GRADUATE HANDBOOK

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May 2022

TABLE OF CONTENTS

1 INTRODUCTION

The purpose of this guide is to provide students with information on the requirements and procedures for pursuing a graduate degree (M. E., M. S., or Ph.D.) in the Department of Civil and Architectural Engineering and Mechanics (CAEM) at the University of Arizona. The Department is active in research in the general areas of Engineering Mechanics, Geomechanics/Geotechnical Engineering, 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 CAEM. Information found in the Graduate College website, 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. As a minimum the graduate school requirements must be adhered to, but the Department may have more stringent requirements than the graduate school. 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, 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 CAEM Office or the Graduate College website.

2 GENERAL PROGRAM INFORMATION

2.1 Degree Programs

The Department offers the following graduate degrees:

- Master of Engineering (M.E.) in Civil Engineering and Engineering Mechanics
- Master of Science (M.S.) in Civil Engineering and Engineering Mechanics
- Doctor of Philosophy (Ph.D.) in Civil Engineering and Engineering Mechanics

The M.E. degree is a coursework only program. It is intended to be a terminal professional degree with academic standards equivalent to, but different from, a traditional M.S. degree.

The MS degree has two options: (i) thesis and (ii) report. The M.S. degree thesis option is intended for students who want to gain experience in formulating and researching civil engineering topics and will work closely with a faculty member on a research project. Students planning to pursue a Ph.D. degree are strongly encouraged to choose the thesis option. The M.S. degree report option is intended for students desiring a broad education. The report provides a similar experience to the thesis not intended to be a research project; rather it is an advanced engineering study. The report topic is generally engineering practice motivated; typically toward implementable design or design process. Both M.S. options are comprised of coursework in several areas, a thesis or report, and a final defense (called a Master's/Specialist Completion Final).

The following background is general for all degree programs.

3 FINANCIAL SUPPORT

3.1 Types of Financial Support

Financial support is available in a number of forms. A limited number of highly selective fellowships are available to PhD students. Faculty recommend exceptional candidates for these awards during the admission process. Fellowships do not have specific responsibilities attached to their funding.

Assistantships and graders, on the other hand, do have job responsibilities. *Research Assistantships (RAs)* are provided by CAEM faculty member's research grants. These faculty are responsible for identifying students to work on these projects. In addition, a limited number of CAEM *Teaching Assistantships (TAs)* are

available to qualified students. Faculty members provide recommendations to the Department Head for these positions. Students are paid based on the standard rate and the hours of the appointment. There is a tuition reduction automatically for an RA or TA with a 1/4-time or higher appointment. A 0.25 time appointment waives out-of-state tuition and half of in-state tuition while a 0.5-time appointment (20 hours per week) carries a full waiver of in and out of state tuition. Students are responsible for other fees.

Course grader positions are often available and paid hourly. Departmental scholarships are also available but are generally restricted to ongoing students who submit an inclusive scholarship application early in the spring semester. CAEM also has allocated funds for graduate tuition (GTS) and registration (GRS) stipends, primarily for ME students. A GTS waives the portion of the student's 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.

3.2 TA and RA Requirements

To be employed as a RA or TA, a student must be enrolled for a minimum of 12 credit hours. Further, teaching assistants must complete the mandatory Teaching Assistant/Associate Training Online (TATO) online training prior to starting their position.

To serve as a TA, International graduate students must demonstrate high English competency as demonstrated by meeting one of the following requirements.

- TOEFL IBT Speaking Section – score of 24
- IELTS - total minimum score of 7.5 or above with no score lower than 7 on any section of the test. A score of 8 is the recommended level.

If an International TA has not taken any of the approved tests (listed above) or does not meet the minimum passing score(s), the department can perform an English Speaking Proficiency Evaluation (ESPE). The Graduate College requires that the English-Speaking Proficiency Evaluation be completed prior to the student being

3.3 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.

4 GRADUATE STUDENT SUPPORT

4.1 CAEM Graduate Coordinator

The CAEM Graduate Program Coordinator is the first point of contact for incoming graduate students (https://caem.engineering.arizona.edu, 520-621-6577). Upon arrival to campus, she/he will familiarize the students with support and requirements for students. The Program Coordinator supports students during their graduate studies and serves as a conduit to the Graduate School. She/he will collect required forms, help with registration, and all academic process issues.

4.2 CAEM Department Office

The CAEM department office handles assigning office space to graduate assistants and providing scholarships. HMBC is the college business office and handles financial and other non-academic functions including employment paperwork. HBMC does not have expertise to respond financial aid and immigration status question. Support for those questions should be addressed by the Financial Aid department.

4.3 Academic Advisor

Early in the student's academic program, he/she identifies an academic advisor who agrees to work with the student. The advisor is the student's primary educational contact. 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.

Specifically, the advisor's responsibilities include identifying coursework that will benefit the student in reaching his/her academic goals, developing a plan of

study, collaborating with the student in identifying his/her thesis/report/dissertation topic, meeting regularly to advance the research, and assisting in writing the final research product. The academic advisor and graduate program coordinator ensure that all degree requirements are satisfied and the student is progressing toward his/her degree. 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 6.0). The process for selecting and confirming an academic advisor is described in Section 5.2.

4.4 Degree Counselor

The Graduate College assigns a degree counselor in their office for each major. The Graduate College Degree Counselor is the first contact for unresolved departmental issues and performs a preliminary final degree check.

5 GRADUATE PROCESSES AND PROCEDURES

This section provides and overview of administrative processes, procedures, and tools to advance toward a graduate degree in our department. Details on degree specific forms and processes are addressed by program in Section 9 for Master of Science, Section 10 for Master of Engineering, and Section 11 for Doctoral programs.

5.1 GradPath

Upon arrival to campus, the Graduate Coordinator will introduce the incoming graduate student to GradPath. GradPath is the Graduate College's paperless degree audit process that tracks and monitors student progress. Students can fill in and submit forms online through GradPath forms.

At the outset of his/her program, the graduate student should become familiar with the degree requirement and the steps required for achieving the degree and consult the checklist. Details for CAEM graduate programs including recommended timing to complete each step are given by program in Section 9, 10, and 11. Required forms can be found at Graduate Student Academic Service.

5.2 Selecting an Academic Advisor

An Academic Advisor must be chosen prior to the beginning of the second semester of study. Incoming graduate students are encouraged to talk to all 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 Graduate Coordinator's Office, see Appendix 3) is completed and retained in the student's file.

If an incoming student has not identified a faculty advisor prior to arriving on-campus, the Department Head will assign a faculty member as a temporary advisor to help select classes during the student's first semester.

A student for good reason may choose to change his/her Academic Advisor. In this case, the old and the new Academic Advisors and the Student's Advisory Committee must agree to the change with at most one dissenting vote. A new Advisor Selection form is then filed with the final approval of the Department Head.

5.3 Academic Advising

It is the student's responsibility to arrange an 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 held as the student progresses in his research. It is the student's responsibility to arrange these meetings.

5.4 Course Registration

Registration for each semester in residence should be completed after meeting with an Academic Advisor. Course registration is completed using **UAccess,** the University's web-based password-protected self-service portal. While GradPath monitors and accepts forms for degree progress, UAccess is the main student portal to access personal information, enroll for classes, perform university-related transactions, and check financial aid status. The **Schedule of Classes** and course catalog are linked to UAccess each semester.

5.5 Registration Requirements/Supplementary Registration

During the fall and spring semesters, full-time status consists of enrollment for nine (9) units of graduate credit for domestic and international students without RA/TA support. CAEM requires all students supported with a RA/TA to take twelve (12) units per semester. The minimum units required for graduate students vary depending on students' status, academic progress, and semester. A summary of the CAEM minimum and maximum units for CAEM graduate students is summarized in Table 5.1. Only 500, 600 and 900 level courses are counted toward the minimum enrollment required by University of Arizona.

Table 5.1 Units of Graduate Credit Required for Graduate Students

Student Status	**Registration Limit**	**Spring or Fall Semester**				**Summer Semester**	**Winter Semester**
		No-aid	Hourly worker	RA/ TA	No-aid-in last semester	all graduate students	
Domestic	Minimum	1	6	12	1	See **Note**	
	Maximum	19	19	19	19	6-7 units	3-4 units
International	Minimum	9	9	12	1-3 units depending on his/her country of origin	See **Note**	
	Maximum	19	19	19	19	6-7 units	3-4 units

Note: Graduate students who have maintained continuous enrollment, fulfilled all their other degree requirements, and were enrolled in thesis or dissertation unit(s) in the prior semester may defend and file for the degree in the summer or winter term without registration. If, however, students need library privileges or plan to use other University facilities or need significant faculty time during the summer or winter session, enrollment is required. Enrollment in the non-credit GRAD 922 to allow access to the Library during the summer or winter terms will now be available for eligible master's as well as doctoral students.

5.6 Continuous Enrollment Requirements

Commented [1]: Please link to our page; these requirements change now and then and you want to ensure they get up to date info

A student should keep up to date with the current Continuous Enrollment Policy. The requirements below are current as of February 2022.

A student in the M.E. or M.S. degree program must register every fall and spring semester from initial matriculation until all degree requirements are met. If not graduating in the summer term, M.S. candidates do not have to register for graduate units during summer sessions unless they plan to make use of University facilities or faculty time, where they must enroll for a minimum of one (1) unit of graduate credit in the term(s) in which they are using facilities or faculty time.

A student admitted to a Ph.D. program must register every fall and spring semester from initial matriculation until the completion of all course requirements, written and oral comprehensive exams, and eighteen (18) dissertation units. When these requirements are met, doctoral students not on financial assistance and/or needing to maintain appropriate visa status, may register for a minimum of one (1) unit every fall and spring semester until all course and dissertation requirements are met.

Note that students receiving funding such as assistantships, fellowships, loans, grants, scholarships or traineeships may be required by their funding source to register for more than one (1) unit to meet full-time status requirements (see Table 7.1) and should check with their program advisor regarding such requirements to ensure that they remain qualified for funding. Summer or winter session registration is not required for doctoral and master students who will be taking comprehensive exams, the final oral exam (i.e., defense) and/or will be graduating during that session. However, if they plan to make other use of university facilities or faculty time during summer/winter sessions, doctoral students must enroll for a minimum of one (1) unit of graduate credit in these terms. If degree requirements are completed during the winter or summer session, the student must have been registered for a minimum of one (1) unit during the preceding semester.

Student completing requirements for a PhD degree must be a continuous student during the semester in which the final exam is completed. However, students

can have the final exam in the following summer or winter session without enrollment if no library privilege, faculty time, or university facility is needed, otherwise, he/she needs to enroll in GRAD 922. This includes any semester during which a preliminary or final examination is scheduled. M.S. students who have completed all the degree course requirements and still must register to meet the requirements of M.S. Report (3 units) or Thesis (6 units) credit hours. Report CE 909 is for the non-thesis option, CE 910 for thesis, and CE 920 for dissertation. Such registration may be used to reach the one (1) unit minimum for the final academic semester for M.S. or M.E. students or the summer/winter session.

Unless excused by an official graduate **Leave of Absence** (which may not exceed one year throughout the student's degree program), all graduate students are subject to the Continuous Enrollment Policy. If the student fails to obtain a Leave of Absence or maintain continuous enrollment, he or she will be required to apply for readmission and to pay the Graduate College application fee. There is no guarantee of re-admission. Tuition or registration waivers cannot be applied retroactively.

5.7 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. The form must be submitted no later than the last day for adding classes via UAccess for the semester the leave of absence is to start. No retroactive Leave of Absences will be accepted.

5.8 Course Offerings

To assist students in developing their study plans, CAEM 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 available on the CAEM website.

5.9 Courses

Some courses have only a 400-level number (4xx). These courses are NOT available for graduate credit. Some 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.

Co-convened courses, which are 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. CAEM graduate students must enroll in the 5xx version of all co-convened courses whether they are in the major or not.

Cross-listed (e.g., CE 6xx/CHEE 6xx) courses will have identical course titles for both numbers. The catalog description for each course will also include a reference to the cross-listed course. The student should check the titles for verification.

5.10 Seminar

The CAEM Department requires that all full-time M.S. and full-time Ph.D. if funded through CAEM students take the CE 596A Seminar each semester, each seminar announcement will be posted. Part-time M.S. and Ph.D. students require to take this course at least once. 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. or M.E. 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.

5.11 Manual for Theses and Dissertations

The formatting guides for Dissertation and Thesis Formatting Guidelines have been made to assist you with the proper formatting of your doctoral dissertation or master's thesis.

Each student should read this manual before attempting to prepare a thesis or dissertation and discuss the proper format with his/her Academic Advisor.

5.12 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 from the publisher.**

Permission to use copyrighted material should be in writing and retained by the author with a copy being submitted to the CAEM 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 in Washington, DC.

6 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 CAEM Graduate Studies Committee for a final decision. All appeals and approvals must be given in writing.

7 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.

8 CERTIFICATE NON-DEGREE PROGRAMS

8.1 Geotechnical Engineering

Course requirements - 12 units

Courses

Required

Elective

8.2 Hydraulics and Water Resources Engineering (Certificate NDP)

8.2.1 Program Description

Students will have a working knowledge of detailed hydraulic and hydrologic design and planning and operation of water resources systems and be prepared to apply these concepts in practice.

- Provide a curriculum of study for Graduate students that explores hydraulics and water resources engineering topics.
- Introduce basic features of hydraulic and water resources engineering principles that are relevant to professional practice in the field.
- Provide the opportunity for research in particular areas of interest related to hydraulics and water resources engineering.

Educational Aims

- Introduce the principles of fluid mechanics, hydraulic engineering and water resources systems to professional practice.
- Familiarize students with experimental and research techniques that are applicable to hydraulics and water resources engineering.

8.2.2 Program Requirements

Incoming and graduation GPA are 3.0 in the last 60 undergraduate units and in the 12 units in the certificate.

Twelve units of graduate coursework is to be completed from:

Core Courses (minimum of 9 units)
CE 522 - Open Channel Flow
CE 523 - Hydrology
CE 524 - Sedimentation Engineering
CE 526 - Soil and Water Conservation Engineering
CE 527 - Computer Applications in Hydraulics
CE 529 - Special Topics in Hydraulics & Water Resources Engineering
CE 555 - Soil and Water Resources Engineering
CE 556 - Irrigation Systems Design
CE 558 - Soils, Wetlands and Wastewater Reuse
CE 655 - Stochastic Hydrology
RNR 573 -Spatial Analysis and Modeling

Elective Coursework (maximum of three units)
CE 522 Open-Channel Flow
CE 523 Hydrology
CE 527 Computer Applications in Hydraulics
CE 529 Special Topics in Hydraulics and Water Resources Engineering
CE 549 (HWR) - Statistical Hydrology
CE 655 (HWR) Stochastic Methods in Surface Hydrology

8.3 Advanced Transportation Engineering Certificate (NDP)

8.3.1 Program Description

8.3.2 Program Requirements

9 MASTER OF SCIENCE (M.S.) 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 provides additional details. Appendix 4A supplies the deadlines of completion for various steps in the Master's program.

9.1 Credit Requirements

An M.S. degree requires a minimum of thirty (30) units. Each student must take the Graduate Seminar course at least one semester. Regardless of the number of semesters enrolled in the Graduate Seminar course, a student will only receive one (1) unit of credit for the course toward their degree requirement. There are two M.S. program options, and the requirements for each option are listed below:

Plan A (thesis option)

Coursework: Twenty-four (24) units of 500 or 600 level courses and six (6) thesis units (CE/EM 910). The final examination is an oral defense of the thesis.

Plan B (technical report option)

Coursework: Twenty-seven (27) units of 500 or 600 level courses and three (3) units for a written engineering report (CE 910/EM 909). The final examination is an oral defense of the report.

All coursework must be in courses graded A, B or C except for one independent study course. To complete the degree requirements, the cumulative GPA in graduate level courses must be equal to or greater than 3.0. A student whose GPA falls below 3.0 will not be permitted to register for additional courses (see Graduate College Policies). Course credits up to 12 units from Accelerated Master's Program from other departments can be used for MS degree requirements with faculty approval.

A master's thesis is a piece of original scholarship written that attempts to answer a research question. A master's thesis is similar to a doctoral dissertation, but it is generally shorter and more narrowly focused. The thesis requires a thorough literature review, identification of the research question, data collection, analysis and

discussion on the resolution of the question. An engineering report, on the other hand, focuses on a design or analysis for a specific field condition or development of an engineering methodology for addressing a specific problem.

9.2 Time Limitation

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

9.3 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.

9.4 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 CAEM Graduate Studies Committee must approve the program of study prior to submission to the Graduate College.

Students may obtain a **Plan of Study Form** at UAccess GradPath in the Student Center online. 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. Graduate courses offered are posted at the department web page at *http://caem.engineering.arizona.edu/*. The Five Year Academic Schedule is available under the **Graduate Programs/advising** menu. This list is frequently updated with new courses and adjustments to the existing courses. The schedule is also available in the CAEM Department Office. Students choosing the M.S. thesis option must complete six (6) units of CE 910/EM 910 (Thesis), while the technical report option must complete three (3) units of CE 909/EM 909 (Report).

9.5 Academic Advisor

The Department Head will designate a faculty member to serve as an interim Academic Advisor before a permanent Academic Advisor is selected. The 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.

9.6 M.S. Advisory Committee Members

The Master's Advisory Committee consists of the Academic Advisor, who must be a tenure-track CAEM faculty member, and at least two additional members. At least one of the two additional members must be a tenure-track faculty member and holds a faculty appointment in CAEM. 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. "If the third member is not a current tenure-track UA faculty member, he or she must be approved by the Graduate College as a special member." A Special Member form 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 participate in the final oral examination for the master's degree.

9.7 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 UAccess GradPath after the thesis/report has been reviewed by the examining committee (i.e., the Master's 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/report approved by the student's Academic Advisor (not necessarily library-ready copies) at least two weeks prior to the oral examination.

The examination is composed of two parts. The first part is open to the public, the advisory committee members as well as other faculty, students, colleagues, can attend the first part. In the first part, the student gives an oral presentation of the thesis/report. The presentation may be interrupted to permit questions to clarify points and questions concerning fundamental principles that are directly related to the thesis/report. The second part of the examination is by the committee members only after the non-committee members have left the exam room. This part consists of questioning the student on graduate courses, particularly as they relate to the thesis/report.

The results of the examination are reported at UAccess GradPath after 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 are posted on the Graduate College website.

Following a successful defense, the candidate must submit a copy of the thesis/report to the Graduate College through the Dissertation/Thesis Submission website. The thesis/report must be submitted as a hardbound copy and a readable CD or a thumb drive to the CAEM 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, or hardbound copy. The candidate needs to check with his/her Academic Advisor for any special requirements.

In the event of a failure, the candidate must choose to have a second exam or exit the program within one week. If he/she decides to continue, the examining committee will determine what the student must do before a second examination may be scheduled. Upon recommendation of the Examining Committee, and approved by the Department Head, a second examination will be granted after a lapse of at least four months. The examining committee must be the same as for the first examination. The results of the second examination are final.

9.8 Thesis Work In Absentia

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

10 MASTER OF ENGINEERING DEGREE IN CIVIL ENGINEERING AND ENGINEERING MECHANICS

The Master of Engineering Program requires the completion of at least thirty (30) graduate credits, which include at least three (3) credit hours of courses in each of the following engineering subject areas, and eighteen (18) credit hours of major requirements and elective courses.

Category 1. Engineering management/business

Category 2. Applied engineering mathematics

Category 3. Entrepreneurship/Innovation/Design

Category 4. Advanced Engineering Science

The engineering subject areas are intended to be broadly interpreted. The remaining eighteen (18) credit hours of courses should be in student's major area. A typical program study plan is outlined in Table 10.1.

Table 10.1 Program of study framework

Course Requirements	Credit Hours
Engineering Management/Business (Category 1)	3
Applied Engineering Mathematics (Category 2)	3
Entrepreneurship/Innovation/Design (Category 3)	3
Advanced Engineering Science (Category 4)	3

Major Requirements and Electives	18
Total	**30**

10.1 CAEM Program Specific Requirements

Major requirements and electives (18 units, 1 unit of Graduate seminar)

The courses in major area should be proposed by the student and approved by the advisor. The majority of these units are expected to be Civil Engineering and Engineering Mechanics courses that include:

- A maximum of three (3) units of independent study may be applied

- These courses must 500 or above with course approval from the advisor (see Section 11.3)

--one (1) unit of CAEM Graduate Seminar

Practice-oriented project (0 units)

No project is required for this degree and a three (3) unit independent study can be used to provide this experience.

A student must focus on one emphasis area choosing from geotechnical, hydraulics, structures, transportation, or engineering mechanics, but may take elective courses from more than one emphasis. A general timetable for completion is in Appendix 4B.

10.2 Engineering Subject Area Courses

Below is a list of courses in each category. Deviations from this list may be permitted if they are reviewed and approved by the advisor. Any deviation should still be generally consistent with the general category definitions.

Category 1 – Engineering management/business (3 units) – Valid for all emphases

SIE/ENGR 514 Law for engineers/scientists

SIE/ENTR 557 Project Management

Other courses may be approved by the Advisor

Category 2 – Applied engineering mathematics (3 units)

CE/EM 502 Introductory Finite Element Method

Other courses may be approved by Department Advisor

Category 3 – Entrepreneurship/Innovation/Design (3 units)

CE 540 Foundation Engineering

CE 527 Computer Applications in Hydraulics

CE 537 Advanced Structural Design in Concrete

CE 560 Special Topics in Transportation Engineering

Other courses may be approved by Department Advisor

Category 4 – Advanced Engineering Science (3 units)

CE 510 Probability in Civil Engineering

Other courses may be approved by Department Advisor

10.3 Major Requirements and Elective Courses

Major requirements and electives courses are approved by the student's academic advisor and checked and confirmed by the Director of Graduate Studies Committee. Representative courses are listed below by specialization.

Engineering Mechanics

CE/EM 502 Introductory Finite Element Method

CE 510 Probability in Civil Engineering

CE/EM 606 Wave Propagation in Solids & Ultrasonic NDE

EM 504 Theory of Elasticity

EM 508 Fracture Mechanics

EM 605 Mechanical Behavior of Materials II

EM 633 Structural Dynamics and Earthquake Engineering

EM 634 Advance Structural Dynamics

Geotechnical

CE 510 Probability in Civil Engineering

CE 540 Foundation Engineering

CE 541 Earth Structures in Geotechnical Engineering

CE 542 Ground Improvement

CE 544 Special Topics in Geomechanics

CE 545 Geoenvironmental Engineering

CE 546 Geotechnical Earthquake Engineering

CE 548 Numerical methods in Geotechnical engineering

Hydraulics

CE 510 Probability in Civil Engineering

CE 522 Open Channel Hydraulics

CE 523 Hydrology

CE 526 Watershed Engineering

CE 527 Computer Applications in Hydraulics

CE 529 Numerical Methods in Hydraulics

CE 549 Statistical Hydrology

CE 524 Sedimentation Engineering

CE 655 Stochastic Hydrology

Structural

CE 510 Probability in Civil Engineering

CE 532 Advanced Structural Design in Steel

CE 534 Design of Wood and Masonry Structures

CE 535 Prestressed Concrete Structures

CE 537 Advanced Structural Design in Concrete

CE 638 Structural Stability

Transportation

CE 510 Probability in Civil Engineering

CE 560 Special Topics in Transportation Engineering

CE 561 Traffic Modeling & Simulation

CE 561A Statistical Methods in Transportation Engineering

CE 562 Traffic Engineering and Operations

CE 563 Traffic Flow and Capacity Analysis

CE 565 Transportation Data Management and Analysis

CE 566 Highway Geometric Design

CE 567 Traffic Safety

CE 568 Urban Transportation Planning

CE 569 Travel Demand Modeling

CE 663 Advanced Transportation Modeling and Analysis

SIE 561 Traffic Modeling and Simulation

11 DOCTORAL PROGRAM IN CIVIL ENGINEERING AND ENGINEERING MECHANICS

Attainment of a Doctor of Philosophy (Ph.D.) degree at 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 CAEM Department. A general timetable for completion is in Appendix 5

11.1 Academic Advisor

The primary role of the Academic Advisor, also known as major professor, 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 **Doctoral Advisory Committee** members, as well as developing and completing a Plan of Study.

Upon arrival on campus, if a student has not selected an 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. Once the permanent Academic Advisor has been selected, the Advisor Selection Form (Appendix 3) must be filled out.

11.2 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. The Graduate Coordinator will complete and submit a Special Member form to the Graduate College for Doctoral Advisory Committee members who are non-tenured or are outside of University of Arizona. Students are expected to complete the committee appointment form at UAccess GradPath. 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.

11.3 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 twelve (12) 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 University of Arizona or, in the case of transfer units, their equivalent at other institutions.

Up to thirty (30) units of graduate credits 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 through GradPath before the end of their first year of study to the Graduate College through Gradpath. At least one-half of the graduate credit must be in courses in which regular grades (A, B, C) have been earned. As for 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 CAEM Graduate Studies Committee.

11.4 Minor Subjects

The minor subject area may be taken within or outside of the Department of Civil and Architectural Engineering and 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. A minor in Civil Engineering or Engineering Mechanics requires twelve (12) units. Students are required to take a written minor exam with his/her minor advisor.

11.5 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.

11.6 Foreign Language Requirements

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

11.7 Qualifying Examination

11.7.1 Exam Timing

Each prospective candidate for a doctoral degree must pass a qualifying examination in the proposed major field that is organized and administered by the Graduate Studies Committee. The qualifying examination is typically scheduled to take place on Tuesday in the first week of each Spring Semester. Summer and Fall entrants must take the exam in the spring semester during the first year of residency. A spring semester entrant may take the qualifying exam on enrolling or at the beginning of their second year of study. Students should contact their faculty advisor about the exam and scheduling.

11.7.2 PhD Qualifying Exam Structure

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, yet also includes 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.

To test the breadth of knowledge, the qualifying exam consists of three sections: (a) Fundamental Topics (90 minutes); (b) CEEM topics areas (90 minutes); (c) Specialization exam (3 hours. The exam timetable is as follows.

8:30-10:00 am: **Fundamental Topics**: This portion of the exam will be closed book with the student required to complete 6 questions (~15 min each) selected by the student from 12 fundamental areas

10:00-10:30 am: Break.

10:30-noon: **CEEM Topic Areas:** This portion of the exam will be open book with 3 questions (30 min each) in the Civil Engineering and Engineering Mechanics Topic areas. There will be 7 questions of which the student is expected to complete 3, at least 2 of which must outside their primary area.

Noon-1:30 pm: Break.

1:30pm-4:30 pm: **Specialization Exam**: This portion of the exam will be in the Graduate Student's Area of specialization. It is envisioned that this will be one to two open-ended or creative solution questions.

11.7.3 Content Descriptions

MORNING SESSION: General Exam in Civil Engineering and Engineering Mechanics

Objective: Demonstrate a breadth of knowledge in the fundamentals, and a general knowledge of the broader field of civil engineering

Fundamental Topic Areas: Math: Linear Algebra, Calculus, Physics: Mechanics, Waves, Electricity & Magnetism; Statics, Dynamics, Strength of Materials, Fluids, Probability, Engr. Economics, Chemistry

CEEM Topic Areas: Environmental, Geotechnical, Hydraulics/Hydrology, Mechanics, Numerical Methods, Transportation, Structures

For the **CEEM Topic Area**, a list of topic areas to be included in the exam is given below.

AFTERNOON SESSION: Specialized Exam in Graduate Student's Area

Objective: Evaluate research potential and demonstrate a depth of knowledge in the field of interest and relevant areas

11.7.4 CEEM Topic References/Materials

Environmental:

Water Chemistry by Mark M. Benjamin, ISBN-13: 978-1478623083 – Chapters 3-7

Introduction of Environmental Engineering by Gilbert M. Masters & Wendell P. Ela, ISBN 0-471-41813-7 - Unit Operations, Chapters 1, 5, and 6

Geotechnical:

Reference book: Soil Mechanics and Foundations, by M. Budhu, John Wiley and Sons, 2010, 3rd Edition.

Chapter 2: 2.0 – 2.5

Chapter 4: 4.0 – 4.5, 4.6.1, 4.6.2, and related examples at the end of chapter.

Chapter 5: 5.0 – 5.6, and related examples at the end of chapter.

Chapter 6: 6.0 – 6.9, and related examples at the end of chapter.

Chapter 7: 7.0, 7.9, 7.10, 7.11.6, 7.11.7

Chapter 9: 9.0 – 9.4, 9.5.1, 9.5.2, 9.6 – 9.8, and related examples at the end of chapter.

Chapter 10: 10.0 –10.7, and related examples at the end of chapter.

Chapter 15: 15.0 –15.5

Hydraulics/Hydrology:

Reference book: Water Resources Engineering, by Larry W. Mays, John Wiley and Sons, Third Edition.

Chapters 4, 5, 8.1-8.8, 15, 16

Mechanics:

Most textbooks on statics and strength of materials cover the following topics:

Statics: equilibrium in 2 and 3 dimensions, trusses – method of joints and method of sections, frames, beams – shear force and bending moment diagrams, fluid statics, friction, centroids

Strength of Materials: uniaxial stress, uniaxial strain, bar behavior, shear, shaft behavior, beams, shear flow, stress transformation, generalized Hooke's law and plane strain, spherical/cylindrical pressure, combined stress, beam deflections and statically indeterminate beam, columns.

Numerical Methods:

Reference book: *Numerical Methods for Engineers and Scientists: An Introduction with Applications using MATLAB*, Authors - Amos Gilat and Vish Subramaniam, Pub. John Wiley, 2nd Edition

1. Roots of Nonlinear Equations (Chapter 3)
    - Bisection Method (Section 3.3)
    - Regula Falsi (Section 3.4)
    - Newton-Raphson Method or Newton's Method (Section 3.5)
    - Secant Methods (Section 3.6)
2. Solving System of Linear Equations (Chapter 4)

- Gauss Elimination method (Section 4.2)
- Gauss Elimination with Row Pivoting (Section 4.2)

3. Curve Fitting and Interpolation (Chapter 5)
   - Polynomial Interpolation – Lagrange Polynomial (Section 5.5)
   - Least Squares Polynomial Fit (Sections 5.2 and 5.4)
4. Numerical Differentiation (Chapter 6)
   - Finite Difference Methods – Forward, Backward and Central Difference formulae (Sections 6.2 and 6.3)
5. Numerical Integration (Chapter 7)
   - Trapezoidal, Simpson and Gauss Quadrature schemes (Sections 7.3, 7.4 and 7.5).
6. Solution of Ordinary Differential Equations: Initial Value Problems (Chapter 8)
   - Euler's explicit method (Section 8.2.1)
   - Modified Euler's method and Midpoint method (Sections 8.3 and 8.4)
   - Runge-Kutta methods (Section 8.5.1)

Structures:

Fundamentals of Structural Analysis (Reference book: Structural Analysis, R.C. Hibbeler, 8th Ed., Prentice Hall):

Topics:

- Beam and Frame Moment, Shear and Axial Force Diagrams
- Truss Forces: Method of Joints, Methods of Sections
- Cables and Arches
- Truss Deflections, Beam Deflections and Rotations
- Indeterminate Structures: Method of Consistent Deformations

Basic Structural Design (e.g. Structural Steel Design, 5th Ed: McCormac and Csernak; Design of Reinforced Concrete, 8th Ed: McCormac and Brown)

Topics:

- Steel tension members
- Compression Members: Euler buckling
- Flexural Members: Reinforced Concrete and Steel Beam Design

Transportation:

Reference books:

1. Papacostas, C.S. and Prevedouros (2001) Transportation Engineering and Planning, 3rd ed. Prentice Hall, Inc., Englewood Cliffs, New Jersey.

2. Highway capacity manual

Topics:

- Traffic stream flow model 3.1 - 3.6
- Highway capacity and level of service analysis 4.1 – 4.5
- Intersection traffic control and traffic simulation 4.6 – 4.9
- Intersection traffic control and traffic simulation 15.3
- Transportation planning and travel demand forecasting 7.1-7.3, 8.1-8.5

11.7.5 Exam Outcomes

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, a second qualifying examination may be granted. Third qualifying examinations are not permitted. Only the portions of the exam that students did not pass are re-taken.

If a student fails two qualifying exams, the graduate committee will consult his/her advisor to determine if the student should be allowed to continue in PhD program. If he/she is permitted to continue, the GSC and faculty advisor will identify the deficiency courses that the student needs to take. In general, the number of courses is the number of areas he/she failed in the exam. For instance, if a student failed two areas in the fundamental test, he/she must take a course in each of these areas. After his/her advisor agrees with the GSC recommendation, GSC notifies the student the deficiency courses. The student needs to complete these courses within one year after receiving the notification.

If he/she obtains a B or above grade on all the deficiency courses, he/she will be granted a pass in the PhD qualifying exam. In the event that he/she did not obtain a B grade on any deficiency course, he/she will be disqualified from the PhD program.

11.8 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 through the GradPath system 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 University of Arizona which the student intends to apply toward the graduate degree; and
3. Additional coursework to be completed to fulfill degree requirements including the minor program.

The Plan of Study must be approved by the student's Academic Advisor, the Graduate Studies Committee, and the Department Head prior to submission to the Graduate College. The Plan of Study must be approved by the Graduate College no later than two months before the Oral Comprehensive Examination.

11.9 Comprehensive Examination

Admission to graduate study does not imply admission to candidacy for an advanced degree. Before admission to degree candidacy, the student must first pass the qualifying examination in the chosen fields of study. Second, the student must pass a comprehensive examination conducted before the Doctoral Advisory Committee members. The comprehensive examination must be taken within three years in the PhD program and no later than six months prior to the date of the Final Oral Defense Examination. It is encouraged that students sit for the comprehensive exam near the end of or shortly after completing their coursework. Graduate College Policy.

No later than four weeks before the Comprehensive Examination, the student must complete the Application for Comprehensive Examination Form in GradPath in UAccess. 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 on the written and oral components of the comprehensive examination, the doctoral advisory 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 committee. The second attempt is permitted only after the lapse of four months. A third attempt is not permitted.

Upon successfully passing the comprehensive examination, results are reported to Graduate Student Academic Services (GSAS) office and the student will be admitted to Candidacy. ~~the Graduate Degree Certification Office~~. Deadlines for the submission of paperwork pertaining to the Comprehensive Examination are available in the GSAS Office.

11.9.1 Structure of Comprehensive Examination

The comprehensive exam consists of three portions: a written proposal in the major area, a written exam in the minor area, and an oral exam.

Major Area – Written proposal

The written proposal for the CAEM Department major area is a properly prepared technical document that describes the proposed Ph.D. research. The proposal is of central importance to the Comprehensive Examination. Its purpose is to indicate the academic preparation of the studentand her 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 exam

The written exam 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 exam

The written exams must be passed before scheduling the oral exam. The oral exam must last a minimum of two hours but no more than three hours. During questioning only members of the doctoral advisory committee may be present.

The oral examination begins with a 30-50 minute presentation by the student on his/her proposed research that is open to the public. Members of the audience may interrupt the presentation with pertinent questions. When such interruptions occur, an appropriate increase in the time allowed for the presentation will be made. After the presentation is complete, the public audience is asked to leave. The examination committee will then continue with questions on the proposed research and related areas. The presentation and related questioning usually takes about one hour. The remainder of the examination the student is asked to respond to questions on pertinent coursework and fundamentals relating to the student's research.

11.10 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 their chosen field. The most important aspect of the doctoral program is the dissertation, that is the evidence of this fundamental contribution.

CAEM requires the completion of a dissertation that meets required standards of scholarship and demonstrates the candidate's ability to conduct original research. 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 manuscript be submitted for publication before the completion of the doctoral program.

11.11 Format of Dissertation

Instructions relating to the format of the thesis and required abstracts are included in the Dissertation Formatting Guide that is available in the Graduate College website.

11.12 Announcement of Final Oral Defense

When the student has an approved Doctoral Plan of Study on file, has satisfied all coursework, residence requirements, passed the Comprehensive Examination, and

completed a draft dissertation, he/she must file for an Announcement of Final Defense. This form can be found at the UA GradPath Forms in UAccess on the Graduate College Forms page. The completed form is submitted via GradPath.

The Announcement of Final Oral Examination must be filed in UAccess and identify all Doctoral Advisory Committee members on the application form. Submission must provide adequate time for all approvers to grant approval one week prior to the exam to permit a public announcement of the upcoming exam. It is recommended that the process is initiated **no later than three (3) weeks prior to the proposed date** of the Final Oral Examination. Further, prior to approval, the examining committee members must have read the penultimate draft of the dissertation and agree that it is ready to defend.

The Graduate College posts deadlines for holding the Final Oral Defense Examination to graduate in a specified semester.

11.13 Final Oral Defense Examination

The dissertation examining committee is comprised of the Doctoral Advisory Committee. The oral defense of the dissertation may include a public portion where the candidate presents a summary of the research conducted to a general audience followed by a brief question and answer session. After the public portion has concluded the audience will be dismissed and the defense committee will convene with the candidate for a private defense of the research conclusions and dissertation document.

11.14 Submission of the Dissertation

Following a successful defense, the candidate will submit a copy of the dissertation to the CAEM Departmental office for a format check. After the necessary corrections, the candidate submits the approved dissertation in electronic format to the Graduate College via UAccess - for further instructions check the Dissertation/Thesis Submission site. The dissertation must be submitted in PDF

format to the CAEM department's office on a thumb drive along with a hardcopy of the dissertation that the student can verify is readable. In addition, the candidate's Academic Advisor and Doctoral Advisory Committee may request copies of the dissertations in electronic format, hardbound and/or loose pages. Check with your Academic Advisor for any special requirements.

11.15 Minor in Civil Engineering or Engineering Mechanics

Twelve (12) units of approved coursework are required for a minor in Civil Engineering and Engineering Mechanics. The minor Academic Advisor will coordinate the written portion with other faculty in the area. Usually, the minor committee member(s) tests the student on coursework taken in the minor. The examination time will be determined between the student and the minor advisor.

11.16 Steps in Completing the Ph.D. Program

A checklist for completing the steps toward your Ph.D. degree is given in Appendix 5 in the Supplementary Material Section.

11.17 Additional Information

Additional information on the doctoral program, necessary forms and steps involved can be obtained online at the Graduate College website.

APPENDIX 1

Graduate Programs in CAEM

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 CAEM Department as well as in other related Departments; e.g., Aerospace and Mechanical Engineering, Applied Mathematics, Mining and Geological Engineering, and Materials Science and Engineering.

The interdisciplinary nature of the program is covered and coordinated through the Engineering Mechanics, Geomechanics and Structural Mechanics Programs. Faculty members from the CAEM 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:

- Structural Health Monitoring (SHM) using ultrasonic & electromagnetic waves
- Development of constitutive models for accurate characterization of the mechanical response of solids and composites
- Laboratory determination of material parameters using mechanical and nondestructive testing
- Linear and Nonlinear ultrasonic NDE for crack detection in structures
- 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
- Smart materials and smart structures
- Additive Manufacturing
- Stability of structural systems
- Fracture mechanics
- Wavelet analysis for multiscale modeling

GRADUATE COURSE OFFERINGS

A list of courses under this program in the Department of Civil and Architectural Engineering and 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:

Dominic Boccelli, PhD

Head, Department of Civil and Architectural Engineering and 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 603 Elasticity

EM 605 Advanced Solid Mechanics

EM 508 Fracture Mechanics

CE/EM 606 Wave Propagation in Solids

EM 633 Structural Dynamics and Earthquake Engineering

EM 634 Advanced Structural Dynamics

Aerospace and Mechanical Engineering

AME 550 Advanced Dynamics

AME 561 Finite Element Methods

AME 563 Advanced Finite Element Analysis

AME 564A Mechanics of Deformable Solids

AME 564B Mechanics of Deformable Solids

Mining and Geological Engineering

GEN/MNE Geomechanics 527

GEN 529 Rock Slope Analyses and Design

GEN 580 The Mechanics of Fracture in Rock and Other Brittle Materials

Mathematics

MATH 456 Applied Partial Differential Equation

MATH 475 Mathematical Principles of Numerical Analysis

MATH 513 Linear Algebra

MATH 520 Complex Analysis

MATH 553 Partial Differential Equations

MATH 568 Applied Stochastic Processes

Materials Science and Engineering

MSE 551 Integrated Computational Materials Science and Engineering

MSE 555 Physical Metallurgy

MSE 560 Materials Science of Polymers

FACILITIES

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

Mechanical Testing and Characterization Facilities

- Several Mechanical testing machines
- Optical Microscope, SEM, TEM (on campus)

Non-Mechanical Testing Facilities

- Ultrasonic Pulser-Receiver: ultrasonic device for measurement of ultrasonic velocity and attenuation of a reference waveform.
- Ultrasonic C-Scanner: Piezoelectric transducer produces converging acoustic waves, which are used for crack detection and characterizing materials.
- EMAT (Electro Magnetic Acoustic Transducer) for pipe inspection
- Acoustic Microscope
- 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.
- Profilometer for roughness measurements.
- Additive Manufacturing of Metals and non-metals (on campus).

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 and Architectural Engineering and Mechanics

Robert Fleischman

(Ph.D., Lehigh University) 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.

Tribikram Kundu

(Ph.D., University of California, Los Angeles) Professor—Structural Health Monitoring & Nondestructive Testing - Elastic wave propagation, fracture mechanics, acoustics, ultrasonic and electromagnetic wave based NDE techniques, composites, computational mechanics.

Hongki Jo

(Ph.D., University of Illinois) Associate Professor—Structural health monitoring (SHM), wireless smart sensor networks, bio-inspired sensing technologies, smartphone network for SHM, computer vision-based sensing, big data for structural reliability and risk assessment, structural damage identification, advanced functional materials, wind/bridge engineering, energy harvesting, full-scale dynamic testing.

Hamid Saadatmanesh

(Ph.D., University of Maryland) 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.*

Hee Jeong Kim

(PH.D. – Korea Advanced Institute of Science and Technology(KAIST), Daejeon, South Korea) Assistant Professor – Multiscale chemo-mechanical characterization on cementitious materials, development of innovative and new efficient construction materials, identifying deterioration, carbonation, hydration mechanism of cementitious materials, digital fabrication, application of new advanced materials in civil engineering, carbon capture utilization and storage, development of sustainable concrete and low-CO2 concrete, improvement of sustainability and resilience of civil infrastructure.

Collaborating Faculty in Other Departments

S. Missoum

Associate Professor, Aerospace and Mechanical Engineering, Computational Optimal Design of Engineering Systems (CODES), Computational design optimization, Uncertainty quantification, Finite element analysis.

J. Kemeny

(Ph.D. University of California, Berkeley), Professor and Head, Mining and Geological Engineering–geomechanics, rock fracture mechanics, numerical simulation in rock mechanics, and developing 3D imaging and sensing technologies for mining and geotechnical applications. Dr. Kemeny is a leading expert on the use of terrestrial LIDAR for rock engineering applications. Dr. Kemeny is Partner and Co-Founder of Split Engineering LLC, a company that specializes in image processing software for the mining and geotechnical industries. Originally developed at the University of Arizona, the Split software analyzes digital images to determine the size distribution of rock fragments. Dr. Kemeny has over 30 years of experience in rock mechanics and over 20 years of experience with using new technologies such as digital image processing and LIDAR for rock engineering applications. Dr. Kemeny has been at the University of Arizona since 1989.

GRADUATE STUDY AND RESEARCH IN GEOMECHANICS/GEOTECHNICAL ENGINEERING

INTRODUCTION

The Geomechanics/Geotechnical program in the Department of Civil and Architectural Engineering and Mechanics at the University of Arizona includes such interdisciplinary areas as soil and rock mechanics, foundation engineering, geoenvironmental engineering, recycling and utilization of solid wastes, sustainable and green construction materials, dust control, soil dynamics and geotechnical earthquake engineering, 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 and 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 and Geological 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 and Architectural Engineering and 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 either using some of the existing unique devices developed by the faculty or constructing new ones.

Current areas of research include:

- Liquefaction of soils due to earthquake loading.

- Enhanced ground control for improving the safety of underground mining.
- Biopolymer stabilization of soils and mine tailings.
- Eco-friendly control of soil and mine tailings dust.
- Recycling and utilization of solid wastes (fly ash, mine tailings, and C&D wastes).
- Development of sustainable and green construction materials such as geopolymer bricks and concrete.
- Discrete element method (DEM) simulations of soils and rocks.
- Molecular dynamics (MD) simulations of materials.
- Soil behavior and soil properties.
- Three-dimensional (3D) multi-scale characterization and investigation of rock fractures.
- Development of Rock Expert System (RES) for efficient evaluation of rock properties.
- Enhancement of reservoir (oil, water, and thermal) production in rock.
- Sustainable foundation systems including both shallow and deep foundations.
- Retaining walls;
- Geotechnical safety related to underground compressed air energy storage (CAES).

COURSE OFFERINGS

(Through CAEM)

CE 502 Introduction to Finite Element Methods

CE 540 Foundation Engineering

CE 541 Earth Structures in Geotechnical Engineering

CE 542 Ground Improvement

CE 545 Geoenvironmental Engineering

CE546 Geotechnical Earthquake Engineering

EM 508 Fracture Mechanics

(Through Mining and Geological Engineering)

GEN 515 Rock Excavation

GEN 516 Field Studies in Geophysics

GEN 524 Fundamentals of Geotechnics

GEN 527 Geomechanics

GEN 529 Rock Slope Analyses and Design

GEN 548 Geophysical Exploration and Engineering

GEN 580 The Mechanics of Fracture in Rock and Other Brittle Materials

(Through Hydrology and Water Resources)

HWRS 503 Subsurface Fluid Dynamics

HWRS 518 Fundamentals of Subsurface Hydrology

HWRS 535 Advanced Subsurface Hydrogeology

HWRS 566 Soil and Groundwater Remediation

(Through Chemical and Environmental Engineering)

CHEE 573 Biodegradation of Hazardous Organic Compounds

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 major research equipment includes:

- Consolidation equipment with computerized data acquisition system
- Computer controlled direct shear device for soils

- Computer controlled cylindrical triaxial apparatus for soils
- Automatic mechanical compactor
- MTS frame and accessories for compression and tension tests
- Cyclic multi-degree-of-freedom shear (CYMDOF) device for translational, torsional, and rocking modes for testing interfaces and joints
- Wind tunnel for testing wind-blown dust

FACULTY

Civil and Architectural Engineering and Mechanics

Lianyang Zhang

(Ph.D. MIT, P.E. Massachusetts) Professor --

Three-dimensional (3D) multi-scale characterization and investigation of rock fractures; Development of Rock Expert System (RES) for evaluation of rock properties; and Enhancement of reservoir (oil, water, and thermal) production in rock; Recycling and utilization of fly ash, mine tailings and construction and demolition (C&D) wastes through geopolymerization; Bio-enhancement of cementitious material; Dust control with biopolymers; Geotechnical safety related to underground compressed air energy storage (CAES); Piles (especially drilled shafts socketed into rock) under different loading conditions; Dynamic properties of soils and rocks; and enhanced ground control for improving the safety of underground mining.

Collaborating Faculty in Other Departments

J. Kemeny

(Ph.D. University of California, Berkeley), Professor and Head, Mining and Geological Engineering–geomechanics, rock fracture mechanics, numerical simulation in rock mechanics, and developing 3D imaging and sensing technologies for mining and geotechnical applications. Dr. Kemeny is a leading expert on the use of terrestrial LIDAR for rock engineering applications. Dr. Kemeny is Partner and Co-Founder of Split Engineering LLC, a company that specializes in image processing software for the mining and geotechnical industries. Originally developed at the University of Arizona, the Split software analyzes digital images to determine the size distribution of rock fragments. Dr. Kemeny has over 30 years of experience in rock mechanics and over 20 years of experience with using new technologies such as digital image processing and LIDAR for rock engineering applications. Dr. Kemeny has been at the University of Arizona since 1989.

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 and Architectural Engineering and Mechanics at The University of Arizona. Students may specialize in such areas, such as traffic engineering, transportation planning, pavement design, and paving materials. The program is 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
- Performance measurement
- Big data analytics
- Traffic detection and sensors
- 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 and Architectural Engineering and Mechanics

CE 502 Introduction to Finite Element Method

CE 510 Probability in Civil Engineering

CE 511 Research Methods and Data Analysis in Civil Engineering

CE 523 Hydrology

CE 541 Earth Structures in Geotechnical Engineering

CE 560 Special Topics in Transportation Engineering

CE 561 Traffic Modeling and Simulation

CE 562 Traffic Engineering and Operations

CE 563 Traffic Flow and Capacity Analysis

CE 565 Transportation Data Management and Analysis

CE 566 Highway Geometric Design

CE 567 Traffic Safety

CE 568 Urban Transportation Planning

CE 569 Travel Demand Modeling

CE 664 Transportation Economics

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 Production System Analysis

SIE 678 Transportation Systems

Planning

PLG 501B Introduction to Planning

PLG 516B Geographic Information Systems for Geography and Regional Development

PLG 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 DynusT Lab and the Smart Transportation Lab are two major laboratory facilities managed by Drs. Yi-Chang Chiu and Yao-Jan Wu, respectively. The Transportation Library is widely used by our students.

FACULTY

Civil and Architectural Engineering and Mechanics

Yao-Jan Wu

(PH.D. – University of Washington, Seattle. P.E., Missouri) Associate Professor – ITS information technology applications in transportation, advanced safety vehicles (ASV), image processing and computer vision applications in transportation, traffic detection technology development, data management, mining, and analysis, and traffic operations), transportation safety analysis and accident modeling, Geographic Information Systems (GIS), traveler behavior analysis, and sustainable transportation systems (sustainable infrastructure and transit system improvement).

Alyssa M. Ryan

(Ph.D. - University of Massachusetts Amherst) Assistant Professor - Transportation safety, transportation equity, human factors, driving simulation, data analysis, unmanned aerial systems, automated vehicles, crash modeling, machine learning, Geographic Information Systems (GIS) and sustainable transportation systems)

Collaborating Faculty in Other Departments

Larry Head

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.

Young Jun Son

Professor, Systems and Industrial Engineering-- modeling and control of complex enterprises; modeling human decision-making, distributed federation of multi-paradigm simulations; computer integrated manufacturing; modeling and control in emerging applications (renewable energy power network; emergency evacuation; homeland security; mining logistics; UAV/UGV coordination)

Wei Lin

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

GRADUATE PROGRAM AND RESEARCH IN HYDRAULICS AND WATER RESOURCES

INTRODUCTION

Students interested in hydraulic engineering will find extraordinary 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 CAEM 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 water resource management, hydrology, and hydraulic engineering have included:

- Optimizing pipe flow designs
- Resilient and sustainable water distribution system
- Computational simulation of flow and sediment transport
- Experimental studies of turbulence flow field around bridge piers and abutments
- vegetation resistance and sediment transport in vegetated channels
- high-speed camera applications to fluid mechanics
- monitoring erosion and sedimentation using state-of-art technology
- River meandering processes and simulation
- Real-time flood forecasting
- Optimal control of pumping facilities
- Large-scale reservoir system operations
- US-Mexico transboundary water resources management

- Flow duration curves for ungauged basins
- Hydrologic forecasting using climatic precursors
- Estimation of flood frequency distributions for ungauged catchments
- Characterization of droughts
- Use of remote sensing data in hydrologic models

COURSES OFFERED

CE 422/522 Open Channel Flow

CE 423/523 Hydrology

CE 427/527 Computer Applications in Hydraulics

CE 429/529 Special Topics in Water Resource (Computational Hydraulics)

CE 455/555 Soil and Water Resources Engineering

CE 458/558 Soils, Wetlands and Wastewater Reuse

CE 503 Subsurface Fluid Dynamics

CE 504 Numerical Methods in Subsurface Hydrology.

CE 522 Open Channel Flow

CE 525 Sediment Transport Analysis

CE 526 Watershed Engineering

CE 622 Sedimentation Engineering

CE 655 Stochastic Methods in Surface 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.

CAEM Department

CE 502 Introduction to Finite Element Methods

CE 541 Earth Structures in Geotechnical Engineering

CE 545 Geoenvironmental Engineering

Aerospace and Mechanical Engineering Department

AME 536(a), 536(b) Fundamentals of Fluid Mechanics

Agricultural Engineering Department

ABE 526 Watershed Engineering

ABE 556 Irrigation Systems Design

Hydrology and Atmosphere Science Department

HWRS 505 Vadose Zone Hydrology

HWRS 516 Hydrologic Transport Processes

HWRS 518 Fundamentals of Subsurface Hydrology

HWRS 520 Fundamentals: Water Resources Policy, Management, Planning and Rights

HWRS 521 Water Resource Systems Planning and Management

HWRS 531 Hydrogeology

HWRS 535 Advanced Subsurface Hydrology

HWRS 545 Introduction to Data Assimilation

HWRS 566 Soil and Groundwater Remediation

HWRS 582 Applied Groundwater Modeling

HWRS 642 Analysis of Hydrologic System

HWRS 645 Stochastic Methods in Subsurface Hydrology

Renewable Natural Resources-

Watershed Management

RNR 517 Geographic Information Systems for Natural and Social Sciences

RNR 520 Advanced GIS

WSM 562 Watershed Management

RESEARCH FACILITIES

Computers: A variety of microcomputers and workstations are available for graduate research. The university also has a high-performance computer (HPC) system with clusters of nodes for students' use.

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., a large-scale open channel flume has been built for hydraulic and sediment transport research. Advanced 2D and 3D computational hydrodynamic models were developed. Highly advanced as well as standard equipment for conducting research is always available, e.g., Vectrino Velocity Profiler, Micro-ADVs, and High-speed camera systems, 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

Civil and Architectural Engineering and Mechanics

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.

Jennifer G. Duan

(Ph.D., University of Mississippi. P.E., Arizona and Nevada) Professor – Computational simulation of surface flow and sediment transport in rivers and watershed, river stability research, river engineering methods, bridge scour analysis, experimental researches on turbulence flow, vegetated open channel flow, and sediment transport, innovative instrumentation for flow and sediment measurements.

Dominic L. Boccelli

(Ph.D., Carnegie Mellon University) Professor--Systems analysis techniques, and lab- and field-scale experimentation applied to urban water infrastructure

systems; applications include real-time modeling, sensor networks, contamination warning systems, disinfectant dynamics and by-product formation; techniques include parameter estimation, uncertainty analysis, Bayesian methods, time series analysis, cluster analysis, optimization, and numerical methods.

Collaborating Faculty in Other Departments

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 water hydrology, terrestrial hydrometeorology, land-atmosphere models, flood-forecasting, model evaluation, diagnostic model correction and learning, multi-criteria analysis, sensitivity analysis, uncertainty analysis, Bayesian estimation, information content of data, data assimilation, model structure estimation, application of remotely sensed data, estimation of precipitation from remotely sensed data, artificial neural networks, global optimization, multi-resolution multi-disciplinary integrated modeling, decision analysis and decision support systems, applications of information theory to modeling and hydrology, bridging natural and social sciences.

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.

Tom Meixner

*(*Ph.D.) Professor, Hydrology and Water Resources, -- Watershed hydrology and biogeochemistry hydrologic controls on water quality, GIS, remote sensing, hydrochemical modeling, atmospheric chemistry, aqueous geochemistry, water quality modeling, sensitivity analysis, automatic parameter estimation, semiarid hydrology, riparian

GRADUATE STUDY AND RESEARCH IN STRUCTURAL ENGINEERING

INTRODUCTION

The Structural Engineering program in the Department of Civil and Architectural Engineering and Mechanics (CAEM) 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, computational mechanics, computer-aided design, infrastructure monitoring, sensors and sensor networks, 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, report and non-thesis options, Master of Engineering, and Doctor of Philosophy in Civil Engineering. Students can select courses from a wide variety offered by CAEM. 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 CAEM 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 assistantships and teaching assistantships are available to qualified prospective students. Prospective students are encouraged to contact the faculty of their choice and explore all possibilities.

- 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
- Disproportional Collapse
- Structural health monitoring
- Wireless smart sensor setworks
- Bio-inspired sensing
- Bridge scour monitoring and prediction
- Structural vibration control and mitigation
- Smartphone network for Infrastructure monitoring
- Wind engineering
- 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 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 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 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 633	Structural Dynamics and Earthquake Engineering
EM 634	Advanced Structural Dynamics (Experimental Dynamics)
EM/CE 648	Constitutive Laws for Engineering Materials
AME 562	Composite Materials
AME 564a	Mechanics of deformable Solids I

AME 564b Mechanics of deformable Solids II

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. 3-DOF Seismic shaking table has been built recently, which composed of three dynamic actuators of 4.3kips, allowing up to 40Hz excitation with 1 tonf payload capacity (30Hz excitation with 2 tonf payload), a feed-back controller, a hydraulic service manifold. Another 1DOF electromagnetic shaker also has been purchased for small-scale tests and sensor calibrations. 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 toolmaking 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 and Architectural Engineering and Mechanics

Robert Fleischman

(Ph.D., Lehigh University) 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.

Hongki Jo

(Ph.D., University of Illinois) Associate Professor—Structural health monitoring (SHM), wireless smart sensor networks, bio-inspired sensing technologies, smartphone network for SHM, computer vision-based sensing, big data for structural reliability and risk assessment, structural damage identification, advanced functional materials, wind/bridge engineering, energy harvesting, full-scale dynamic testing

Tribikram Kundu

(Ph.D., University of California, Los Angeles) Professor-—structural health monitoring & nondestructive testing - elastic wave propagation, fracture mechanics, acoustics, ultrasonic and electromagnetic wave based NDE techniques, composites, computational mechanics.

Dean Papajohn

(M.S., University of Illinois, P.E., Arizona & Illinois) Associate Professor of Practice—Alternative project delivery methods, public-private partnerships, sustainable infrastructure assessment.

Hamid Saadatmanesh

(Ph.D., University of Maryland) 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 ADMISSIONS

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

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. 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).

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 AND ARCHITECTURAL ENGINEERING AND 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
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 submit Responsible Conduct of Research Statement and establish your plan of study	1st semester
Submit the **PLAN OF STUDY** on the GradPath in UAccess	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
Department will submit the Completion of Degree Requirements Form to the Graduate Office	Final semester
Submit electronic copy of the thesis to the grad college (must be archived thru the grad college) https://grad.arizona.edu/gsas/dissertaions-theses/submitting-and-archiving-your-thesis	Final semester
One hardcopy and a thumb drive of thesis/report submitted to the Department of Civil and Architectural Engineering and Mechanics Office	Final semester

APPENDIX 5
CHECKLIST FOR COMPLETING THE STEPS IN M.E. DEGREE

Read "mentoring"	1st semester
Choose your advisor - (complete Appendix 2)	1st semester
Meet your advisor, submit Responsible Conduct of Research Statement and establish your plan of study	1st semester
Submit the **PLAN OF STUDY** on the GradPath in UAccess	2nd semester
Department submits the Completion of Degree Requirements Form	Final semester

APPENDIX 6
CHECKLIST FOR COMPLETING THE STEPS IN PH.D. DEGREE

Submit research integrity in gradpath and transfer credit form if necessary	1st semester
Choose your advisor - complete Appendix 2	1st semester
Meet with your advisor, submit Responsible Conduct of Research Statement and establish your plan of study (submit transfer credit document if necessary)	1st semester
Qualifying Examination	Beginning of Spring semester
Select your committee	3rd semester
Submit the finalized **Plan of Study** to the gradpath	3rd semester
Complete **Comprehensive Examination**	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 Exam to the Graduate College in UAccess GradPath.	Three weeks before the date of the exam
Submit electronic copy of the dissertation to the University of Arizona Campus Repository at https://grad.arizona.edu/gsas/dissertations-theses/dissertation-and-thesis-formatting-guides.	See published deadlines in your department or on the Graduate College website: http://grad.arizona.edu/Current_Students/Deadlines/
One hardcopy and one thumb drive of dissertation submitted to the Department of Civil and Architectural Engineering and Mechanics Office	When you are finished making changes