REDESIGNING A CONSTRUCTION MATERIALS COURSE TO PROMOTE LIFE LONG LEARNING

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Abstract

Milwaukee School of Engineering's (MSOE) degree-granting engineering programs were required, by our administration, to reduce the total number of credits required for graduation. To reduce the total number of credits in Architectural Engineering (AE&BC) programs, we redesigned three existing AE&BC courses—a three-credit materials and methods survey course, a one-credit materials and methods lab, and a three-credit chemistry of building materials course into one four-credit freshman course. The primary goal of this new course is to introduce students to materials (unique origins, chemistry, properties, standards, industry applications and trade associations) used in the construction industry, including metals (iron and steel, aluminum, copper), inorganics (aggregate, concrete, masonry, gypsum) and molecular materials (wood, asphalt, plastics). A related goal is to introduce students to research and communication skills that will enable them to access technical information on materials, evaluate that information for quality, summarize findings concisely and communicate those findings both in writing and orally, skills essential for academic success, as well as for life long learning. The new course includes a traditional lecture component (lectures, exams, portfolio), a laboratory component (based on current ASTM standards) and a research project (on a topic of the student's interest). Determining course content involved systematically combining the content of the existing courses for each of the building materials, emphasizing materials science content; identifying relevant ASTM standards, trade association web sites and information sources; and addressing ABET requirements and FE exam requirements. From a day-by-day topic outline, faculty stakeholders, who teach advanced courses, and seniors, who have taken existing courses, were asked to prioritize topics. Based on feedback, we dropped some topics and emphasized others. Course development is ongoing and will also address faculty development and delivery at a level appropriate for freshmen.

1.0. Background

Milwaukee School of Engineering

Milwaukee School of Engineering (MSOE) is a private, coeducational nonsectarian university located in a metropolitan center. It provides a balanced education -- undergraduate and graduate -- for men and women in the disciplines of engineering,

engineering technology, business, communication, construction management, medical informatics, nursing and perfusion (http://www.msoe.edu/president/mission.shtml). The mission is accomplished through an organized environment that places carefully recruited students among highly qualified faculty, a dedicated support staff and strategic partners in business and industry - all committed to meeting the ultimate objective of a graduate fully prepared for immediate productivity and advancement.

The fundamental beliefs of Milwaukee School of Engineering are the following studyhttp://www.msoe.edu/president/philosophy.shtml:

- The focus is on the individual student.
- Lifelong learning is essential for success.
- Dedicated faculty with relevant, up-to-date experience are the heart of our teaching process.
- Scientific and mathematical reasoning and processes are essential.
- Applied research and evolving and interdisciplinary technologies are vital in exploiting opportunities.
- The development of communication skills is needed to function effectively.
- The student experience is strengthened by interaction with the business, industry and healthcare fields.
- The development of leadership and entrepreneurial characteristics are essential.
- Students, faculty, staff and volunteers all share the responsibility of learning.
- Strong personal values are necessary for success.
- The alumni strengthen the institution through their counsel, encouragement and support.
- Freedom with responsibility is the foundation of free enterprise.
- There is strength in diversity.
- Global awareness must be reflected in all activities.
- Initiation and acceptance of change is required to anticipate and capitalize on opportunities.

Architectural Engineering & Building Construction Department

The AE&BC Department offers a bachelor of science degree in architectural engineering, a bachelor of science degree in construction management, a master of science degree in structural engineering, and a master of science degree in environmental engineering (http://www.msoe.edu/ae/).

Concentration, on the undergraduate level, is in building construction, economics, methodology, management, and construction management and design (electrical, environmental and structural). The department uses various technical facilities to support the specialization, including CAD laboratories, AE-dedicated microcomputer laboratory, senior project design studios, energy systems laboratory, strength of materials laboratory, construction materials laboratory, and structural/construction testing laboratory.

All incoming full-time students are enrolled in a mandatory laptop computer program. Many classrooms are wired for connection to the network and Internet and many software packages are installed directly on the laptops. Students can work without connecting to the network and do laboratory work from many locations on campus, including the library and campus center building (**http://www.msoe.edu/ae/)**.

Curriculum changes

Over the years, Milwaukee School of Engineering's programs, in an effort to remain at the cutting edge, continued to add new courses and content without realistically evaluating whether students were able to graduate in four years. Recently, engineering programs at MSOE re-evaluated course credits required for graduation.

MSOE is on the quarter system. The rationale for reducing credits came from a comparison of total credits with other schools on a semester system. The outcome of the evaluation was a decision to reduce the total number of credits for graduation. If one prorates our quarter-credit requirements to the equivalent in semester credits, one would find that MSOE continues to have high credit requirements for graduation. In spite of this reduction, we continue to meet ABET requirements. The challenge to reduce the number of credits has had the side benefit of forcing faculty to take a fresh look at course content and goals. The AE&BC Department's redesign included combining three existing courses—a three-credit materials and methods survey course, a one-credit materials and methods lab, and a three-credit chemistry of building materials course into one four-credit materials' course for freshman. This report summarizes the process used.

"The Green Report: Engineering changes for a changing world"

The "Green Report" makes a number of recommendations for engineering education that have been integrated into this new course. "One factor that will promote development of students' "process" skills is widespread use of multimedia, worldwide information networks. Using this resource, students can access new information and course work, as well as interact with other students, researchers, practicing engineers in industry and government, and experts from around the world."[Green Report] New assignments will include readings from the textbook as well as "scavenger hunts" to construction industry web pages for information that reinforces lectures and readings. In other words we will be teaching students to go right to the source of the latest information on standards and properties of materials. "These changes in the teaching and learning environment will make engineering education more attractive to both students and faculty, if faculty are given the opportunity to stay up to date."[Green Report]

2.0. New course development

AE-1231 Building Construction Materials was developed to be a new course required of all students who enter MSOE's Architectural Engineering and Building Construction programs beginning fall 2002. Students take the course in the third quarter of their freshman year. It is four credits, meeting for three hours of lecture and two hours of laboratory per week. The course is designed to meet ABET criteria for one science credit, two credits in engineering topics, and one credit in general education. The course will be offered for the first time in the spring quarter 2003.

The objective of new course development for AE-1231 Building Construction Materials was to incorporate material from three existing courses, which were being dropped—AE-123 Materials and Methods I (meets for four hours of lecture per week, no hours of lab and worth four credits); AE-222 Construction Materials Laboratory (meets for one hour of lecture, two hours of lab per week and worth one credit); and CH-350 Chemistry of Building Materials (meets for three hours of lecture per week, no hours of lab and worth three credits). AE-123 content covers typical construction materials with an emphasis on mechanical properties. Student feedback over the years relate to the large volume of material covered. AE-222 experiments cover aggregate, steel, concrete, mortar, wood, primarily. Student feedback has indicated that the course is "a lot of" work for only one credit. CH-350 covers the chemistry of typical construction materials, including cement, steel, wood and asphalt. Students take this course in the junior year after completing the two-quarter chemistry sequence, so the level is appropriately higher. These three courses had evolved separately over many years, were not systematically coordinated during those years, but together gave students a foundation of information on construction materials.

Goals of AE-1231 Building Construction Materials

Lecture component

The primary goal of the lecture component is to introduce students to materials used in the construction industry. Materials include metals (iron and steel, aluminum, copper), inorganics (aggregate, concrete and masonry, glass, gypsum) and molecular materials (wood, asphalt, plastics). Each material has unique origins, chemistry, properties, standards, construction industry applications and trade associations, which are included in this introduction. A secondary goal is to incorporate more materials science content for each material, giving students a better foundation in scientific principles and understanding of physical and chemical properties, which determine the behavior of materials in practice. A third goal is to ensure that AE&BC Department faculty can count on a foundation of fundamentals for subsequent upper-level courses.

Laboratory component

MSOE has a tradition of hands-on engineering education with a strong emphasis on laboratories in all of our programs. That emphasis was to be continued in the new course. The laboratory experiments and manual, however, needed updating and streamlining.

Research component

Because there is no way students can be introduced to all of the materials they will encounter during construction, another goal is to introduce them to research tools and skills that they can use to find and evaluate information for themselves. In many AE&BC courses, students are required to assemble a portfolio of their work. It was decided to require them to assemble a portfolio of technical information sources on materials that they can use as they progress through their engineering education at MSOE and beyond as practicing engineers.

With the explosion of information available on the Internet, it is increasingly important for students to develop skills for evaluating material for quality and bias. To that end,

students are required to write one-page critiques on articles, evaluating credentials of authors, the purpose and audience for the information, the funding source and, in particular, indicating if the conclusions are reasonable based on information given in the article.

Because communicating technical information concisely and clearly is increasingly important to engineers, students are required to do a research project on a subject of their choice and to write a report (five pages maximum per person) summarizing their findings, on which they make a brief presentation (less than 10 minutes) to the class. These presentations are peer-reviewed by their classmates.

We decided to take an inclusive approach to developing course content on materials and give members of the department an opportunity to participate in the sifting and winnowing process later. The first working draft of AE-1231 included a list of all of the construction materials covered in the three existing courses. All of the lecture notes from the existing courses were sorted by construction material and included in the draft outline.

ASTM standards referenced in previous lecture and laboratory course notes were identified and updated. Research was done to identify important trade associations and their web sites for each construction material. A list of these sites was compiled. Recent study guides for the engineering fundamentals exam were evaluated for the types of content, particularly on materials science, included for each material. This content was also included on the outline by material.

From this broad outline, a day-by-day topic outline was developed. The number of days given to each construction material was based on the authors' estimation of its importance. The syllabus was developed to give members of the department course goals, grading guidelines, and a grading matrix by which student reports are to be evaluated. Also included for each day were a list of objectives, an outline, study questions, text and web-based resources, and relevant ASTM standards.

The 55-page day-by-day course outline was given to each faculty member, and each was asked for feedback. Not surprisingly, few responded, so a one-page matrix was developed and distributed to faculty. Each of the construction materials and/or topics was listed on the left and faculty were asked to rank the importance of the topic from "much more emphasis needed" to "drop." This matrix can be found in Appendix 1.

Most of the seniors were given this survey, as well. It was assumed that they had completed all three of the courses. Several of the students had also taken the fundamentals of engineering exam. Appendix 2 contains student responses to the survey. Table 1 summarizes responses; items to drop and reduce emphasis were combined and ranked by number of responses. Items for which more emphasis was needed were ranked similarly. Items in bold were identified as topics potentially covered on the fundamentals of engineering exam.

Concrete, masonry, insulation, iron and steel (and corrosion) and wood were identified for more emphasis, particularly by faculty. Several fundamentals of engineering exam topics (polymeric state, crystal structure, and chemical bonding), cement chemistry, asphalt and asphalt shingles and gypsum were identified, particularly by students, as topics to de-emphasize. However, because engineering fundamentals of engineering exam topics were considered as essential by the authors, they were not deleted.

Table 1. Summary of survey responses.

Rank	Drop + Reduce	OK	More + Much more
1	**Polymeric state**	**Iron and steel**	Concrete
2	**Intro. to crystal structure**	Wood	Masonry
3	**Chemical bonding**	Composites	Insulation
4	Cement chemistry	**Properties of materials**	CSI etc.
5	Paints, etc.	Soil	**Iron and steel**
6	Asphalt shingles	Aggregate	Admixtures
7	Asphalt	Al, Cu, and other metals	**Corrosion of iron and steel**
8	Gypsum	Masonry	Wood

Based on feedback, the goals, outline, and syllabus were revised. The daily lecture topic outline can be found in Appendix 3. The syllabus with report grading matrix can be found in Appendix 4. A sample daily lesson for aggregate can be found in Appendix 5. The laboratory outline can be found in Appendix 5.

Because none of the faculty had previously taught all three courses, we realized that a significant effort would be required to update faculty, particularly on the chemistry aspects of materials. Sessions on chemical bonding, cement chemistry, metals, polymers and wood chemistry were held and resource materials provided to participating faculty. There is ongoing coordination to assure consistency in meeting course objectives, topics covered, homework, and grading.

Assessment tools are also being developed, which will include both pre- and post-assessment surveys.

Additional considerations.
The new materials course is to be taught to freshmen. Previously, the materials and methods course was taught in the sophomore year and Chemistry of Building Materials in the junior year. Freshmen will come into this course with less chemistry and physics fundamentals and less maturity than previous classes. The success of the new course will depend on bridging these gaps.

REFERENCES

http://www.msoe.edu/president/mission.shtml

http://www.msoe.edu/president/philosophy.shtml

http://www.msoe.edu/ae/

http://www.asee.org/publications/reports/greenworld.cfm

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Michael McGeen is an Associate Professor of AE&BC at MSOE. He is active in the Rapid Prototyping Center at MSOE and has served as an adviser for the Research Experiences for Undergraduate program since 1998. Professor McGeen is a registered Architect with a Masters degree in Architecture from the University of Wisconsin – Milwaukee. In May of 2002 he was the recipient of the Milwaukee School of Engineering, Karl O. Werwath Research Award.

CAROL DIGGELMAN, PhD
Carol Diggelman is a professor in the Architectural Engineering & Building Construction (AE&BC) Department at Milwaukee School of Engineering (MSOE). She is in her 25th year of teaching at MSOE and teaches across two departments- the AE&BC and Physics and Chemistry Departments. She teaches undergraduate courses, including Building Construction Materials, General Chemistry, Chemistry of Building Materials, and Environmental Issues and a graduate class, Hazardous and Solid Waste Minimization, in MSOE's MS in Environmental Engineering Program. She won the Falk Engineering Educator Award in 1988, the Oscar Werwath Teaching Award in 1991 and the Karl O. Werwath Engineering Research Award in 1999. She received her PhD in Environmental Engineering from the University of Wisconsin-Madison in 1998. Her current environmental engineering research activities are in solid waste and recycling.

APPENDIX 1. MATRIX TO PRIORITIZE TOPICS

AE1231 Building Construction Materials.

Course Primary goal: To introduce students to materials used in the construction industry. Materials include metals (iron and steel, Al, Cu), inorganics (aggregate, concrete and masonry, glass, gypsum) and molecular materials (wood, asphalt, plastics).
Secondary goal: To introduce students to research tools and communication skills that will enable them to access technical information on materials, evaluate that information for quality, summarize findings concisely and communicate those findings effectively.

To enable us to revise the proposed course outline for AE 1231will you please take a few minutes to check the box for each topic item which most closely matches your assessment. Thank you C. Diggelman and M. McGeen.

Item	Drop	Reduce emphasis	Emphasis OK	More emphasis needed	Much more emphasis needed	Comments
Lecture (quizzes and portfolio) = 45%						
Project = 25%						
Laboratory = 30%						
Daily lecture topic outline						
Week/Day						
1/1. CSI, *Master Format,* specs, stds, codes						
1/2. chemical bonds and material properties						
1/3. properties of materials						
2/1. soil						
2/2 & 2/3. aggregate						
3/1. cement chemistry						
3/2. concrete						
3/3. admixtures						
4/1 & 4.2. masonry						
4/3/ introduction to crystal structure						
5/1. iron and steel						
5/2. corrosion of iron and steel						
5/3. aluminum, copper and other metals						
6/1 & 6/2. wood						
6/3. engineered wood and treated lumber						
7/1. polymeric state						
7/2. plastics						
7/3. paints, coatings, adhesives						
8/1. insulation						
8/2. asphalt						
8/3. asphalt shingles and roofing materials						
9/1. glass						
9/2. gypsum						
9/3. composite materials						
Other topics						

APPENDIX 2. STUDENT SURVEY RESPONSES

AE1231 BUILDING CONSTRUCTION MATERIALS						
Student survey- number of responses						
Item	**Drop**	**Reduce emphasis**	**Emphasis OK**	**More emphasis needed**	**Much more emphasis needed**	**Total**
CSI, Master Format, Specs, stds, codes	8	13	27	9	0	57
Chemical bonds and material properties	**7**	**27**	**21**	**2**	**1**	**58**
Properties of materials	**2**	**11**	**38**	**5**	**0**	**56**
Soil	3	10	35	5	0	53
Aggregate	1	18	37	1	0	57
Cement chemistry	2	28	26	2	0	58
Concrete	3	13	32	10	1	59
Admixtures in concrete	2	17	33	9	0	61
Masonry	2	9	33	10	0	54
Introduction to crystal structure	**14**	**22**	**19**	**1**	**1**	**57**
Iron and steel	**1**	**7**	**39**	**9**	**0**	**56**
Corrosion of iron and steel	**3**	**13**	**34**	**8**	**0**	**58**
Al, Cu and other metals	2	13	34	5	0	54
Wood	1	9	42	7	1	60
Engineered wood and treated lumber	5	13	32	5	2	57
Polymeric state	**8**	**29**	**18**	**0**	**1**	**56**
Plastics	4	21	39	2	0	66
Paints, coatings, adhesives	5	23	26	5	0	59
Insulation	1	20	27	10	0	58
Asphalt	3	22	30	3	0	58
Asphalt shingles and roofing materials	2	25	27	3	0	57
Glass	3	18	32	5	1	59
Gypsum	3	20	33	2	0	58
Composite materials in construction	2	12	35	1	1	51
Average percent	6	30	54	9	1	100

APPENDIX 3. AE1231 BUILDING CONSTRUCTION MATERIALS
DAILY LECTURE TOPIC OUTLINE

P.4.	WEEK 1. Day 1.	Topic. Course introduction.
P.6.	WEEK 1. Day 2.	Topic. Introduction to soil classification.
P.82.	WEEK 1. Day 3.	Topic. Aggregate.
P.11.	WEEK 2. Day 1.	Topic. Chemical bonding.
P.13.	WEEK 2. Day 2.	Topic. Introduction to crystal structure.
P.15.	WEEK 2. Day 3.	Topic. Properties of materials.
P.15	WEEK 3. Day 1.	Topic. Properties of materials.
P.17.	WEEK 3. Day 2.	Topic. Composite materials.
	WEEK 3. Day 3.	**Exam 1. Soil classification through composites.**
P.19.	WEEK 4. Day 1.	Topic. Cement chemistry and gypsum.
P.21.	WEEK 4. Day 2.	Topic. Concrete.
P.21.	WEEK 4. Day 3.	Topic. Concrete.
P.24.	WEEK 5. Day 1.	Topic. Admixtures.
P.26.	WEEK 5. Day 2.	Topic. Masonry.
P.26.	WEEK 5. Day 3.	Topic. Masonry.
	WEEK 6. Day 1.	**Exam 2. Cement chemistry through masonry**
P.30.	WEEK 6. Day 2.	Topic. Metals - iron and steel.
P.30.	WEEK 6. Day 3.	Topic. Metals - iron and steel.
P.33.	WEEK 7. Day 1.	Topic. Metals - corrosion.
P.35.	WEEK 7. Day 2.	Topic. Metals - aluminum, copper and others.
P.36.	WEEK 7. Day 3.	Topic. The polymeric state.
	WEEK 8 Day 1.	**Exam 3. Metals.**
P.39.	WEEK 8. Day 2.	Topic. Wood.
P.39.	WEEK 8. Day 3.	Topic. Wood.
P.42.	WEEK 9. Day 1.	Topic. Engineered wood and treated lumber.
P.43.	WEEK 9. Day 2.	Topic. Plastics and insulation.
P.46.	WEEK 9. Day 3.	Topic. Asphalt.
P.48.	WEEK 10. Day 1.	Topic. Final presentations.
P.48.	WEEK 10. Day 2.	Topic. Final presentations.
P.48.	WEEK 10. Day 3	Topic. Final presentations.
WEEK 11.		**FINAL EXAMINATION**

APPENDIX 4. AE1231 BUILDING CONSTRUCTION MATERIALS COURSE SYLLABUS.

TEXT: **Mamlouk, Michael S. and John P. Zaniewski. 1999** *Materials for Civil and Construction Engineers,* Addison Wesley Longman, Inc., 2725 Sand Hill Road, Menlo Park, CA 94025.

COURSE GOALS: The primary goal of this course is to introduce students to materials used in the construction industry. Materials include metals (iron and steel, aluminum, copper), inorganics (aggregate, concrete and masonry, glass, gypsum) and molecular materials (wood, asphalt, plastics). Each material has unique origins, chemistry, properties, standards, construction industry applications and trade associations, which are included in this introduction.

A related goal is to introduce students to research and communication skills that will enable them to access technical information on materials, evaluate that information for quality, summarize findings concisely and communicate those findings both in writing and orally. The student will assemble a portfolio of information that has the potential to be a useful resource on materials throughout their academic career at MSOE and beyond.

GRADING GUIDELINES: The course grade will be determined from three primary activities—lecture, project and laboratory. There are weekly quizzes (with the lowest dropped). Students are required to develop a resource portfolio that includes class notes, homework, graded laboratory reports, and related resource material. Students are required to do a research project comparing an existing to a new construction material, application, product or process on a topic the student chooses. Project requirements include submitting data search findings for review, submitting a rough draft for evaluation, a final project report (approximately five pages per person) and short presentation (six minutes) on the final project report.

Grading guidelines are given below:

Lecture:	
Three one-hour exams	35%
Portfolio	5%
Class notes	
Homework	
Project:	20%
Data search	
Rough draft	
Final project	
Presentation	
Laboratory reports	20%
Final examination	20%
Total	100%

AE1231 Building Construction Materials Grading Matrix for Paper		
Report Section and Checklist	**Points**	**Your Points /Comments**
Abstract In one paragraph give ○Project definition and purpose ○Methods used ○**Most important findings**	**10**	
Project definition **Baseline material/process/product** ○Physical, chemical, engineering properties ○Design life ○Cost **New material/process/product** ○Physical, chemical, engineering properties ○Design life ○Cost	**30**	
Literature review summary ○Engineering data bases ○ASTM specifications ○Internet sources ○Practitioner interviews ○Other	**20**	
Comparison ○Performance ○Costs ○Environmental impacts (For example, energy impacts, hazardous materials used, recyclability, air and water pollution impacts) ○Discussion of life-cycle performance, cost, environmental impacts	**20**	
Conclusions and recommendations	**10**	
References Use ASCE format http://www.msoe.edu/library/technical_style_guide.html .	**10**	
Appendix With vendor information, MSDS, specifications and supporting information		
Total	**100**	

APPENDIX 5. AE1231 BUILDING CONSTRUCTION MATERIALS SAMPLE DAILY LESSON

AE1231. WEEK 1. Day 3.
Topic-Aggregate.

Objectives

1. Define aggregate.
2. What is the difference between a natural and a synthetic (artificial) aggregate?
3. **Explain the three sources of origin for aggregate and compare specific gravity, porosity and compressive strengths, in general.**
4. Explain the difference between a continuous, uniform or gap graded aggregate.
5. **Explain how the particle shape impacts properties of Portland cement and asphalt concretes.**
6. **Explain how the porosity of aggregate impacts properties of Portland cement and asphalt concretes.**
7. **What are the four moisture states of aggregate?**
8. **Which can be used as a reference? Why?**
9. **What is the relationship between porosity and bulk density, strength, elastic modulus and abrasion resistance?**
10. What are considered deleterious substances in aggregate?

Topic Outline.

1.0. Definitions
- 1.1. Crushed stone
- 1.2. Sand
- 1.3. Gravel
- 1.4. Aggregate

2.0. Quantities and applications

3.0. Composition and origins
- 3.1. Igneous
- 3.2. Sedimentary
- 3.3. Metamorphic

4.0. Physical properties
- 4.1. Particle shape
  - 4.1.1. Angularity
  - 4.1.2. Sphericity
- 4.2. Particle size and grading
- 4.3. Toughness, hardness and abrasion resistance
- 4.4. Pore structure
  - 4.4.1. Impermeable
  - 4.4.2. Permeable
- 4.5. Porosity
- 4.6. Moisture states
  - 4.6.1. Oven dry

4.6.2. Air dry
4.6.3. Saturated surface dry
4.6.4. Wet
4.7. Specific gravity

5.0. Chemical properties
5.1. Solubility
5.2. Slaking
5.3. Surface charge
5.4. Coatings
5.5. Reactivity

6.0. Deleterious substances

7.0. Chemical processes that adversely impact concrete and asphalt concrete and corrective alternatives.

8.0. Mechanical properties
8.1. Strength
8.2. Mass stability
8.3. Particle stiffness
8.4. Resilience to repeated loadings
8.5. Durability

9.0. Types of instability

Study Questions.

1. Discuss the three sources of origin for aggregates, comparing specific gravity, porosity and the compressive strengths, as given in Table 10.1 (From Young).
2. What are differences between crushed stone and gravel?
3. What are the steps between rock and aggregate ready to use?
4. Why are aggregates important in Portland cement concretes and asphalt concretes? How do particle shape and porosity of aggregate impact properties of Portland cement concrete and asphalt concrete?
5. Define aggregate porosity; explain its impact on strength and toughness.
6. What are four moisture states of aggregate? Which can be used as references?
7. Why might there be durability problems with aggregate with high absorption capacities?
8. What are examples of synthetic or artificial aggregate? Why might they be used?
9. Identify and briefly describe three physical or chemical processes that result in the breakdown or deterioration of an aggregate.
10. Identify three deleterious substances that occur commonly in natural mineral aggregates and explain why each is considered to be detrimental.
11. What kind of aggregate is found in Wisconsin?

Resources.

Mamlouk, Michael S. and John P. Zaniewski. 1999 *Materials for Civil and Construction Engineers,* Addison Wesley Longman, Inc., 2725 Sand Hill Road, Menlo Park, CA 94025 pp.112-139.

Questions and problems: 5.4, 5.5, 5.6, 5.7, 5.14

Simmons, H.L. 2001. *Construction: Principles, Materials and Methods,* 7th Edition, John Wiley & Sons.

Young, J.F., S. Mindness, R.J. Gray & A. Bentur. 1998. *The Science and Technology of Civil Engineering Materials,* Prentice Hall, pp. 189 to 201.

National Stone, Sand and Gravel Assn (NSSGA) **http://www.nssga.org**

Aggregate-

ASTM C29/C29M-97 Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate.

ASTM C127-01 Standard Test Method For Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate.

ASTM C128-01 Standard Test Method For Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate.

ASTM C566-97 Standard Test Method for Total Evaporable. Moisture Content of Aggregate by Drying.

ASTM C136-01 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

APPENDIX 6. AE1231 BUILDING CONSTRUCTION MATERIALS LABORATORY SCHEDULE.

Week	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1	Introduction									
2	**Report Due**	Soils								
3		**Soils Report Due**	Aggregate							
4			**Aggregate Report due**	Steel Corrosion set up						
5				**Steel report due** ↓Corrosion data	Concrete Mix Design					
6				↓Corrosion data	**Report A due**	Mixing Concrete				
7				↓ Corrosion data		**Report B due**	Concrete 7-day Tests Mortar Mix			
8				↓ Corrosion dat			↓Concrete 14 day test ↓Mortar 7 day test	Wood-Part I		
9				**↓Corrosion report due**			↓Concrete 21 day test ↓Mortar 14 day test		Wood-Part II **Wood report due (Parts I & II) Corrosion report due**	
10							**Concrete report due Mortar report due**			**Concrete report due Mortar report due All work due**

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