system for graduate students, and increased the number of fellowships awarded that would provide $5,000/year in stipend augmentation to allow us to recruit nationally competitive students. In addition, the Graduate College now waives all tuition up to the number of credits necessary for the degree, and that helps us retain our students throughout their program as well. Now we have more chances to succeed in turning applications into matriculations. The fact that we have been successful in retaining our students through graduation over the past seven years is a testament to our college's culture and collegiality.

Conclusions

Graduate student stipend augmentation was provided to seven University of Oklahoma (OU) Graduate Students within the College of Engineering (CoE). These funds help to recruit high quality applicants who would normally have accepted offers elsewhere. In addition, recruiting and retention measures were bolstered within the CoE through this project, and have provided a sustainable program for the future. All seven OkTC Fellows have obtained transportation related employment after graduation or are pursuing advanced degrees. All participants agreed that the increase in stipends and graduate student quality of life measures implemented helped make their tenure more enjoyable.

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