GRADUATE HANDBOOK

Department of Civil Engineering and Engineering Mechanics

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1.0 INTRODUCTION

The purpose of this guide is to provide students with information on the requirements and procedures for pursuing a graduate degree (M.S., M.E., or Ph.D.) in the Department of Civil Engineering and Engineering Mechanics (CEEM) at The University of Arizona. The Department is active in research in the general areas of Engineering Mechanics, Geomechanics/Geotechnical, Highway and Transportation, Hydraulics and Water Resources, and Structures. Details of faculty, ongoing research and resources in each area are included in Appendix 1.

This guide is a compilation of current policies, practices, and procedures of the Graduate School and the Department of Civil Engineering and Engineering Mechanics (CEEM). Information found in the Graduate catalog, which the student is expected to be familiar with, is to be used as the basis for the resolution of any special problems, the treatment of any extraordinary conditions, and the source for details not covered by this guide. In some instances, requirements differ between the Graduate College handbook and this document. In these instances the departmental requirements supercede Graduate College requirements. If a topic is not covered in this handbook, the Graduate College regulations will be enforced. The requirements listed herein are effective from the handbook publication date.

Contained in this guide are general program information, admission requirements, general administration of the graduate program and deadlines for the submission to the Graduate College of items such as study programs, reports on examinations, etc. The Graduate College publishes official specific deadline dates. A copy of official deadline dates can be obtained from the CEEM Office or the Graduate College website (http://grad.arizona.edu/).

2.0 GENERAL PROGRAM INFORMATION

2.1 Degree Programs

The Department offers the Master of Science (M.S.), Master of Engineering (M.E.), and the Doctor of Philosophy (Ph.D.) degree in Civil Engineering and Engineering Mechanics. There are two options in the M.S. program (i) thesis option and (ii) non-thesis option. The M.S. degree thesis option is intended for students who want to study in a specialized area and to work closely with a faculty member on a unique research topic. Students planning to pursue a Ph.D. degree are strongly

encouraged to choose this option. The non-thesis M.S. degree option is intended for student's desiring a broad education. It is comprised of coursework in several areas, a report and a comprehensive final examination. The M.E. degree is intended as a terminal professional degree with academic standards equivalent to, but different from, a traditional M.S. degree. Arizona's three state universities administer this focused degree in a format that combines distance learning with on–campus coursework, further information is available at the Tri-University Partnership website (http://www.oneflexibledegree.com/). The following background is general for all degree programs.

3.0 ADMISSION

3.1 Admission Requirements

The application for admission along with transcripts for all completed collegiate work should be on file with the Dean of the Graduate School at least four months prior to registration. In addition, all applicants must submit scores from the Graduate Records Examination. Three letters of recommendation and the applicant's statement of purpose should support the application. An individual who is applying for a Graduate Teaching Assistantship is advised to complete the admission process well in advance of the deadline dates given in the Application for Graduate Degree Program form. Evaluation of applicants for teaching assistantships for the fall semester begins on February 1st.

A departmental committee made up of faculty from the student's area of interest evaluates the application and transcripts. The Department Head transmits the decision regarding admission to the Graduate School. Applicants are evaluated on the individual merits of their academic achievements and individual scholarly potential to complete graduate level coursework and research requirements. Although all relevant materials are taken into account, priority is given to grade point average and GRE scores. A minimum cumulative grade point average of 3.0 over the last 60 units of undergraduate coursework is required for admission to the M.S. program. A minimum grade point average of 3.5 during the M.S. study is required for admission to the Ph.D. program.

To be considered for the Graduate program, the applicant must hold a Bachelor degree from a recognized undergraduate program. Degrees that are recognized are based on programs of study that meet or exceed the general educational requirements

for comparable majors and degrees at The University of Arizona. Admission to the Ph.D. program requires an MS from an approved institution. For more details see: http://grad.arizona.edu/Catalog/Admissions_Requirements/

3.2 Additional Requirements for International Students

It is recognized that educational systems in other countries differ from that of the United States. Generally, a four-year, first university degree can be considered as comparable to the U.S. bachelor's degree, provided that it was earned at an institution that has official recognition by the Ministry of Education as a university-level academic institution in that country.

In addition to the academic requirements for all applicants, international students must satisfy English proficiency, financial guarantee, and health insurance requirements. To demonstrate proficiency in English, submission of a minimum score of 550 (or a computer-based score of 213) on the Test of English as a Foreign Language (TOEFL) is required for all applicants whose native language is not English. The 550 score (or a computer-based score of 213) is a Graduate College requirement and cannot be waived. The Educational Testing Service should send an official report to The University of Arizona (institution code is 4832). The test date must be within two years of the intended term of enrollment. The Graduate College has a conditional admission option for those not achieving the required TOEFL score. Please consult the Graduate College website for the current option: http://grad.arizona.edu/Prospective_Students/Admissions_Requirements/Conditional_Admission.php. International students seeking graduate teaching assistantships must also obtain a score of 230 on the Test of Spoken English (TSE) on the (TOEFL) or the Speaking Proficiency English Assessment Kit (SPEAK). Interested students are encouraged to take these examinations before leaving their home countries.

Students on non-immigrant visas must certify that they possess adequate financial resources to support themselves while in residence at The University of Arizona. In addition, these students are required by The University of Arizona to carry student accident and medical insurance coverage for each term of enrollment. Students may be exempted from The University of Arizona's insurance plan only when their government or sponsoring agency has submitted accident and medical insurance plans deemed acceptable by The University of Arizona. For detailed explanations refer to The University of Arizona graduate catalog: http://grad.arizona.edu/Catalog/

3.3 Notification of Admission

Each applicant recommended for graduate admission by the Department of Civil Engineering and Engineering Mechanics (CEEM) will be issued a Certificate of Graduate Admission for the term for which he/she has applied. The Certificate of Graduate Admission can be issued only by the Dean of the Graduate College and is the sole official verification that graduate admission to The University of Arizona has been approved for a specific term. Applicants who do not enroll for the term to which they have been admitted must contact CEEM if they wish to defer enrollment to another term. The Certificate of Graduate Admission will specify the status to which the applicant has been admitted from the following:

3.4 **Regular Graduate Status**: A student who meets all admission requirements, may be admitted to Regular Graduate Status to undertake work leading to an advanced degree. Only students in Regular Graduate Status can be awarded a graduate degree.

3.5 Admission with Deficiencies: When previous academic work has not met the general requirements for a B. S. degree in Civil Engineering at The University of Arizona, up to sixteen (16) undergraduate semester units may be required. This coursework may be completed after admission to a graduate program but no graduate credit will be earned for this work. Deficiencies will be included in the letter of acceptance. Following removal of deficiencies, the student is automatically transferred to regular student status. The minimum coursework requirements for each of the general areas are listed in Appendix 2.

3.6 Provisional Admission: Provisional admission indicates some reservations with regard to the applicant's qualifications to undertake graduate work leading to an advanced degree. If admitted provisionally, a student can request regular graduate standing upon completion of nine (9) credit hours of graduate coursework in CEEM. To be granted regular status, the student must meet any other requirements established by CEEM and earn a graduate grade point average of 3.25 or better for admission to the M.S. program and a 3.5 or better for admission to the Ph.D. program. Students on Provisional Status who wish to be admitted to Regular Graduate Status are responsible for submitting a "Provisional to Regular Graduate

Status Request", a form which is available at the following link: http://grad.arizona.edu/nidforms/index_prov_pdf.php

3.7 International Special Status: International students, not qualified for regular graduate status, may be admitted initially to International Special Status. The student may enroll in this status for up to two academic semesters, with the understanding that they may be required to complete a number of units without earning graduate credit, to make up deficiencies. Students admitted to this status must enroll as a full-time graduate student, taking a minimum of nine (9) units of credit per semester. When the time comes it is the responsibility of the student to initiate the paperwork requesting conversion to Regular Graduate Status. The Graduate College and CEEM will evaluate the student's progress at each conclusion of the student's semester in residence. Subject to satisfying the GPA requirement of 3.25 and 3.5 for M.S. and Ph.D., respectively, in The University of Arizona graduate coursework and other defined requirements, CEEM will recommend a change to Regular Graduate Status. The student can receive graduate credit for all graduate courses taken during the one semester immediately preceding the award of Regular Graduate Status. If CEEM does not recommend a change to Regular Graduate Status after the second semester, the student will be removed from the degree program.

3.8 "Subject to" Admission: A student who is admitted pending completion of Graduate College requirements (as in the case of a student who applies for Fall admission while completing a bachelor's degree the previous spring) must submit the required documentation within 30 days from the beginning of the first term of enrollment to the Graduate Admissions Office.

3.9 Graduate Non-Degree Admission: Individuals holding a bachelor's degree, or its equivalent, from a college or university which grants degrees recognized by The University of Arizona, may enroll in graduate-level courses without being admitted to a graduate degree program. Such students may enroll in graduate-level coursework as their qualifications and performance permit. Up to twelve (12) units of graduate credit, earned in non-degree status and/or transferred from other institutions, may be petitioned for application toward an advanced degree once the student obtains regular admission to a degree program. A maximum six

(6) of those units may be transferred from other institutions for an M.S. program. Applicants who do not meet the minimum required cumulative grade-point average of 3.00, for admission to a graduate degree program, may enroll in Graduate Non-Degree Status. Applicants may apply for admission to CEEM after completing twelve (12) consecutive semester units of grade (A, B, C) in 500 level or higher coursework with a minimum grade-point average of 3.25.

3.10 Removal of Deficiencies

For Admission with Deficiencies (See article 3.3.2), all of the deficiencies will be clearly identified in the admission letter. Deficiencies must be removed by receiving credit for courses specified by CEEM at admittance. Such credit will usually be earned by taking the specified courses for a letter grade, although under limited circumstances the department will accept credit by examination, or successful completion of the highest-level course of a multiple course sequence as evidence of competence in the other courses in that sequence. In every case, however, a written statement outlining the plan for removing deficiencies, prepared by the student and approved by the student's Academic Advisor, must be submitted to and reviewed by the CEEM Graduate Studies Committee and approved by the Department Head. All deficiencies must be satisfied by the second semester in residence for an M.S. student and by the third semester in residence for a Ph.D. student.

If a student disagrees with the written statement of deficiencies given at the time of admission, he/she should review it with their Academic Advisor and submit a revised statement of deficiencies for approval. The student may be required to take an examination in a disputed subject.

4.0 APPLICATION MATERIALS

Application must be made on forms furnished by the Graduate College. Application packets are available by applying online (http://grad.arizona.edu/Prospective_Students/Apply_Now/), e-mailing the Graduate College (gradadm@grad.arizona.edu), or by phone at (520) 621-7816. Electronic submission is highly encouraged. Applicants should also contact CEEM to obtain program application requirements and materials: Department of Civil Engineering and Engineering Mechanics, P.O. Box 210072, Tucson, AZ, 85721-0072. The CEEM

Department can be reached at (520) 621-2266 (phone), (520) 621-2550 (fax) and by e-mail: ceem@arizona.edu. The department's website is http://web.arizona.edu/~civil.

5.0 FINANCIAL SUPPORT IN THE CEEM DEPARTMENT

Financial support is available in a number of forms. *Research Assistantships (RAs)* are provided by individual faculty member's research grants. These faculty members are responsible for identifying students to work on these projects. In addition, a limited number of *Teaching Assistantships (TAs)* are available to qualified students. Faculty members provide recommendations to the Department Head for these positions. In order to be a teaching assistant, international graduate students must take the SPEAK portion of the TOEFL exam and have a passing score of 230, in addition to completing the TA training class. Finally, *hourly grader positions* are often available at rates below assistantships.

Graduate fellowships that do not have specific responsibilities attached may also be available to exceptional students. CEEM is allocated some graduate tuition (GTS) and registration (GRS) stipends. A GTS serves to waive the out-of-state portion of tuition and a GRS waives both the in-state and out-of-state fees. These stipends are distributed on a competitive basis. A GTS comes automatically for an RA or TA with at least a 1/4-time appointment.

5.1 Tax Information

Students should be aware of current tax laws that may impact salaries or stipends received from graduate teaching/research assistantships, fellowships, and stipends. Contact the Graduate College, Administration Building, Room 322, for additional information, or the IRS at (800) 829-1040 and ask for the Scholarship/Fellowship publication.

6.0 GENERAL ADMINISTRATION OF THE GRADUATE PROGRAM

6.1 Academic Advisor

The Head of the Department will designate a faculty member to serve as an interim Academic Advisor. A permanent Academic Advisor must be chosen by the beginning of the second semester of study. The student is encouraged to talk to faculty in his/her area of study before selecting an Academic Advisor. After the advisor has been selected, the Advisor Selection Form (available in the CEEM Office, see Appendix 3) must be completed. This form is retained in the student's file. A

new form must be filed before the Department Head approves a change of advisor.

It is the student's responsibility to arrange an early appointment with the Academic Advisor to organize a tentative study program. The student and Academic Advisor should also review the proposed study program and discuss the selection of a research topic for the degree.

The student should meet with his/her Academic Advisor frequently, but at least twice per semester to discuss research plans, progress in coursework, etc. More frequent meetings should be planned as the student progresses in the research. It is the student's responsibility to arrange these meetings. The primary role of the Academic Advisor is to guide the student in coursework and research and to keep the student informed on whether he/she is making satisfactory progress. If the student disagrees with a decision or course of action recommended by the Academic Advisor, he/she can appeal the decision. The appeal procedure is as described in the Academic Appeal Policy (Section 8.0).

A student for good reason may choose a new Academic Advisor. Both the old and the new Academic Advisors and the Student's Advisory Committee must agree to the change, with at most one dissenting vote. Unacceptable decisions can be appealed using the procedure described in the Academic Appeal Policy (Section 8.0).

6.2 Registration

Registration is accomplished using WebReg, the University's web-based course registration program, available online through The University of Arizona Student Link program. Detailed information including dates and times to call will be published in the Schedule of Classes for each semester and for summer terms. Registration for the first semester in residence should be completed after meeting with an Academic Advisor.

6.3 Registration Requirements/Supplementary Registration

Each student, who is associated with The University of Arizona in any capacity, utilizes University facilities or faculty time during any academic semester must be registered for at least three (3) units of graduate credit. No summer enrollment is required to maintain continuous status with The University of Arizona. Nine (9) units

of graduate coursework or research are considered full-time enrollment for residency requirement purposes. The maximum registration for fall and spring is sixteen (16) graduate units and six (6) graduate units for each summer session.

All graduate students in the College of Engineering, who are supported by or through The University of Arizona, are expected to officially enroll in some combination of coursework, research, or independent study that results in at least twelve (12) units of credit each semester. The only exception to this rule is that 1/2 time Graduate Teaching Assistants are expected to officially enroll in at least nine (9) units of credit each semester. Only 500, 600 and 900 level courses count toward the minimum enrollment required by The University of Arizona for assistantships, taking oral examination, etc. 400 level courses will count toward the College enrollment requirements.

Each student completing requirements for an advanced degree must be registered during the semester or summer term in which the final exam is completed, or the previous semester if requirements are completed during an intercession. This includes any semester during which a preliminary or final examination is scheduled. Students who have completed all the degree course requirements and still must register should enroll for M.S. Report CE 909 for the non-thesis option, CE 910 for thesis and CE 920 for dissertation. Such registration may be used to reach the three (3) unit minimum enrollment requirement for academic semesters and the one (1) unit minimum for summer sessions for the final semester.

6.4 Leave of Absence Policy

The status, Graduate Student Leave of Absence, may be approved for up to two consecutive semesters for graduate degree program students for extraordinary situations. Graduate students that do not return at the end of the approved leave of absence or students that miss a semester without being granted official leave of absence are required to apply for readmission and are subject to all rules and regulations in force. The right to use University facilities is suspended while the leave of absence is in effect. Leave of Absence forms may be obtained at the Graduate College Degree Certification, Administration 316 or the CEEM Office. The form must be returned to Graduate Degree Certification no later than the last day for adding classes via WebReg for the semester the leave of absence is to start. No

retroactive Leave of Absences will be accepted.

7.0 COURSE OFFERINGS

To assist students in developing their study plans, CEEM has developed and will continue to update a *5-year* plan for graduate course offerings (i.e., those numbered 500 and above). The most recent plan is included in Appendix 4.

7.1 Dual Numbered Courses

The University of Arizona has adopted a dual numbering system. Some courses have only a 400 level number (4xx). These courses are NOT available for graduate credit, except for a maximum of six (6) units in the minor as discussed in the Ph.D. degree requirements section. Other 400 level numbered courses may be taken as deficiency courses when appropriate, but will not receive graduate credit or be included in the graduate GPA.

Courses, which are dual numbered (4xx/5xx), will normally meet at the same time in the same room, and there will be substantial additional requirements for graduate students as identified in the catalog and the course syllabus. CEEM graduate students must enroll in the 5xx version of all dual numbered courses whether they are in the major or not.

The existence of a number pair (e.g. CE 676/CHEE 676) does NOT imply that this is a dual numbered course. You should check the titles for verification. Dual numbered courses will have identical course titles for both numbers. The catalog description for each will also include a reference to the dual course.

7.2 Seminar

The CEEM Department requires that full-time M.S. and Ph.D. students take the CE596a Seminar every semester, the seminar schedules are posted on the CEEM Bulletin Board. The purpose of these seminars is for the faculty and students to gain knowledge in the different research areas of civil engineering. One (1) unit of credit will be applied to the graduate program for all semesters enrolled in Seminar for an M.S. student. Ph.D. students will be granted one (1) unit of credit if the student has taken Seminar one to four times and one additional unit if he/she takes the course five or more times.

7.3 Manual for Theses and Dissertations

A manual describing proper format for thesis and dissertations is available in the textbook department of the ASUA Bookstore, or online (http://grad.arizona.edu/PDF/ETD_Diss_Manual.pdf). Each student should read this manual before attempting to prepare a thesis or dissertation and discuss the proper format with his/her Academic Advisor.

7.4 Use of Copyrighted Material In Theses And Dissertations

The use of copyrighted materials in a thesis, dissertation or document requires formal permission. Any exceptions, sometimes pertaining to small fractions of a musical score or other documents, are governed by the concept of "fair use". Here, the following factors must be weighed: purpose and character of the use, including whether such use is of a commercial nature or is for non-profit educational purposes; the nature of the copyrighted work as a whole; and the effect of the use upon the potential market for or value of the copyrighted work. According to the Association of American University Presses, permission is required for quotations of sections of books, maps, charts, graphs, tables, drawings, or other illustrative materials. If there is any doubt the student should obtain permission.

Permission to use copyrighted material should be in writing and retained by the author with a copy being submitted to the CEEM Department for retention in the student's records. The release letters should indicate that permission extends to Internet use, microfilming and publication by University Microfilms International (UMI) and the copyright owners are aware that UMI may sell, on demand, single copies of the thesis, dissertation or document, and other materials, for scholarly purposes.

The process of obtaining permission to use copyrighted material may be both time-consuming and expensive and should be initiated as early as possible during the conduct of the thesis, dissertation or document. It is good practice to obtain permission to use non-copyrighted material, which may or may not be acknowledged in the text (note phraseology in Statement by Author required for any thesis, dissertation or document).

Additional information about copyrighted material may be obtained from the Copyright Public Information Office (http://copyright.gov/) in Washington, DC at (202) 479-0700, weekdays between 8:30 a.m. and 5 p.m. (Eastern Time Zone).

8.0 ACADEMIC APPEAL POLICY

It is recognized that the varied backgrounds, objectives, and needs of students may occasionally require interpretation of these guidelines. Under these circumstances, the Student's Advisory Committee may recommend limited adjustments in the requirements. The Student's Advisory Committee must recommend any changes in writing to the Graduate Studies Committee that makes the final judgment. There must be no more than one dissenting vote.

If there is disagreement with any interpretation made by the Academic Advisor, the appeal process is as follows: the Student's Advisory Committee may review an advisor's decision and adjudicate the disagreement with a maximum of one dissenting vote. If this committee's decision is found unacceptable, the matter is then referred to the CEEM Graduate Studies Committee for a final decision. All appeals and approvals must be given in writing.

9.0 SUPPLEMENTAL INFORMATION

Additional information regarding Graduate College and University regulations, Student Services, phone directories, and the Code of Academic Integrity are included in the Supplementary Material to this document.

10.0 MASTER OF SCIENCE (MS) DEGREE IN CIVIL ENGINEERING AND ENGINEERING MECHANICS

This section summarizes the requirements and steps for completing a master's degree. The requirements for Master's Degrees on the Graduate College website (http://grad.arizona.edu/Current_Students/Program_Requirements/) provides additional details. The table at the end of this section supplies completion deadlines for various steps in the Master's program.

10.1 Entrance Requirements

1. B.S. degree from recognized undergraduate school (see the graduate catalog for details);
2. Ordinarily GPA > 3.0 for last sixty (60) undergraduate units;
3. Competitive GRE score;
4. TOEFL score > 550 (or > 213 in the computer-based test) if native language is not English, for further details refer to the Graduate College website: http://grad.arizona.edu/Prospective_Students/Admissions_Requirements/Proficiency_in_English.php
5. Three letters of recommendation; and
6. Statement of Purpose.

10.2 Credit Requirements

An M.S. program contains a minimum of thirty (30) units. Each student must take the Graduate Seminar course every semester. Each student must write a master's thesis or master's report and pass a final oral examination. Regardless of the number of semesters enrolled in the Graduate Seminar, a student will only receive one (1) unit of credit for the course toward their degree requirement.

There are two M.S. program options:

Plan A (thesis option)

Coursework: Twenty-four (24) units, all are 5xx or 6xx level courses and six (6) thesis units (CE/EM 910). The final examination is an oral defense of the thesis.

Plan B (non-thesis option)

Coursework: Twenty-seven (27) units of 5xx or 6xx level courses and three (3) units for a written engineering report (CE/EM 909). M.S. non-thesis option must complete

three (3) units of CE/EM 909. The final examination is an oral defense of the project.

All coursework must be in courses graded A, B or C except for one independent study course. To complete degree requirements, the cumulative GPA in graduate level courses must be 3.0. A student whose GPA falls below 3.0 will not be permitted to register for additional courses (see Graduate College Policies online at http://grad.arizona.edu/Catalog/Policies/).

10.3 Residence Requirements

A minimum of twelve (12) units of coursework must be completed in residence at The University of Arizona.

10.4 Time Limitation

All requirements for the master's degree must be completed within six (6) years. Time-to-degree begins with the earliest course to be applied toward the degree, including credits transferred from other institutions. Work more than six (6) years old is not accepted toward meeting degree requirements.

10.5 Transfer Credit

Up to six (6) units for a master's degree may be transferred from other accredited institutions. To transfer, the coursework must have been taken for graduate credit and an A or B grade must have been earned. These grades will not be included in the student's GPA.

10.6 Master's Plan of Study Form

Each student, in consultation with his/her Academic Advisor and Master's Advisory Committee (Section 10.7), will select a program of study for the degree by the second semester in residence. The CEEM Graduate Studies Committee must approve the program of study prior to submission to the Graduate College.

Students choosing the M.S. thesis option must complete six (6) units of CE 910 (thesis). Students may obtain a Plan of Study Form in the Department Office or at the Graduate College Degree Certification Office. To assist in planning a program of study, the department maintains a continuously updated schedule of graduate

courses to be offered over a *5-year* span. The schedule is available in the CEEM Department Office and is included in the Supplementary Material section in Appendix 3. Students choosing the M.S. non-thesis option must complete three (3) units of CE/EM 909.

10.7 Academic Advisor

The Head of the Department will designate a faculty member to serve as an interim Academic Advisor. A permanent Academic Advisor must be chosen by the end of the first semester of study. After the Academic Advisor has been selected, the Advisor Selection Form (Appendix 3) must be filled out. The Academic Advisor will act as the student's mentor who will be responsible for helping the student in selecting Masters Advisory Committee members, as well as developing and completing a Plan of Study. The primary role of the Academic Advisor is to guide the student in coursework and to keep the student informed on whether he/she is making satisfactory progress.

10.8 M.S. Advisory Committee Members

The Master's Advisory Committee consists of the Academic Advisor, who must be a tenure-track CEEM faculty member, and at least two additional members. At least one of the two additional members must be tenure-track faculty at the rank of Assistant Professor or higher, and holds a faculty appointment in CEEM. One of the two additional members can be from another academic unit within the University or someone from outside the University. The latter is called a Special Member. A Special Member form (http://grad.arizona.edu/Degree_Certification_Forms/SpecialMemberForm.pdf) must be completed and submitted to the Graduate College. The student's Academic Advisor must approve the Master's Advisory Committee members.

The Master's Advisory Committee must approve the program of study, the master's thesis/report and participates in the final oral examination for the master's degree.

10.9 Final Oral Examination

Scheduling of the final oral examination and the satisfaction of all requirements relating to this examination are the sole responsibility of the student. The final oral examination must be scheduled through the CEEM office after the thesis/project

report has been reviewed by the examining committee (i.e., the Masters Advisory Committee), provided that the student has completed his/her coursework or is in his/her final semester. The examination is scheduled in consultation with the examining committee members. Each of the examiners for the final oral examination must receive a copy of the thesis/project report approved by the student's Academic Advisor (not necessarily library-ready copies) at least two weeks prior to the oral examination.

The examination will last up to two hours and is composed of two parts. In the first part (about 30 minutes), the student gives an oral presentation of the thesis/project report. The presentation may be interrupted to permit questions to clarify points and questions concerning fundamental principles that are directly related to the thesis/project report. The second part of the examination consists of questioning the student on graduate courses, particularly as they relate to the thesis/project.

If the student is interested in pursuing a Ph.D. degree, the final oral M.S. examination may also serve as the Ph.D. qualifying examination for CEEM. The committee should be informed if the student desires to follow this option when scheduling the examination. The second part of the examination would then be more detailed in terms of coursework and basic principles. Prior to beginning questioning for the qualifying examination, a student may decide not to continue the Ph.D. qualifying examination component and defer it until after he/she enters the Ph.D. program. The examination may last over two hours but cannot be more than three hours.

The results of the examination are reported to the Graduate College on a standard form that is included in the student's file at the time of the examination. Results must be reported to the Graduate College at least three weeks before the date on which the degree is to be conferred; specific deadlines from the Graduate College are posted online: http://grad.arizona.edu/Current_Students/Deadlines/.

Following a successful defense, the candidate submits a copy of the thesis/report to the departmental office to have the format reviewed. After the required corrections, the candidate then submits the approved thesis/report in electronic format to the Graduate College. For further details, check the Dissertation/Thesis Submission

website: http://dissertations.umi.com/arizona/. The thesis/report must be submitted in PDF format on a readable CD to the CEEM department's office. The candidate's Academic Advisor and Master's Advisory Committee may require copies of the thesis/report as well, either in electronic format, hardbound and/or loose pages. Check with your Academic Advisor for any special requirements.

In the event of a failure, the examining committee will determine what the student must do before a second examination may be scheduled. Upon recommendation of the Examining Committee, the Department Head, and approval by the Graduate Council to the University, a second examination will be granted after a lapse of at least four months. The second examination must be scheduled through the Graduate College at least three weeks in advance of the date of the examination. The examining committee must be the same as for the first examination, except that a representative of the University Committee on Graduate Study will preside. The results of the second examination are final.

10.10 Thesis Work In Absentia

Students are discouraged from doing thesis work in absentia. They should consult with their advisor before doing so.

10.11 Minors in Civil Engineering and Engineering Mechanics

Master's students from other departments who wish to minor in Civil Engineering and Engineering Mechanics must complete at least six (6) units of 4xx numbered courses or higher. The minor advisor must approve course selection.

10.12 STEPS IN COMPLETING M.S. DEGREE

A summary of steps to completing a M.S. degree is listed in Appendix 5.

11.0 MASTER OF ENGINEERING DEGREE IN CIVIL ENGINEERING AND ENGINEERING MECHANICS

The M.E. degree programs for the Hydraulics and Water Resources engineering program and the Transportation engineering program have been implemented, while other areas are in varying stages of development. For additional information contact CEEM or visit the Tri-University Master of Engineering Partnership website: http://www.oneflexibledegree.com.

12.0 DOCTORAL PROGRAM IN CIVIL ENGINEERING AND ENGINEERING MECHANICS

Attainment of a Doctor of Philosophy (Ph.D.) degree at The University of Arizona requires outstanding scholarship and demonstration of distinguished research leading to a dissertation that contributes significantly to the general pool of knowledge in the discipline. This section describes the requirements for completion of the Ph.D. degree within the Department of CEEM. A general timetable for completion is given at the end of the section.

12.1 Entrance Requirements

1. M.S. Degree from an approved institution (see Graduate College Admission handbook for institution description);
2. Graduate GPA > 3.5;
3. Competitive GRE scores;
4. TOEFL score > 550 (or > 213 for computer-based tests) if native language is not English. (See Graduate College website for further details: http://grad.arizona.edu/Prospective_Students/Admissions_Requirements/Proficiency_in_English.php);
5. Three letters of recommendation; and
6. Statement of purpose.

12.2 Academic Advisor

The Head of the Department will designate a faculty member to serve as an interim Academic Advisor. The primary role of the Academic Advisor is to guide the student in coursework and to keep the student informed on whether he/she is making satisfactory progress. The Academic Advisor will act as the student's mentor and will be responsible for helping the student select Masters Advisory Committee members, as well as developing and completing a Plan of Study. A permanent Academic Advisor must be chosen by the end of the first semester of study. Once the Academic Advisor has been selected, the Advisor Selection Form (Appendix 3) must be filled out.

12.3 Doctoral Advisory Committee

The Doctoral Advisory Committee consists of at least three faculty members who represent the major subject area and one or more faculty members who represent the minor subject area. The Doctoral Advisory Committee participates in administration

and evaluation of the student's Qualifying Examination, approves the Doctoral Degree Study Program and constitutes the examining committee for the Comprehensive Examination and the Final Oral Examination for the defense of the doctoral dissertation. Since the Doctoral Advisory Committee plays such a central role in the doctoral program, it should be formed as soon as possible. Any tenured or tenure track person may serve on the Doctoral Advisory Committee upon approval by the student's academic advisor and the Heads of the major and minor departments. A Special Member Form must be completed and submitted to the Graduate College for Doctoral Advisory Committee members who are non-tenured or are outside of The University of Arizona. The form is available on the Graduate College website at: http://grad.arizona.edu/Degree_Certification_Forms/SpecialMemberForm.pdf. All committee members are expected to be present and participate in the Comprehensive and Final Oral Examinations. Minor subject area members cannot waive attendance at these examinations.

12.4 Credit Requirements

For a Ph.D. in Civil Engineering or Engineering Mechanics, the minimum total units required including the dissertation is seventy-two (72). A minimum of fifty-four (54) units of graduate coursework exclusive of the dissertation must be completed. This includes:

1. A Minimum of nine (9) units in the minor subject and a minimum of thirty-six (36) units in the major subject**.**
2. A maximum of six (6) units may be taken as Independent Study units. The student's Academic Advisor must approve independent study courses.
3. Eighteen (18) units of dissertation must be completed.
4. At least a one (1) unit Graduate Seminar course.

Master's thesis credit is not counted in the Ph.D. program. All required units of credit must be at the 500-level or above at The University of Arizona or, in the case of transfer units, their equivalent at other institutions.

Graduate credit earned at other approved institutions, if accepted by the major department and the Graduate College, may be counted toward the requirements of this degree. Students who wish to use transfer credit must submit a request (http://grad.arizona.edu/Degree_Certification_Forms/TransferCreditForm.pdf) before the

end of their first year of study to the Graduate College. Six (6) units of 400-level credit taken at The University of Arizona may be used in the minor but these units will not receive graduate credit or be calculated in the graduate grade-point average. At least one-half of the graduate credit must be in courses in which regular grades (A, B, C) have been earned. Credit for correspondence courses or extension work obtained at other institutions will not be accepted for graduate credit. As for The University of Arizona courses, repeated courses, even those taken at other institutions, are not allowed for credit in the graduate program. Verification of courses is the responsibility of the Doctoral Advisory Committee and must be approved by the CEEM Graduate Studies Committee.

12.5 Residence Requirements

To meet the minimum Graduate College residence requirement, the student must spend two regular semesters of full-time work in residence, and at least thirty (30) units of graduate credit must be completed at the University of Arizona. Any semester during which a doctoral student in actual residence at The University of Arizona is registered for at least nine (9) units of graduate coursework or research will be counted toward meeting the residence requirement.

12.6 Minor Subjects

The minor subject area may be taken within or outside of the Department of Civil Engineering and Engineering Mechanics. The student may choose one or two minor areas, which are determined in consultation with his/her Academic Advisor. The department in which the minor is sought determines specific requirements. The minimum number of minor coursework is nine (9) units, but most minor programs require twelve (12) units of coursework. A minor in Civil Engineering or Engineering Mechanics requires twelve (12) units.

The Graduate College will permit up to six (6) units of credit on a graduate degree program outside of the major department at the 400 level, subject to the following rules:

1. If a student has a GPA below 3.0 on the 500-level coursework on the study program he/she will not be permitted to register for additional courses. The student may be allowed with approval from his/her academic advisor to add

coursework at the 500 level to bring the GPA up to 3.0 and file a revised program of study; 400 level course grades will not be included in the graduate GPA or added to the total earned hours.

2. Doctoral students, who have split minors, may NOT use six (6) 400 level units in each part of the minor.

12.7 Time Limitation

Students must complete their degree within five years of passing the Comprehensive Examination. A student not finishing within that time period may be allowed to re-take the Comprehensive Examination with permission of the Doctoral Advisory Committee.

12.8 Foreign Language Requirements

No Foreign Language requirement exists for the doctoral degree in the Department of Civil Engineering and Engineering Mechanics.

12.9 Qualifying Examination

Each prospective candidate for a doctoral degree must pass a qualifying examination in the proposed major field. The only exception is an M.S. graduate from The University of Arizona, Department of Civil Engineering and Engineering Mechanics who, elected to take and have passed the qualifying examination as part of his/her M.S. final defense. The qualifying examination is recommended to be taken during the first semester of residency but must be taken by the end of the second semester. In any case, the qualifying examination must be taken during the first year of residency. The in-class portion of this examination is given twice a year, **once on the last Saturday in November, and once on the last Saturday in March**. Any take-home exams must be taken before those dates.

Each semester, one faculty in each area will be assigned as coordinator for the qualifying exam in his area. Students should contact that faculty early in the semester when he/she intends to take the exam. In some specializations, the student has the option to select one or more topic area(s) to be tested on. In these cases, the student will select the topics with guidance from his/her Academic Advisor. If necessary, input should be sought from the Advisory Committee. If the examination is a mixed take-home/in-class format, the student must schedule timing

of the take-home portion.

Questions may involve elements of general civil engineering and engineering mechanics knowledge. Requirements for a qualifying examination will depend on the student's area of interest, i.e. Engineering Mechanics, Geomechanics/Geotechnical, Highways and Transportation, Hydraulics and Water Resources, and Structures. A list of topics to be covered in the examination and a listing of suggested reference books can be found in Appendix 7.

Implicit in acceptance to the graduate program is the assumption that the student is knowledgeable in the undergraduate areas that pertain to the graduate work. The Qualifying Examination focuses on graduate studies taken for the Master's degree, but may include questions from undergraduate studies. The student is fully responsible for knowledge from the undergraduate areas that are pertinent to answering questions on the Qualifying Examination. At the discretion of the examiner(s) questions may be closed book or open book. In addition, open-ended questions may be asked. The faculty member in charge of the examination for a given topic shall provide the students with details of the extent of the material on the examination.

Within six weeks of the examination, the Department Head will notify the student of the examination results and provide a copy to the Academic Advisor. In the event of a failure, only a second qualifying examination will be granted. Third qualifying examinations are not allowed. Refer to Appendix 7 for further details.

12.10 Plan of Study

In conjunction with the Academic Advisor, with input from the results of the qualifying exam, each student is responsible for developing a Plan of Study during their first year in residence. The Plan is to be filed with the Graduate College no later than the student's third semester in residence. The Plan of Study identifies:

1. Courses the student intends to transfer from other institutions;
2. Courses already completed at The University of Arizona which the student intends to apply toward the graduate degree; and
3. Additional coursework to be completed in order to fulfill degree requirements.

The Plan of Study must have the approval of the student's Academic Advisor, the Graduate Curriculum Studies Committee, and the department head before it is submitted to the Graduate College. The plan of study, which includes courses in the minor as well as the major area, must be filed in the Graduate College no later than two months before the oral preliminary examination.

12.11 Preliminary or Comprehensive Examination

Admission to graduate study does not imply admission to candidacy for an advanced degree. Before admission to degree candidacy, the student must pass a general examination in the chosen fields of study. This examination is intended to test the student's comprehensive knowledge of the major and minor subjects of study, both in breadth across the general field of study, and in depth within the area of specialization. The examination is composed of two parts:

1. A written portion covering the major field, and
2. An oral portion, which is to be conducted before the Doctoral Advisory Committee members. The oral portion must be taken no earlier than two weeks or later than six months after successful completion of the written portion.

The written and oral portions of the Comprehensive Examinations are to take place within two successive semesters, not including summer sessions. Students must pass the written examination and results must be reported to the Graduate Degree Certification Office before the oral examination is held. Deadlines for the submission of paperwork pertaining to the Oral Comprehensive Examination are available in the Graduate Degree Certification Office. The Comprehensive Examination is to be held when essentially all coursework has been completed, research proposal has been accepted by the faculty members in the major area, and no later than three months prior to the date of the Final Oral Defense Examination.

No later than four weeks before the Comprehensive Examination, the student must contact the Department of Civil Engineering and Engineering Mechanics office to fill out the Application for Oral Comprehensive Examination Form. It will be the responsibility of the student to schedule the day, time and place for the examination, in consultation with his/her committee and Academic Advisor.

Based on the student's combined performance in the written and oral portions, the examining committee awards a grade of pass or fail. In the event of a failure the student may be permitted a second attempt to pass the examination, but only if recommended by the examining committee. The second attempt is permitted only after the lapse of four months, third attempts are not allowed.

12.12 Structure of Comprehensive Examination

Major Area – Written Area

The written portion for the Department of Civil Engineering and Engineering Mechanics Major Area is a properly prepared technical document that describes the proposed Ph.D. research. The document, called the Proposal, is of central importance to the Comprehensive Examination. The purpose of the Proposal is to indicate, not only the academic preparation of the student, but also his ability to carry out original, creative research and to communicate this effectively in a professional manner. Although guidance from the Academic Advisor is permitted, the Proposal must essentially be an independent creation by the student.

The Proposal may be based on discussions between the student and his/her Academic Advisor, appropriate references, independent research, and other materials such as books, coursework, or input from faculty. All second-hand information must be clearly referenced, and the wording must be that of the student.

Minor Area - Written Area

The written portion in the minor area is scheduled in the department(s) of the Minor Area(s). Scheduling this examination is the responsibility of the student.

Major and Minor Areas - Oral Portion

The written portions of the examinations must be passed before scheduling the oral portion. The oral portion must last a minimum of two hours but no more than three hours. The Graduate College representative will preside. During questioning only members of the examining committee may be present.

The oral examination begins with a 30-minute presentation (which may include visual aids) by the student of his/her proposed research. Members of the examining committee may interrupt the presentation with pertinent questions. When such

interruptions occur, an appropriate increase in the time allowed for the presentation will be made. The student's presentation is followed by questions on the proposed research and related areas. The presentation and related questioning usually takes about one hour. For the remainder of the examination the student is asked to respond to questions on pertinent coursework and fundamentals relating to the student's research.

12.13 Advancement to Candidacy

When the student has an approved Doctoral Plan of Study on file, has satisfied all coursework, residence requirements, and passed the written and oral portions of the Comprehensive Examination, he/she must file an Application to Advance to Candidacy. This Application must be submitted to the Graduate Degree Certification Office no later than six months before the Final Oral Defense Examination is scheduled. The student must identify all Doctoral Advisory Committee members on the application form. To obtain a copy of the application form, refer to the following link: http://grad.arizona.edu/Current_Students/Program_Requirements/Advancement_to_Candidacy.php.

12.14 Dissertation

A candidate for the degree of Doctor of Philosophy must demonstrate the ability to devise and execute a program of study and research, which makes a fundamentally new contribution to the chosen field. The Department of Civil Engineering and Engineering Mechanics requires the completion of a dissertation that meets required standards of scholarship and demonstrates the candidate's ability to conduct original research. The most important aspect of the doctoral program is the dissertation, which is the evidence of this fundamental contribution.

A collection of facts and information, no matter how carefully organized or described does not, by itself, constitute a Ph.D. dissertation. A Ph.D. dissertation will often make use of the contributions from a faculty member or others, but it should be clear about the creative contributions that the doctoral candidate has made.

The Ph.D. dissertation must present:

1. The development of new principles, theories, or techniques
2. The use of established principles, theories, or techniques in a new and/or unique manner; and/or

3. The use of available information and the discovery of new findings if it is described in terms of an original model or process.

It should also lead to at least one significant paper published in a peer-reviewed journal. As evidence that the above criterion has been met, it is strongly recommended that a draft of the paper should be submitted for publication before the completion of the doctoral program.

12.15 Format of Dissertation

Instructions relating to the format of the dissertation and required abstracts are included in the 'Manual for Theses and Dissertations', which is available in the Graduate Degree Certification Office and online: http://grad.arizona.edu/PDF/ETD_Diss_Manual.pdf.

12.16 Final Oral Defense Examination

The completed Request to Schedule the Final Oral Examination form must be filed with the Graduate College **no later than three (3) weeks prior to the proposed date** of the Final Examination and approximately five (5) weeks prior to the proposed date to the CEEM Office. Prior to filing the form, the examining committee members must have read the penultimate draft of the dissertation and have agreed to examine the student at a designated time and place.

The Final Oral Defense Examination focuses on the dissertation itself but can include general questioning related to the field(s) of study within the scope of the dissertation. The exact time and place of this examination shall be scheduled with the Graduate Degree Certification Office and announced publicly in *Lo Que Pasa* at least one (1) week in advance.

The examining committee is comprised of the Doctoral Advisory Committee. Except for an initial seminar portion during which the student presents the dissertation, the examination is closed to the public.

It is the responsibility of the Student's Academic Advisor to propose the membership of the oral examining committee to the CEEM Graduate Studies Committee and Department Head who then make a recommendation to the Graduate College, who

will make the final appointment. Usually the members of the student's Doctoral Advisory Committee are named to the oral examining committee. The Student's Academic Advisor and/or the minor department may request the addition of one or more representatives of the minor field to the committee.

12.17 Submission of the Dissertation

Following a successful defense, the candidate will be required to submit a copy of the dissertation to the CEEM Departmental office for a format check. After the necessary corrections, the candidate must submit the approved dissertation in electronic format to the Graduate College - for further instructions check the Dissertation/Thesis Submission site (http://dissertations.umi.com/arizona/). The dissertation must be submitted in PDF format to the CEEM department's office on a CD that the student can verify is readable. In addition, the candidate's dissertation advisor and Doctoral Advisory Committee may require copies of the dissertations in electronic format, hardbound and/or loose pages. Check with your Academic Advisor for any special requirements.

12.18 Minor in Civil Engineering or Engineering Mechanics

Twelve (12) units of approved coursework are required for a minor in Civil Engineering or in Engineering Mechanics. The minor Academic Advisor will coordinate the written portion with other faculty in the area. Usually, the two minor committee members test the student on coursework taken in the minor. Preliminary minor examinations will be given once a semester. The examination time will be announced at the beginning of each semester.

12.19 Steps in Completing the Ph.D. Program

A checklist for completing the steps to your degree is given in Appendix 6 in the Supplementary Material Section.

13.0 ADDITIONAL INFORMATION

A summary of the formal university requirements is included in Appendix 6. Additional information on the doctoral program, necessary forms and steps involved can be obtained online at:
http://grad.arizona.edu/Catalog/Program_Requirements/Doctor_of_Philosophy.php.

APPENDIX 1
Graduate Programs in CEEM

GRADUATE STUDY IN ENGINEERING MECHANICS

INTRODUCTION

The Engineering Mechanics program at The University of Arizona offers a broad spectrum of graduate study with emphasis on a wide range of topics in solid and structural mechanics, material modeling, laboratory mechanical and nondestructive testing and computational methods for linear and nonlinear, and static and dynamic problems. The program provides opportunities for course work and research involving a combination of theory, laboratory testing and applications. The student can plan a program of study, with the assistance of faculty advisors, according to his/her interest in basic theoretical work to practical applications. A variety of courses are available in the CEEM Department as well as in other related Departments; e.g., Aerospace and Mechanical Engineering, Applied Mathematics, and Mining and Geological Engineering.

The interdisciplinary nature of the program is covered and coordinated through the Engineering Mechanics, Geomechanics and Structural Mechanics Programs, and the Center for Material Modeling and Computational Mechanics. Faculty members from the CEEM as well as other Departments participate in these programs through teaching, research and professional activities.

LIST OF RESEARCH TOPICS

Areas of research in which you might become involved also cover a broad range of interesting and important subjects. Some of the recent research topics in engineering mechanics at The University of Arizona include:

- Development of constitutive models for accurate characterization of the mechanical response of solids and composites
- Behavior contacts (interfaces and joints)
- Laboratory determination of material parameters using mechanical and nondestructive testing
- Ultrasonic NDE for Crack Detection in pipes and plates
- Probabilistic and stochastic methods in structural mechanics
- Efficient and robust algorithm for integration with advanced constitutive models, and time integration for dynamic and field problems
- Adaptive mesh refinement, pre- and post-processors including graphics for finite element programs
- Elastic wave propagation in solids
- Static and dynamic response of cracks in composites and homogenous solids
- Stability of structural systems
- Flow and mass transport through soils
- Fracture mechanics and biomechanics
- Parallel processing for problems in mechanics
- Design and reliability in electronic packaging
- Wavelet analysis for multiscale modeling

GRADUATE COURSE OFFERINGS

A list of courses under this program in the Department of Civil Engineering and Engineering Mechanics and other

departments is given below.

Detailed descriptions of the requirements for these degrees, together with a list of course offerings, can be obtained by writing to:

Head, Department of Civil Engineering and Engineering Mechanics
University of Arizona
P.O. Box 210072
Tucson, Arizona 85721, USA

Related Graduate Course Offerings

Civil Engineering and Engineering Mechanics

CE/EM 402/502 Introduction to Finite Element Method
EM 508 Fracture Mechanics
EM 603 Theory of Elasticity and Applications
EM 604 Theory of Plasticity and Applications
CE/EM 606 Elastic Wave Propagation
EM 633 Structural Dynamics and Earthquake Engineering
EM 639 Energy Methods in Engineering Mechanics
EM 648 Constitutive Laws for Engineering Materials

Aerospace and Mechanical Engineering

AME 430 Mechanical Vibrations
AME 436 Finite Element Methods of Structural Analysis
AME 438 Composite Materials
AME 535 Mechanics of Composite Materials
AME 539 Advanced Structural Mechanics
AME 541 Finite Element Analysis in Nonlinear Solid Mechanics
AME 564 Structural Dynamics

Mining and Geological Engineering

GEN 550 Earthquake Engineering
GEN 557 Fundamentals of Geomechanics
MnE 627 Fracture of Rock
MnE 629 Rock Slope Design

Mathematics

410 Matrix Analysis
421 Fourier Series and Orthogonal Functions
422 Advanced Analysis for Engineers
431 Calculus of Variations
456 Applied Partial Differential Equation
475 Mathematical Principles of Numerical Analysis
520 Complex Analysis
536 Calculus of Tensors and Exterior Differential Forms
553 Partial Differential Equations
568 Applied Stochastic Processes

FACILITIES

The principal research facilities available include the experimental mechanics and constitutive modeling laboratory, and the materials laboratory. The facility for testing of solids (geomaterials, concrete, composites, ceramics, space materials, etc.) and interfaces and joints include some of the most up-to-date and unique equipment. Excellent computer facilities are available including a satellite computer laboratory. A list of available equipment is given below.

Mechanical Testing Facilities

- Compression Testing Equipment (Uniaxial)
- MTS Triaxial Device: mechanical testing device equipped with a complete data acquisition system. It is servo-controlled and can be used for uniaxial and triaxial testing
- Truly Triaxial Device I: capacity of 250 psi normal stress on each of the six sides of cubical (4x4x4 inch) samples, used for testing low strength materials such as soils
- Truly Triaxial Device II: capacity of 20,000 psi normal stress on each of the six sides of cubical (4x4x4 inch)

samples, used for testing of high strength brittle materials such as rock, concrete
  - Cyclic Multi-Degree of Freedom Dynamic Shear Devices: for dynamic testing of interfaces and joints
  - Grinder: for rocks, concrete, metals
  - Thermomechanical/Digital image correlation devices for testing materials and joints in electronic packaging
  - Simple Shear Device

Non-Mechanical Test Facilities

- Ultrasonic Pulser-Receiver: state of the art (Panametrics) ultrasonic device for measurement of ultrasonic velocity and attenuation of a reference waveform.
- Acoustic Microscope: Piezoelectric transducer produces converging acoustic waves, which are used for crack detection and characterizing materials.
- EMAT (Electro Magnetic Acoustic Transducer) for pipe inspection
- High Temperature Furnace: box furnace for temperatures up to 1700C, for heat processing samples of different sizes and shapes. Non-atmospheric (Argon) environment can be created in the furnace.
- Vacuum Pump: mechanical-diffusion pump used to simulate lunar vacuum.
- Digital Vacuum Gage: Pirani vacuum gage with two sensors used to monitor the vacuum pressure.
- X-Ray Machine (to be assembled-donated by IBM)
- Profilometer for roughness measurements.

Structures Testing Facilities

- Two Hydraulic Actuators: capacity of 110 kips.
- Hydraulic Pump: capacity of 23 gallons per minute.
- Data Acquisition and Reduction System: capable of reading 70 strain gages and 20 Linear Variable Differential Transducers (LVDT's).
- Load Cells: capacities ranging from 5 to 200 kips, single and double action.

FACULTY

Civil Engineering and Engineering Mechanics

Muniram Budhu
(Ph.D., Cambridge University, P.E., Arizona, Florida) Professor--*Soil mechanics and foundation, soil dynamics, earthquake engineering, constitutive laws for materials, soil-structure interaction, piles, flow through porous materials, advanced materials testing and mechanics of granular materials.*

Chandrakant S. Desai
(Ph.D., University of Texas at Austin; P.E., Mississippi; Chartered Structural Engineer, UK) Regents' Professor, Director of Center for Material Modeling and Computational Mechanics--*Solid and geomechanics, structural dynamics, constitutive modeling, mechanical and nondestructive testing, flow and mass transport through porous media, computer methods, electronic packaging.*

George Frantziskonis
(Ph.D., University of Arizona) Associate Professor--*Mechanics, geomechanics, new materials, damage and fracture, instabilities, advanced material testing.*

Achintya Haldar
(Ph.D., University of Illinois; P.E., Arizona), Professor--*Risk-based design, random vibration, stochastic finite element, stochastic optimization, stochastic system identification, shape optimization, dynamics, earthquake*

engineering, nonlinear analysis, reliability-based inspection, maintenance and integrity assessment, steel structures, all aspects of damage.

Tribikram Kundu
(Ph.D., University of California, Los Angeles) Professor--*Elastic wave propagation, fracture mechanics, acoustics, ultrasonics and nondestructive testing, composites, computational mechanics.*

Hamid Saadatmanesh
(Ph.D., University of Maryland) Associate Professor -- *Advanced materials such as fiber composites for strengthening of existing structures, rehabilitation of infrastructure systems, space materials, and behavior of steel and concrete structures.*

Aerospace and Mechanical Engineering

B. Simon
Professor -- *Biomechanics*.

Mining and Geological Engineering

P. Kulatilake
Professor -- *Reliability and stochastic modeling, numerical modeling geological materials, joints, rock mass.*

J. Kemeny
Associate Professor--*Micro-mechanics.*

GRADUATE STUDY AND RESEARCH IN GEOMECHANICS/GEOTECHNICAL ENGINEERING

The Geomechanics/Geotechnical program in the Department of Civil Engineering and Engineering Mechanics at The University of Arizona includes such interdisciplinary areas as soil and rock mechanics, geoenvironmental engineering, use of traditional and new (smart) materials to control flow of water and contaminants in porous media, soil dynamics and geotechnical earthquake engineering, constitutive laws, material testing and modeling, and computer methods.

The main objective of the program is to provide an effective connection between the State-of-the-Art and the State-of-the-Practice. The program is designed to provide a balanced education in traditional subjects as well as advanced topics.

The graduate student may select from a wide variety of courses within the department as well as courses offered in other departments such as Mining Engineering, Hydrology and Water Resources, Aerospace and Mechanical Engineering, Mathematics, and Computer Science. The courses offered in the department are directed towards fundamentals and applications to practical problems. Our graduates are educated to do more than "Build With Confidence" – they will be able to "Predict the Performance of Advanced Geotechnical Systems."

RESEARCH PROGRAM

The Faculty in the Geomechanics/ Geotechnical group in the Department of Civil Engineering and Engineering Mechanics are actively involved in a wide range of Geomechanics/geotechnical engineering and interdisciplinary research activities. Graduate students invariably gain significant knowledge in new developments by participating in various innovative areas of research.

Most of these areas of research involve integration of theory, laboratory testing and field verification. The latter is achieved through collaboration with various private and government agencies. The laboratory testing programs are designed to calibrate and validate the theoretical analyses using either some of the existing unique devices developed by the faculty or constructing new ones.

Current areas of research include:

- Static and dynamic soil-structure interaction;
- Seismic response of geotechnical systems;
- Innovative procedures for assessing liquefaction;
- Computer analysis for geotechnical structures;
- Constitutive modeling and testing for geomaterials and interfaces or joints;
- Soil behavior and soil properties;
- Discontinuities such as joints, cracks, and interfaces in soil-structure interaction problems (piles, retaining walls, tunnels, mining support systems, buried and partially buried structures);
- Foundation systems including both shallow and deep foundations;
- Retaining walls;
- Model-based simulation of civil engineering systems;
- Mechanics of granular media;
- Enhanced bioremediation;
- Aerobic degradation of municipal solid waste;
- Permeabilities of soils due to leachate from landfills and hazardous waste sites;
- Traditional and new (smart) materials to control seepage of leachate from waste sites;
- Geosynthetics.
-

COURSE OFFERINGS

(Through CEEM)

CE 502	Introduction to Finite Elements
CE 540	Foundation Engineering
CE 541	Earth Structures
CE 545	Geoenvironmental Engineering
CE 547	Groundwater and Seepage
CE 548	Numerical Methods in Geotechnical Engineering
EM 603	Elasticity
EM 604	Plasticity
EM 605	Wave Propagation
EM 648	Constitutive Laws for Engr. Matls.

(Through Mining and Geological Engineering)

GEN 516	Field Studies in Geophysics
GEN 522	Well Logging Interpretation
GEN 524	Fundamentals of Geotechnics
GEN 525	Geotechnical Investigations
GEN 527	Geomechanics
GEN 529	Rock Slope Analyses and Design
GEN 537	Developments in Rock Mechanics
GEN 548	Geophysical Explorations
GEN 557	Applied Geomechanics
GEN 550	Earthquake Engineering
GEN 551	Probabilistic Methods
MnE 536	Subsurface Environmental Engr.

(Through Hydrology and Water Resources)

HWR 503	Subsurface Fluid Dynamics
HWR 522	Borehole Geophysics
HWR 531	Hydrogeology
HWR 566	Soil and Groundwater Remediation
HWR 584	Advanced Groundwater Modeling

(Through Chemical and Environmental Engineering)

CHEE 573	Biodegradation of Hazardous Organic Compounds
CHEE 574	Environmental Transport Processes
CHEE 578	Introduction to Hazardous Waste Management

FACILITIES

Laboratory

The department has excellent laboratory facilities for conventional soil tests and an array of unique and modern devices. Our traditional devices include triaxial, consolidation, direct shear, and soil identification apparatus. These devices have all been updated to add computerized data acquisition capabilities.

Our research equipment includes:

- Simple shear device for soils
- Rod shear device for evaluation of interfaces along single piles
- Simple shear/compaction device for asphaltic concrete and large aggregates
- Imaging and image processing
- MTS frame and accessories
- Cyclic Multi-degree-of-freedom shear (CYMDOF) device for translational, torsional, and rocking modes for testing interfaces and joints
- Multiaxial testing of cubical specimens including measurement of pore water pressures and nondestructive measurements
- Computer controlled cylindrical triaxial apparatus
- Multiaxial tension test apparatus for geosynthetics

FACULTY

Civil Engineering and Engineering Mechanics

Muniram Budhu
(Ph.D., Cambridge University, P.E., Arizona, Florida) Professor--*Soil mechanics and foundation, soil dynamics, earthquake engineering, constitutive laws for materials, soil-structure interaction, piles, flow through porous materials, advanced materials testing and mechanics of granular materials.*

Chandrakant S. Desai
(Ph.D., University of Texas at Austin; P.E., Mississippi; Chartered Structural Engineer, UK) Regents' Professor, Director of Center for Material Modeling and Computational Mechanics--*Solid and geomechanics, structural dynamics, constitutive modeling, mechanical and nondestructive testing, flow and mass transport through porous media, computer methods, electronic packaging.*

Collaborating Faculty in Other Departments

J. Kemeny
(Ph.D. University of California, Berkeley), Associate Professor, Mining and Geological Engineering– Rock *mechanics, rock imaging technologies.*

GRADUATE STUDY IN HIGHWAYS AND TRANSPORTATION

INTRODUCTION

Advanced studies and research are available through a broad program of course work and research in the areas of Transportation and Highways in the Department of Civil Engineering and Engineering Mechanics at The University of Arizona. Students may specialize in such areas as traffic engineering, transportation planning, pavement design, and paving materials. The program can be structured to allow flexibility for interacting with other programs in the University and in the College of Engineering.

LIST OF RESEARCH TOPICS

A wide range of topics has been investigated and is of interest for future research. Most research has been directed to solving current problems as directed by project sponsors. Research projects or studies are performed by faculty and graduate students, and include the following:

- Traffic flow models
- Driver behavior
- Highway capacity analysis
- Intelligent transportation systems
- Traffic signal operations and timing
- Traveler information systems
- Public transit service/operations planning
- Long-range transportation planning
- Transportation economics and pricing

GRADUATE COURSE OFFERINGS

Civil Engineering and Engineering Mechanics

CE 502 Introduction to Finite Element Method
CE 510 Probability in Civil Engineering
CE 511 Research and Statistical Methods in Civil Engineering
CE 523 Hydrology
CE 541 Earth Structures in Geotechnical Engineering
CE 561 Traffic Modeling and Simulation
CE 563 Traffic Engineering
CE 566 Highway Geometric Design
CE 567 Traffic Operations and Safety
CE 568 Urban Transportation Planning
CE 569 Travel Demand Modeling
CE 664 Transportation Economics
CE 668 Urban Public Transportation Systems

Systems and Industrial Engineering

SIE 522 Engineering Decision Making Under Uncertainty
SIE 525 Queuing Theory
SIE 530 Engineering Statistics
SIE 536 Exp. Design and Regression
SIE 540 Survey of Optimization Methods
SIE 546 Algorithms, Graphs and Networks
SIE 562 Advanced Production Control
SIE 678 Transportation Systems

Planning

PLN 501 Introduction to Planning
PLN 516 Geographic Information Systems for Geography and Regional Development
PLN 550 Metropolitan and Regional Planning
PLN 555 Introduction to Transportation
PLN 559 Land Use and Growth Controls

FACILITIES

The department has an extensive library, computers and software for use in traffic analyses and transportation planning studies. There is a variety of equipment used for field traffic studies and analysis. The transportation-engineering laboratory includes a research cluster of Pentium computers.

FACULTY

Mark Hickman
(Ph.D., MIT, P.E., Texas) Associate Professor--*Traffic flow, traffic signal operations, transportation planning, public transportation planning and operations, transportation economics.*

Collaborating Faculty in Other Departments

Pitu Mirchandani
Professor, Systems and Industrial Engineering--*Models and algorithms for: optimization, control of stochastic systems, and logistics, routing, location and scheduling, with applications in transportation and traffic.*

Larry Head
Research Professor, Systems and Industrial Engineering--*Traffic and transportation systems, traffic signal control, microscopic traffic simulation, traffic flow theory, systems engineering methodology, software engineering, communications, and human factors.*

Wei Lin
Assistant Professor, Systems and Industrial Engineering--*Transportation network optimization, intelligent transportation systems, traffic flow theory, logistics and supply chain management, computer simulation modeling.*

Sandi Rosenbloom
Professor, Planning Program--*Transportation and community development implications of societal trends, particularly; suburbanization, the aging of society, the increasing labor force involvement of women with children, the growth of groups with special needs; and the role of the private sector in the provision of public services.*

GRADUATE STUDY AND RESEARCH IN HYDRAULICS AND WATER RESOURCES

INTRODUCTION

Students interested in hydraulic engineering will find unusual opportunities for study and research leading to advanced degrees in Civil Engineering at The University of Arizona, Tucson, Arizona. The courses offered in hydraulics are combined with courses from others areas of the CEEM department and from other departments of the university to enable the students to prepare their study programs to suit their particular needs and goals. The Master of Science and Doctor of Philosophy degrees emphasize the development of theory, the application of theory to the solution of contemporary engineering problems, and finally the submission of a research thesis. Ample scope is provided to engage in interdisciplinary studies, since many real-life problems are of an interdisciplinary nature.

LIST OF RESEARCH TOPICS

Areas of research that you could choose for your thesis/dissertation cover a range of interesting and challenging subjects. These subjects and recent research projects in hydraulic engineering have included:

- Minimization of waterhammer pressures and stresses in pipelines
- Finite element (FE) analyses of overland flows
- FE analyses of groundwater flow and mass transport
- Saltwater intrusion into coastal aquifers
- Boundary element techniques for groundwater flow and saltwater intrusion
- Parameter estimation for water distribution networks
- Real-time flood forecasting
- Optimal control of pumping facilities
- Large-scale reservoir system operations
- US-Mexico transboundary water resources management
- Flow duration curves for ungaged basins
- Operation of Soil-Aquifer Treatment (SAT) facilities
- Location and operation of wells to optimize SAT operations
- Hydrologic forecasting using climatic precursors
- Estimation of flood frequency distributions for ungaged catchments
- Characterization of droughts
- Use of remote sensing data in hydrologic models
- Hydraulics of recharge facilities

COURSES OFFERED

CE 423/523	Hydrology
CE 427/527	Computer Applications in Hydraulics
CE 455/555	Irrigation Engineering (Cross-listed with Ag. Eng. 455/555)
CE 458/558	Drainage of Irrigated Lands (Cross-listed with Ag. Eng. 458/558)
CE 503	Subsurface Fluid Dynamics Cross-listed with Hydr. 503
CE 504	Numerical Methods in Subsurface Hydrology. Cross-listed with Hydr. 504
CE 522	Open Channel Flow
CE 525	Water Quality Modeling
CE 526	Water Quality Management
CE 621	Sediment Transportation
CE 655	Stochastic Hydrology

Other Related Courses

In addition to the courses listed above, the student may select from a wide variety of courses offered by other areas within the CEEM department and other departments in the University.

CEEM Department

CE 502 Introduction to Finite Element Methods
CE 541 Stability Problems in Geotechnical Engineering
CE 545 Geoenvironmental Engineering
CE 547 Seepage and Earth Dams

Aerospace and Mechanical Engineering Department

AME 536(a), 536(b) Fundamentals of Fluid Mechanics
AME 537 Fluid Mechanics of Viscous Flows
AME 539 Finite Element Methods in Fluid Mechanics

Agricultural Engineering Department

ABE 526 Soil and Water Conservation Engineering
ABE 556 Irrigation Systems Design
ABE 650 Advanced Irrigation Management
ABE 655 Surface Irrigation Analysis
ABE 656 Pressurized Irrigation Systems

Hydrology and Water Resources Department

HWR 505 Vadose Zone Hydrology
HWR 506 Water Quality Dynamics
HWR 516 Hydrologic Transport Processes
HWR 518 Survey of Subsurface Hydrology
HWR 520 Water Resources Management, Planning and Rights
HWR 521 Introduction to Water Resources Systems Analysis
HWR 531 Hydrogeology
HWR 535 Advanced Subsurface Hydrology
HWR 536 Ground-Water Resource Evaluation
HWR 545 Statistical Hydrology
HWR 550 Environmental Hydrology
HWR 566 Soil and Groundwater Remediation
HWR 582 Applied Groundwater Modeling
HWR 603 Advanced Topics in Subsurface Hydrology
HWR 642 Analysis of Hydrologic System
HWR 643 Water Resources Systems Analysis
HWR 645 Stochastic Methods in Subsurface Hydrology

Renewable Natural Resources-Watershed Management

RNR 517 GIS for Natural Resources
RNR 520 Advanced GIS
WSM 53 Water Management in Dryland Ecosystems
WSM 560 Watershed Hydrology
WSM 562 Watershed Management
WSM 569 Spatial Analysis of Hydrology and Watershed Management

RESEARCH FACILITIES

Computers: A variety of microcomputers and workstations are available for graduate research. The university also has mainframe computers for students' use, e.g., CONVEX, IBM, etc.

Physical Equipment: A number of flumes of different lengths and capabilities are available for research in open channel flow, sediment transport and erosion around hydraulic structures. Specialized equipment, e.g., Hele-Shaw apparatus, have been constructed for particular research projects. 2D and 3D glass bead models have been constructed to study seepage and mass transport problems. Standard equipment for conducting research is always available, e.g., gages, velocity probes, current meters, etc.

Libraries: The University library system contains more than 5,000,000 items, including books, periodicals, microforms, maps, government publications, manuscripts and non-book media. The Science-Engineering library houses material on science and technology has over 360,000 volumes, over a million microforms and displays current issues of 4,500-plus periodicals. The library offers reference service; on-line searching of computerized databases and bibliographic course-related instruction.

FACULTY

Juan B. Valdes
(Ph.D., MIT, P.E. Texas) Professor and Head--*Hydrologic forecasting using climatic precursors, impact of climatic variability and change in water resources, estimation of floods in ungaged catchments.*

Dinshaw N. Contractor
(Ph.D., University of Michigan; P.E., Arizona) Emeritus Professor and former Head--*Numerical modeling of hydraulic systems, unsteady open channel flows, flow and mass transport in groundwater systems, saltwater intrusion in groundwater, waterhammer in pipes and networks, optimization in water resource systems.*

Kevin E. Lansey
(Ph.D., University of Texas at Austin) Professor--*Application of system analysis techniques to water resources and hydraulic systems, water distribution system design and operation, soil-aquifer treatment systems, reservoir operations, maintenance scheduling, expert systems, hydrology and real-time flood forecasting using remote sensing data.*

Collaborating Faculty in Other Departments

Donald R. Davis
Ph.D., Professor, Hydrology and Water Resources--*Effects of uncertainty on the operation and design of systems with applications in water resources and natural disaster warning-response systems; Bayesian decision theory, systems theory and analysis, flood and environmental risk analysis, value of information.*

Donald C. Slack
Professor and Head, Agricultural and Biosystems Engineering--*Irrigation management, irrigation scheduling, infiltration, porous media flow, water harvesting, appropriate technology.*

Hoshin Gupta
Professor, Hydrology and Water Resources--*Surface hydrology, rainfall-runoff models; research for National Weather Service*.

Shlomo P. Neuman
(Ph.D.) Regents' Professor--*Hydrology and Water Resources.*

T. C. Jim Yeh
(Ph.D.) Professor, Hydrology and Water Resources -- *Numerical modeling, stochastic analysis, and laboratory/field investigation of flow and contaminant transport in variably saturated geologic formations.*

GRADUATE STUDY IN STRUCTURAL ENGINEERING

INTRODUCTION

The Structural Engineering program in the Department of civil Engineering and Engineering Mechanics (CEEM) at The University of Arizona, Tucson, offers excellent opportunities for advanced studies and research in a wide range of topics in structural engineering. The program is flexible and can be developed to fit individual interests, addressing the most recent developments in the area of structural engineering. A program of your choice can be developed to suit your particular needs, emphasizing from a purely professional to a highly research oriented program of study. Possible areas of study within the structural engineering program may include analysis and design of steel and concrete structures, structural mechanics, probabilistic or risk-based design, new materials for structures, earthquake resistant design, computer-aided design, applications of advanced composite materials in civil engineering structures, response of structures to blast loading, and many similar areas emphasizing both the theoretical and the practical aspects of structural engineering.

The program leads to the degrees of Master of Science with thesis and non-thesis options, Master of Engineering, and Doctor of Philosophy in Civil Engineering. Students can select courses from a wide variety offered by CEEM. They are also encouraged to take courses offered in other departments such as Aerospace and Mechanical Engineering, Applied Mathematics, Electrical and Computer Engineering, Statistics, Systems and Industrial Engineering, Materials Science and Engineering, or any other interdisciplinary programs available at The University of Arizona.

LIST OF RESEARCH TOPICS

The faculty in the Structural Engineering program at CEEM is actively involved in a wide variety of research areas, often with interdisciplinary interests from materials science and solid mechanics. The faculty and their current research interests are listed below. Both research and teaching assistantships are available to qualified prospective students. Prospective students are encouraged to contact the faculty of their choice and explore all possibilities.

Recent research topics in structural engineering at The University of Arizona have included:

- Reinforced and prestressed concrete structures
- Prestressed steel structures
- Stochastic finite element
- Stochastic system identifications
- Nonlinear structural dynamics
- Earthquake resistant design
- Seismic retrofitting of structures
- Reliability-based inspection, maintenance and rehabilitation
- Strengthening and rehabilitation of existing bridges and buildings
- All aspects of damage
- Applications of advanced fiber composite materials in civil engineering structures
- High strength concrete
- Development of innovative structural components
- Risk evaluation in random-fuzzy environment
- Finite deformation, stability, post-buckling behavior of structures
- Computational mechanics
- Constitutive modeling for concrete, composites and other structural materials

- Interface behavior
- Elastic wave propagation
- Fracture mechanics
- Acoustics, ultrasonics and nondestructive testing
- Damage and fracture
- Nondestructive evaluation of concrete and wood using nuclear magnetic resonance (NMR)

GRADUATE COURSE OFFERINGS

For your ready reference, the structural engineering graduate courses are listed below. For a detailed description of these courses as well as other courses offered at the College of Engineering and Mines and at The University of Arizona, please consult the Graduate Catalog.

CE 502 Introduction to Finite Element Methods
CE 510 Probability in Civil Engineering
CE 532 Advanced Structural Design in Steel
CE 533 Plastic Analysis and Design
CE 534 Design of Wood and Masonry Structures
CE 535 Prestressed Concrete Structures
CE 537 Advanced Structural Design in Concrete
CE 538 Behavior and Design Structural Systems
CE 540 Foundation Engineering
CE/EM 606 Wave Propagation in Solids
CE 632 Infrastructure Rehabilitation
CE 633 Reinforced Concrete Members
CE 637 Soil-Structure Interaction
CE 638 Advanced Structural Stability
CE 648 Constitutive Laws for Engineering Materials
EM 504 Elasticity Theory and Application
EM 508 Fracture Mechanics
EM 511 Advanced Finite Element Analysis
EM 539 Advanced Structural Mechanics
EM 604 Plasticity Theory and Application
EM 633 Structural Dynamics and Earthquake Engineering
EM/CE 648 Constitutive Laws for Engineering Materials
AME/EM 639 Energy Methods in Engineering Mechanics
AME 562 Composite Materials
AME 564a Mechanics of Deformable Solids I
AME 564b Mechanics of Deformable Solids II
AME 561 Finite Element Analysis in Structural Mechanics
AME 563 Finite Element Analysis in Nonlinear Solid Mechanics

FACILITIES

The CEEM has excellent facilities for testing conventional concrete and steel structures. The structural engineering laboratory is equipped with a 3-foot keep strong reaction floor covering an area of 42 feet by 32 feet with tie-down points at 3-foot center-to-center spacing. Modern testing facilities which have been recently purchased include: a closed-loop dynamic testing machine and load frame with a capacity of 110 kips, three hydraulic actuators, two with a capacity of ± 110 kips and one with a capacity of ± 220 kips, a hydraulic pump with a capacity of 23 gallons per minute, and a data acquisition and reduction system capable of reading 60 strain gages and 20 transducers. In addition, portable data acquisition equipment with 20 data channels is available in the form of an HP 3421 unit with mass storage devices. The laboratory is also equipped with several smaller hydraulic jacks, reaction frames, and testing machines. The Civil Engineering Department Shop is equipped with tool-making machines, and is supported by two machinists and an electrician. The library, computer, laboratory and other necessary facilities are what would be expected at a major American university.

FACULTY

Civil Engineering and Engineering Mechanics

Chandrakant S. Desai
(Ph.D., University of Texas at Austin; P.E., Mississippi; Chartered Structural Engineer, UK) Regents' Professor, Director of Center for Material Modeling and Computational Mechanics--*Solid and geomechanics, structural dynamics, constitutive modeling, mechanical and nondestructive testing, flow and mass transport through porous media, computer methods, electronic packaging.*

Mohammad R. Ehsani
(Ph.D., University of Michigan; Registered Structural Engineer, Arizona) Professor--*Analytical and experimental studies of reinforced and prestressed concrete structures, earthquake resistance of concrete structures, strengthening and rehabilitation of structures, composite materials, and non-destructive evaluation of structures.*

Robert Fleischman
(Ph.D., Lehigh University) Assistant Professor--*Seismic-resistant design of building structures, development of steel connection systems, partially restrained frames, diaphragm flexibility in precast concrete structures, connections for automated construction.*

George Frantziskonis
(Ph.D., University of Arizona) Professor--*Mechanics, geomechanics, new materials, damage and fracture, instabilities, advanced material testing.*

Achintya Haldar
(Ph.D., University of Illinois; P.E., Arizona) Professor--*Risk-based design, random vibration, stochastic finite element, stochastic optimization, stochastic system identification, shape optimization, dynamics, earthquake engineering, nonlinear analysis, reliability-based inspection, maintenance and integrity assessment, steel structures, all aspects of damage.*

Tribikram Kundu
(Ph.D., University of California, Los Angeles) Professor--*Elastic wave propagation, fracture mechanics, acoustics, ultrasonics and nondestructive testing, composites, computational mechanics.*

Hamid Saadatmanesh
(Ph.D., University of Maryland) Associate Professor--*Advanced materials such as fiber composites for strengthening of existing structures, rehabilitation of infrastructure systems, space materials, and behavior of steel and concrete structures.*

APPENDIX 2

MINIMUM COURSE REQUIREMENTS FOR GRADUATE ADMISIONS

The following guidelines should constitute the minimum requirements for non-civil engineering undergraduates for admission to the graduate program in CEEM. An applicant can show his/her proficiency in any of the following requirements by taking the corresponding exams.

ENGINEERING MECHANICS

Students with a bachelor's degree in any engineering discipline, physics, or mathematics can apply for graduate admission.

GEOMECHANICS/GEOTECHNICAL

Ordinarily, the student will be expected to take basic courses in soil mechanics and laboratory procedures (University of Arizona courses CE 343 and CE 349), and structural analysis (CE 333) and fluid mechanics (CE 218). Additionally, the civil engineering basic and pre/co requisites for these courses should be met.

HIGHWAYS AND TRANSPORTATION

Incoming graduate students in highways and transportation are expected to have the ability to understand and apply engineering principles in the following subject areas: Probability and statistics (CE 310 or SIE 305), Engineering economics (ENGR 211P or SIE 265), Numerical methods or mathematical models (CE 303 or SIE 270), and Transportation engineering and pavement design (CE 363).

HYDRAULICS AND WATER RESOURCES

The prerequisite requirements for an advanced degree in the Hydraulics area are courses covering the following material. The University of Arizona equivalent course is shown in parentheses.

Topics

Fluid Mechanics: hydrostatics, conservation laws (mass, momentum and energy) differential and control volume forms, boundary layer theory, friction in pipes (CE 218).

Applied hydraulics: Open-channel flow, natural streams and waterways, hydrologic analysis, fluid measurement apparatus, hydraulic models, economic aspects of water resources (CE 323).

Soil Mechanics: Physical and mechanical properties of soils, shear strength, consolidation, settlement, lateral earth pressures, and bearing capacity (CE 343).

Environmental Engineering: Design of water distribution and wastewater collection systems and fundamental principles of unit treatment processes (CE 370 R,L).

STRUCTURES

Ordinarily, the student will be expected to take basic analysis courses (University of Arizona course CE 333) and design courses (CE 334 or CE 335), and should have a basic understanding in soil mechanics (CE 343). Additionally, the civil engineering basic and pre/co requisites for these courses should be met.

APPENDIX 3

ADVISOR SELECTION FORM

ADVISOR SELECTION FORM
DEPARTMENT OF CIVIL ENGINEERING AND ENGINEERING MECHANICS

After consultation with faculty in my area, Dr. _____ and I have agreed that he/she will serve as my faculty advisor for my Master's/Ph.D. program.

Student Name _____

Student I.D. # _____

Student Signature _____ Date _____

Faculty Advisor Signature _____ Date _____

Department Head Signature _____ Date _____

APPENDIX 4
GRADUATE COURSE OFFERINGS 2005 - 2010

Courses	**F'05**	**S'06**	**F'06**	**S'07**	**F'07**	**S'08**	**F'08**	**S'09**	**F'09**	**S'10**
Hydraulics	1	1	2	1	1	2	2	2	3	0
CE 523 Hydrology (3)	1		1		1		1		1	
CE 527 Computer Applications in Hydraulics (3)		1		1		1		1		
CE 529 Special topics in Hydraulics and WR Eng						1	1	1	1	
CE 655 Stochastic Hydrology (3)			1						1	
Structures	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	
CE 510 Probability in Civil Engineering (3)				1			1			
CE 532 Advanced Structural Design in Steel (3)	1		1		1		1		1	
CE 533 Plastic Analysis and Design (3)										
CE 534 Design of Wood and Masonry Structures (3) – Adjunct	X		X		X			X		
CE 535 Prestressed Concrete Structures (3)				1						1
CE 537 Advanced Structural Design in Concrete (3)		1				1		1		
CE 538 Behavior and Design Structural Systems (3)		1								
CE 632 Infrastructure Rehabilitation (3)	1					1				
CE 633 Reinforced Concrete (3)		1					1			
CE 637 Soil-Structure Interaction (3)										
CE 638 Advanced Structural Stability (3)					1			1		
EM 633 Structural Dynamics and Earthquake Engineering (3)			1			1			1	
Geotechnical/Geomechanics	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**1**	
CE 540 Foundation Engineering (3)	1			1				1		
CE 541 Earth Structures in Geotech. Engineering (3)			1		1		1			1
CE 544 Special Topics in Geomechanics (3)		1				1				
CE 545 Geoenvironmental Engineering (3)		1				1			1	
CE 546 Geotechnical Earthquake Engineering (3)	1				1		1			
CE 548 Computer Methods in Geomechanics (3)				1						1
Transportation	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	
CE 511 Research and Statistical Methods in Civil Engineering			1			1				1
CE 563 Traffic Flow and Capacity Analysis (3)	1			1			1			
CE 563 Traffic Flow and Capacity Analysis (3) Web based										
CE 565 Project Planning and Modeling (3)										
CE 566 Highway Geometric Design (3)		1			1			1	1	
CE 567 Highway Safety and Operations			1						1	
CE 568 Urban Transportation Planning (3) (NAU Web based)	W		W		W	1	W		W	
CE 569 Travel Demand Modeling (3)		1				1				
CE 664 Transportation Economics (3)				1				1		1
CE 668 Public Transit Planning and Operation(3)	1				1					

Engineering Mechanics	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	
EM 502/AME 561 Finite Element (3)	1	AME	1	AME	1	AME	1	AME	1	AME
EM 504/AME 564 Elasticity	1		AME		1		AME		AME	
EM 508 Fracture Mechanics (3)			AME1						1	
EM 511/AME 563 Advanced Finite Element				1						AME
EM 604/AME 564 Plasticity		1		AME		1		AME		*
EM 606 Wave Propagation				AME						1
EM 648 Constitutive Laws		1				1		1		
AME 562 Composite Materials	AME		*		AME		AME		*	

APPENDIX 5

CHECKLIST FOR COMPLETING THE STEPS IN M.S. DEGREE

Read "mentoring"	1st semester
Choose your advisor - (complete Appendix 2)	1st semester
Meet your advisor and establish your plan of study	1st semester
Submit the PLAN OF STUDY to the CEEM Office	2nd semester
Submit your thesis/report to your committee for approval and format review	Final semester
Schedule the final defense of your thesis/report with your committee	Final semester
Submit the Completion of Degree Requirements Form to the Graduate Degree Certification Office	Final semester
Submit electronic copy of the thesis to the Graduate Degree Certification Office. See http://grad.arizona.edu/gcforms/ETD_Diss_Manual.pdf for instructions	Final semester
Two copies of thesis/report (one hardbound and one loose) submitted to the Department of Civil Engineering and Engineering Mechanics Office	Final semester

APPENDIX 6

CHECKLIST FOR COMPLETING THE STEPS IN PH.D. DEGREE

Read "Mentoring"	1st semester
Choose your advisor - complete Appendix 2	1st semester
Meet with your advisor and establish your plan of study	1st semester
Qualifying Examination	End of 2nd semester
Select your committee	3rd semester
Submit the finalized Plan of Study to the CEEM Office	3rd semester
Schedule WRITTEN and ORAL PRELIMINARY EXAMINATIONS. The request to schedule oral exam is due to the Graduate Degree Certification office.	Three weeks before exam
Submit the ADVANCEMENT TO CANDIDACY form to the Graduate College Degree Certification Office	At least SIX MONTHS prior to Oral Defense
Submit final draft of the dissertation to your committee for approval and for format review.	Four weeks before exam
Submit the ANNOUNCEMENT OF FINAL ORAL EXAMINATION TO THE Graduate Degree Certification Office	Three weeks before the date of the exam
Submit electronic copy of the dissertation to the Graduate Degree Certification Office. See http://grad.arizona.edu/gcforms/ETD_Diss_Manual.pdf for instructions	See published deadlines in your department or on the Graduate College website: http://grad.arizona.edu/Current_Students/Deadlines/
Two copies of thesis (one hardbound and one loose) submitted to the Department of Civil Engineering and Engineering Mechanics Office	When you are finished making changes

APPENDIX 7

Qualifying Examination Requirements

The information presented herein is intended to assist the student in preparing for the Ph.D. Major Qualifying Examination in Civil Engineering and Engineering Mechanics. In recognition of the fact that study at the Ph.D. level is of a specialized nature, each of the major areas within the CEEM Department offers separate exams. In all cases, the student should be aware of the fact that the qualifying exam focuses on work at the graduate level. The student is assumed to have mastered such undergraduate subjects considered essential to the graduate material. Note, however, that questions on undergraduate material may be included at the option of the examiners.

A memo should be written to the Department Head verifying if the student has passed or failed the Qualifying Exam.

FROM: (Academic Advisor)

SUBJECT: Ph.D. Qualifying Exam RESULTS for _____

This will serve to notify you that the above student has

_____ PASSED

_____ FAILED

the Ph.D. Qualifying Exam, which was held on _____.

AREAS OF CEEM FOR QUALIFYING EXAM

ENGINEERING MECHANICS

The specific areas and/or courses for the examination, the type of examination and suggested references are given below. The student will be examined over three of the areas of his/her choosing. Common questions will be written for mechanics subjects that are also included in other specialty areas (e.g., common questions on elastic stability will be used for students in structures as well as for students in mechanics). More than one topic can be selected from special topics. Concerned faculty member will provide references for Special Topics.

The following gives topics and references that could prove helpful for the preparation of the qualifying exams:

1. **Theory of Elasticity and Applications**
   Timoshenko and Goodier, Theory of Elasticity, McGraw-Hill, 1970
   Mal and Singh, Deformation of Elastic Solids, Prentice Hall, 1991.
2. **Finite Element Method**
   Desai and Kundu, Introductory Finite Element Method, CRC Press, 2001
   Cook, Concepts and Applications of Finite Element Analysis, Wiley, 1974
3. **Theory of Plasticity and Applications**
   Mendelson, Plasticity, Theory and Application, Oxford, 1950
   Chen and Han, Plasticity for Structural Engineers, Springer-Verlag, 1988
   Fung, Foundations of Solid Mechanics, Prentice-Hall, 1969
4. **Continuum Mechanics**
   Fung, Foundations of Solid Mechanics, Prentice-Hall, 1969
   Frederick and Chang, Continuum Mechanics, Alyn and Bacon, 1965
   Mal and Singh, Deformation of Elastic Solids, Prentice Hall, 1991.
5. **Structural Dynamics**
   Clough and Penzien, Dynamics of Structures, McGraw-Hill, 1975
6. **Elastic Wave Propagation**
   Kundu, Ultrasonic Nondestructive Evaluation: Engineering & Biological Material Characterization, CRC Press, 2004
   Schmerr, Fundamentals of Ultrasonic Nondestructive Evaluations: A Modeling Approach, Plenum Press, 1998.
   Kolsky, Stress Waves in Solids.
7. **Fracture Mechanics**
   D. Broek, Elementary Engineering Fracture Mechanics, Fluwer Academic Pur., 1997.
   Bazant and Planas, Fracture and Size Effect, CRC Press, 1999.
8. **Constitutive Laws for Engineering Materials**
   Desai, C.S., Mechanics of Materials and Interfaces/The Disturbed State Concept, CRC Press, Boca Raton, FL, 2001.
9. **Special Topics: e.g., Applied Mathematics and Physics, Material Sc. And Eng.; Elastic Stability, Energy Methods, electronic packaging.**

GEOMECHANICS/GEOTECHNICAL ENGINEERING

The qualifying examination in the area of geomechanics and geotechnical engineering covers the following areas:

1. Soil Mechanics
- Seepage
- Consolidation
- Shear Strength and stress-strain relations of soils
- Interpretation of soil testing and soil behavior

2. Foundation Analysis and Design
- Shallow foundations
- Pile foundations
- Drill shafts
- Caissons

3. Stability Problems
- Slope stability
- Limit equilibrium
- Earth pressures
- MSE (mechanically stabilized earth) retaining structures
- Rigid and flexible retaining structures

4. Computer Methods
- Finite Element Method (FEM))
- Finite difference method (FDM)
- Spreadsheet applications in seepage, and consolidation
- Soil-Structure interaction
- Soil dynamics

5. Constitutive Laws for Geomaterials and Interfaces
- Plastic hardening or yielding and softening
- Critical state soil mechanics
- Volumetric response
- Microcracking
- Degradation of materials and interfaces
- Disturbed state models

6. Geoenvironmental Engineering
- Geosynthetics
- Design of Water containment systems
- Seepage
- Contaminant containment
- Contaminant transport

The student will be examined in area 1 (Soil Mechanics) and may choose any two from the remaining five areas. Although the examinations will be general, consideration will be given to the background of the candidate. For example, a student with background in BEM, would be examined in BEM rather than FEM. The examination in each area will be approximately 1 to 2 hours long, and, unless otherwise agreed, they will be closed book. The following references could prove helpful for the preparation of the qualifying exams:

1. Soil Mechanics

Budhu, Soil Mechanics and Foundation
Das, Principles of Geotechnical Engineering
Mitchell, Fundamentals of Soil Behavior, 2nd edition
Lamb and Whitman, Soil Mechanics

2. Foundation Analysis and Design

Budhu, Soil Mechanics and Foundation
Bowles, Foundation Analysis and Design, latest
Das, Principles of Foundation Engineering, latest
Elec. Pwt. Resrch. Inst. (EPRI), Manual on Estimating Soil Properties for Foundation Engineering
Peck, Hanson, and Thornburn, Foundation Engineering

3. Stability Problems

Budhu, Soil Mechanics and Foundations
Huang, Stability Analysis of Earth Slopes
Bromhead, The Stability of Slopes, 2nd edition

4. Computer Methods

Desai, C.S. and Kundu, T., Introductory Finite Element Method, CRC Press, Boca Raton, FL, 2001
DSC - SST2D - User's Manuals
Fast Langrangian Analysis of Continua (FLAC) – Users Guide
GeoFEAP – Users Guide
SSOMPPC – Users Manual
UTEXAS4ED – Users Manual

5. Constitutive Laws for Geomaterials and Interfaces

Desai, C.S., Mechanics of Materials and Interfaces: The Disturbed State Concept, CRC Press, Boca Raton, FL, 2001

6. Geoenvironmental Engineering

Sharma and Lewis, Waste Containment Systems, Waste Stabilization, and Landfills
Koerner, Designing with Geosynthetics, 4th edition
Holtz, Christopher, and Berg, Geosynthetic Engineering
Owens and Khera, Geotechnology of Waste Management
Domenico and Schwartz, Physical and Chemical Hydrology
Freeze and Cherry, Groundwater
Cedergren, Seepage, Drainage, and Flow Nets

HIGHWAYS AND TRANSPORTATION

The examinations are closed book but appropriate charts and/or tables as may be needed are provided with the exam materials. The recommended references are the textbooks currently in use for the M.S. programs. The examiners on the basis of the student's prior work at the M.S. level determine specific areas in which a student will be examined.

Highways

1. Paving materials, including asphalt, cement, and soils. Reference: Highway Engineering, Oglesby and Hicks.

2. Pavement design, traffic characteristics and vehicles, stresses in pavement systems, and pavement design methods. Reference: Pavement Analysis and Design, Huang.

Transportation

1. Traffic characteristics, traffic flow, and highway capacity. Reference: Traffic Engineering, Roess, McShane and Prassas; and Traffic Flow Fundamentals, May.
Traffic operations. Reference: Traffic Engineering, Roess, McShane and Prassas.
Geometric design. Reference: A Policy on Geometric Design of Highways and Streets, AASHTO.

2. Transportation planning. Reference: Urban Transportation Planning, Meyer and Miller.

HYDRAULICS AND WATER RESOURCES

1. Specific Sub-Areas or Topics

a. Basic Fluid Mechanics
Hydrostatics; continuity; momentum; energy; laminar and turbulent flow in pipes.

b. Water Resources Engineering
Steady-state open channel flow; pumps and turbines; sedimentation; hydraulic models.

c. Hydrology

Hydrologic cycle; rainfall; evapotranspiration; infiltration; runoff; reservoir routing; statistical and probabilistic analyses of flood records.

d. Sediment Transportation
Erosion, transportation and deposition of sediments by flowing water; sediment properties and their measurement; bed load and suspended load movement; river behavior and control.

e. Open Channel Flow
Continuity, momentum and energy differential equations of unsteady open channel flow; kinematic, diffusion and dynamic wave theories; numerical methods of analysis, e.g., method of characteristics, explicit and implicit methods; dam break models.

f. Hydrologic and Hydraulic computer modeling.

2. Type of Examination

The type of examination given is the prerogative of the instructor. In the past, the examinations have generally been take-home and open book, with some open-ended questions.

3. List of Textbooks

a. Engineering Fluid Mechanics, Crowe, Roberson, and Elger
b. Water Resources Engineering, L.W. Mays
c. Water Resources Engineering, R.K. Linsley and J.B. Franzini
d. Applied Hydrology, Chow, Maidment, Mays
e. Open Channel Flow, F.M. Henderson
f. Hydraulics of Sediment Transport, W.H. Graf
g. Fundamentals of Hydraulic Engineering, A.L. Prashun
h. Water Resources Planning and Development, M.S. Petersen
i Design of Small Dams, U.S. Bureau of Reclamation

STRUCTURES

The subject areas for the qualifying examination are listed below. Each student will be examined in the area of structural analysis, in the area of structural design, and in two other additional areas of his/her choice.

The following references could prove helpful for the preparation of the qualifying exams:

Required Subject Areas

1. Structural Analysis (closed book)

Textbook currently in use in courses in structural analysis.

2. Design (select one of the following areas)

Design in Steel
Design in Concrete
Plastic design
Prestressed concrete

3. Elective subject areas (Select two areas)

a. Theory of Elasticity and Applications (closed book)

i. Timoshenko and Godier, Theory of Elasticity, McGraw-Hill, 1970.
ii. Sokolnikoff, Mathematical Theory of Elasticity, McGraw-Hill, 1964.

b. Finite Element Method (closed book)

i. Desai/Kundu, Elementary Finite Element Method, CRC Press, 2001.
ii. Cook, Concepts and Applications of Finite Element Analysis, Wiley, 1974.

c. Structural Reliability (open book)

i. Haldar & Mahaderan, Probability, Reliability and Statistical Methods in Engineering Design, 2000, Wiley.

d. Elastic Stability (closed book)

i. Timoshenko and Gere, Theory of Elastic Stability, McGraw-Hill, 1961.

e. Structural Dynamics

i. Clough and Penzien, Dynamics of Structures, McGraw-Hill, 1993.
ii. Chopra, Dynamics of Structures, Prentice Hall, 2000.