

Structural Engineering Practicum: The First Course in a Master's Program

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Born and raised in West Lafayette, Indiana, I made the decision during my senior year to attend Rose-Hulman Institute of Technology over Purdue University despite it being right in my back yard and available at a fraction of the tuition costs of Rose. The prestige and reputation of Rose-Hulman attracted me to Terre Haute, Indiana as well as the opportunities it offered. All things considered, it seemed like the right decision to forgo my hometown college and venture away from home to pursue an excellent education. During my tenure at Rose-Hulman, I was a four-year varsity letter winner on the Swimming and Diving Team. I was voted as a team captain by my teammates for both my Junior and Senior campaigns. Throughout my academic career at Rose-Hulman, I developed a strong interest in structural engineering. As a result, I decided to focus on this discipline for the remainder of my undergraduate career, learning as much as possible through my professors and related course-work. I opted to continue my education after having completed my Bachelor's Degree in Civil Engineering. As a result, I decided to return to my Alma mater to complete a Master's curriculum with a focus in structural engineering. After completing my Bachelor's Degree in Civil Engineering in May of 2013, I accepted an internship opportunity with Walter P Moore in Dallas, Texas. During this internship, I worked with the Diagnostics Services Group analyzing structural issues and problems with existing structures. As part of the requirements for the engineering practicum, I conducted interviews with many of the members of the structural design team to learn about various aspects of the culture of both the industry and Walter P Moore as a firm. Currently, I am working towards my Master's Degree at Rose-Hulman where I expect to graduate in May of 2014.

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Abstract:

The Civil Engineering Department at Rose-Hulman Institute of Technology recently created a course-based master's degree program in structural engineering. A distinguishing feature of that program is the Structural Engineering Practicum. Each incoming student must complete the practicum course before beginning the other coursework. The practicum has two requirements: an internship experience with a structural engineering firm and essays on their experience.

The practicum requires each student to write ten essays based on either first-hand experience during their internship or interviews with engineers who have the specific experience. Each essay must address a list of questions that the instructors developed to guide the experience. The essay topics expose the students to aspects of business such as obtaining work for the firm, planning and running client meetings, and project management. Other essays introduce the students to technical aspects such as decision making in the schematic design phase, designing for constructability, integrating gravity and lateral load systems, coordinating non-structural elements, creating construction documents, responding to requests for information from the field, and the quality assurance process.

The practicum requirements encourage the students to meet multiple engineers within the firm in order to see their future career from the perspective of several different people. This paper summarizes feedback from the students and employers about the outcomes of the practicum, what worked well in the experience and what could be improved. It also contains the lessons learned by the faculty. The feedback from the students and employers has been encouraging. A requested enhancement is creating a forum for the students to share their experiences with each other.

Introduction:

Practicums have been a formal part of educational preparation for professions like teaching and nursing for some time. Unlike an internship which provides job experience, the practicum combines job experience with specific educational objectives. The structure provided in a practicum allows faculty to ensure that each student's work experience exposes the student to key situations encountered in practice and provides the student one-on-one guidance. Typically, the practicum involves a practitioner mentor.

The faculty at Rose-Hulman Institute of Technology are applying the practicum model that has been so successful in other fields to the preparation of structural engineers.

Overview of Practicums in Other Fields:

Nursing

Licensure as a nurse typically requires completion of an academic pre-licensure program. Most, if not all, of the state licensing boards require that the program include an integrated practicum (e.g., Kentucky Board of Nursing 2007). The form and specific objectives of the practicum are decided by the school. Reviewing the course catalogs at three of the top nursing programs in the

United States reveals that each of the schools offers a significant number of courses that are either completely practicum or at least include a practicum (Table 1).

Table 1. Number of Practicum Courses Offered at Leading Nursing Schools.

School	Number of Practicum Courses
Johns Hopkins University	29
University of Pennsylvania	12
University of Washington	35

Flood and Powers (2012) describe the nurse educator programs which create faculty for nursing programs. Their focus was on the special practicum candidates go through in order to prepare them to be nurse educators. Not only does the nursing profession value the practicum experience for soon-to-be nurses, it uses the practicum to train nursing faculty.

Teaching

Certification requirements for teachers in most states include student teaching experience. Although different academic programs use different terms, the student teaching experience is a practicum; it has specific educational objectives that are evaluated for course credit, and it involves practical experience in the field.

At Vanderbilt University's Peabody College of Education and Human Development, many of the practicums involve a contract between the student and instructor (Peabody College 2013a). The contract typically includes a summary of what the student thinks the practicum will contribute to his or her professional development, a list of specific activities the student plans to carry out, a list of specific outcomes the student hopes these activities will help him or her achieve, and a list of ways the student expects to document success in achieving those outcomes (Peabody College 2013b).

Wyss *et al.* (2012) studied teaching practicums and made the following observation. As the practicum progressed, students' comfort with unit planning decreased even though they had significant instruction on the topic. The authors hypothesize that the decrease may be due to difficulties student teachers encounter when trying to implement their lesson plans with "real live" students; the actual responses of the K-12 students rarely fit within the plans of the student teachers. An analogy to structural engineering would be the intern who struggles to apply concepts from class to an actual design because the reality does not resemble the situations observed in class.

Other Fields

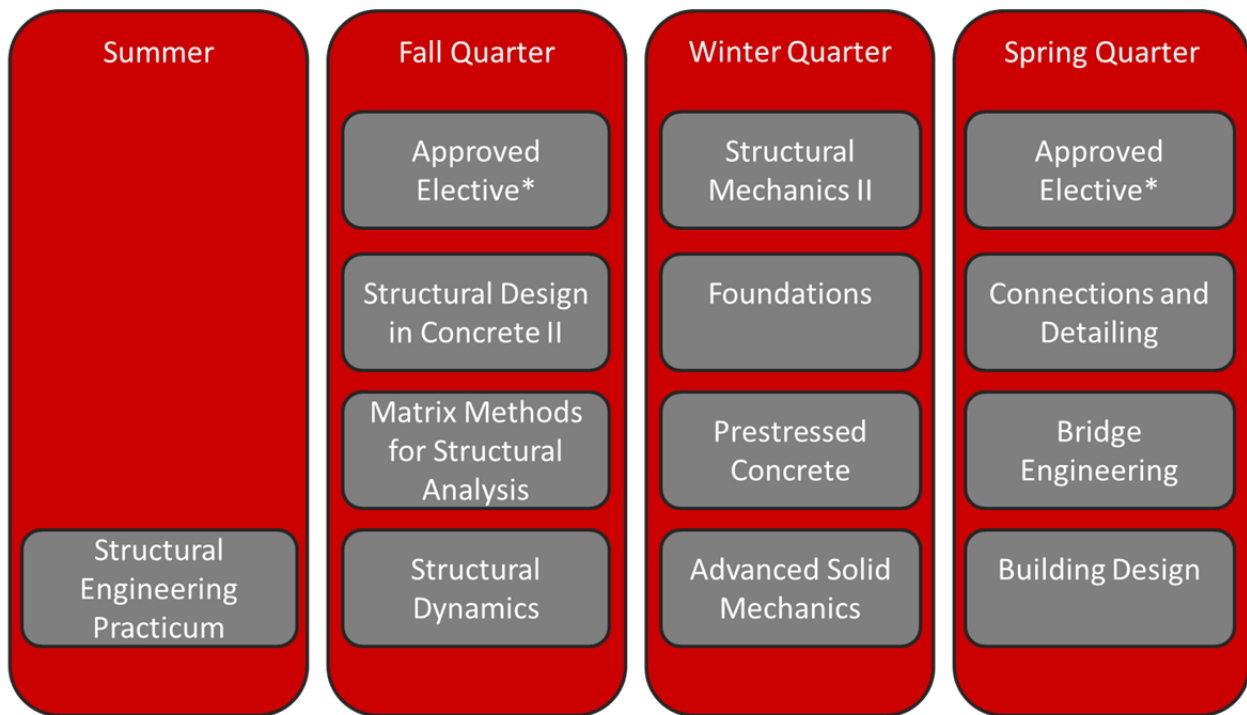
Practicums are commonly used in other fields as well. Li and Fiorello (2011) point out that the practicum is an essential part of school psychologist education, but that the content and length of practicums vary widely between programs. An emerging issue in that field is the combination of practicum experience and experience toward licensure. According to the authors, the Council of Directors of School Psychology Programs developed a task force to address issues with the practicum.

Practicums are common in a Master of Social Work program. Lee and Fortune (2013) conducted research on practicums in MSW programs in order to evaluate the importance of “thinking” activities in addition to “doing” activities. They concluded that student reflection is an important part of the learning process in a practicum, and that “school faculties can facilitate students’ reflection by focusing on application of theories in practice situations” (p. 657).

Several business programs require a practicum. At Stanford University, the Graduate School of Business considers the practicum to be “a key element in the revamped program” for Public Management (Stanford University 2010). One of the avenues for this practicum is the summer internship program. The Wharton School at the University of Pennsylvania offers a “consulting practicum” as part of its MBA program (Wharton 2013). The consulting practicum partners students with a client company in order to develop operational plans for the clients. The program appears to be analogous to civil engineering capstone projects when there is a real-world client.

Overview of Master’s Program:

The new Master’s program in structural engineering at Rose-Hulman is a one-year, course based program. The curriculum consists of twelve courses starting with a practicum the summer before beginning the rest of the curriculum (Fig. 1). The objective of the program is to prepare graduates to practice structural engineering. By understanding structural behavior and fundamental principles, graduates can practice beyond code requirements thus enabling the use of new materials and new structural systems.



*Only one Approved Elective required; can be taken in either term

Figure 1. Curriculum for Master’s Degree in Structural Engineering.

Overview of Structural Engineering Practicum:

Course Objectives

The structural engineering practicum overlays formal learning objectives and structure onto an internship the student arranges. We put the practicum at the beginning of the master's degree course sequence to give students a "big picture" understanding of how structural engineering is practiced before spending nine months delving deeply into the details of structural engineering. This decision helps avoid the difficulty Wyss *et al.* (2012) observed with student teachers.

The practicum course has the following objectives:

1. Gain valuable professional practice experience.
2. Practice skills for learning from mentors.
3. Gather an inventory of decision making processes for structural engineering business and technical decisions.

Course Requirements

The practicum has only two requirements. First, the internship must provide the student with qualifying engineering experience toward professional engineering licensure. Qualifying experience is defined by either the state where the student is working or the state where the student wants to work after graduation. An example of the criteria for qualifying experience is provided by the National Society of Professional Engineers (NSPE 2007).

The second requirement is that the student submits ten essays about business and technical aspects of structural engineering practice. The topics of the essays are prescribed, but the sequence is not. Students can complete the assignments in any sequence based on the opportunities available in their internship.

Course Administration

All of the faculty who teach in the master's program helped develop the assignments, but only one faculty member is needed to administer the practicum. The instructor is responsible for reviewing the student submissions, providing feedback to the students, and scoring the submissions.

Student Role

The student is responsible for finding the internship. However, the faculty help connect each student with potential employers based on where the student would like to work after graduation (e.g., geographic location, size of firm, type of design work). The students are coached to make potential employers aware of the practicum requirements that the students must fulfill. The faculty's expectation is that the students write the essays outside of work hours; therefore, only the interviews should result in non-billable time.

Practicum Assignments:

Development of Assignments

The four faculty associated with the master's program collectively developed the list of ten topics for the assignments. We chose ten because most internships are at least ten weeks long thus allowing the students to focus on one each week.

Because design offices might not experience all of the events described in the assignments during the short time the intern is there, we developed the assignments such that they can be completed from interviews with experienced structural engineers or based on the internship experience of the student. Therefore, each assignment takes the form of a list of questions the student must answer. We divided development of the ten assignments among all four faculty members. Each faculty member developed the questions for two or three of the assignments based on personal experience and/or discussions with practitioners.

Topics

We developed some of the assignments to guide each student to experience aspects of our profession typically reserved for more senior engineers. We developed some to help the student become aware of and understand the reasoning behind decisions made by senior engineers in the design process. And we developed some to expose the student to challenges commonly faced by new engineers. This approach is consistent with the recommendations of Lee and Fortune (2013).

Specifically, the ten topics are the following:

- Business Aspects of Project Management
- Obtaining a Job for the Firm
- Client Meetings
- Decisions Made in the Schematic Design Phase
- Design for Constructability
- Integration of Gravity and Lateral Systems
- How Non-Structural Elements are Integrated into the Design
- Role of the Designer in Creating the Construction Documents
- Quality Assurance Process
- Role of the Designer in the Construction Phase (responding to Requests for Information)

Submissions

The first iteration of the practicum consisted of two students working at different firms. Each submission was made via email to the instructor. The interns submitted one or two essays per week. The lengths of the submissions ranged from 2 to 7 pages double spaced. The average length was 4 pages.

Each submission required about thirty minutes for the instructor to review and provide feedback. If the submission did not earn a score of at least 70% the instructor asked the intern to address the shortcomings and resubmit. Each of the interns needed to resubmit three of the essays.

Feedback:

As part of the assessment process, we gathered feedback from the students, employers and instructor. Highlights of that feedback follow.

Students

What was the best part of the practicum experience:

- “I felt like the practicum assignments were very helpful. Because I was only able to be in Dallas for 10 weeks, there was no way in which I would have been able to experience and learn everything about working at a design firm.”
- “The essay topics got me to learn about aspects of engineering and project management that I would have otherwise not spent time learning at this point. Interns usually only get to focus on design or technical tasks of project work and not have a chance to deal with the complex business relationships and external relationships (working with clients, etc.) that professional engineers are consistently involved in.”

What would make the practicum better:

- “One of the biggest problems for me was trying to find time to schedule all 10 interviews over the course of 10 weeks.”
- “Perhaps if [our] completed papers were somehow made available to one another during the summer, we could have learned details about each other’s experiences.”

Employers

What advantages do you perceive for the firm:

- “I could see where this information would be helpful for the intern – to get them to see a little more global view of what is going on at their place of employment – and thus get a better understanding of what they’d be getting into if hired at this business or this type of business after school. A lot of times, it is tough for the employer to find the time to provide an intern or newer employee this type of information.”
- “Personally, I found the questions intriguing and interesting to think about and answer. They definitely align very closely with the consultant experience and challenges that I have seen over my career.”
- “The overall approach and my experience with the process was favorable and beneficial for the participants, in my opinion.”
- “The advantage for the firm, in doing many of these interviews is twofold.

First and foremost, it helps us prepare the student for real life situations at hand. In giving examples and discussing the topics, the student can hopefully better understand the topic and will be better prepared to handle it when he/she is out of school and in the workplace. As a company, it is our goal for our internship program, to do our best to give the students a real life example of actual engineering, in hopes that they will be better prepared for what is ahead after school, and hopefully we can take advantage of that training if bringing that student onboard full time is an option.

Secondly, I think it gives us the opportunity to review our own policies and situations, so that we can be better prepared for the same situations as they arise in our own work.”

- “This is the first time we have gone through a practicum curriculum like this. The topics discussed were very applicable and seemed very well thought out.”

What would have made the practicum experience better:

- “It might make sense to tailor the questions a little bit to the type of situation the intern is in – or give alternate versions of the questions.”
- “If I were to pick one thing to change, I would maybe customize the questions a bit more for each topic, that way the student might be able to dig a little deeper within each interview and might be able to get more out of it.”
- “I should have more deliberately planned on [the intern] talking with various senior and experienced staff for the various questions so that [the intern] would have gotten a slightly different perspective on the series of questions. We did that some toward the end, but it was more reactive due to constraints on my time, and it would be good to possibly even suggest this to those interns that are working at a large firm, if this has not already been considered.”

Faculty

Unexpected benefits:

- In order to complete the full list of essays, each student interviewed more than one person. We had anticipated that the supervisor would be the interviewee for all of the essays; by interviewing multiple people, the students were exposed to a wider variety of experiences, ways of performing work, and opinions.
- The diversity of experiences shared in the essays broadened the instructor’s understanding of how structural engineering can be practiced.
- The projects described in the essays add to the real world examples that the instructor can use in other courses.

Unanticipated difficulties:

- We did not anticipate how some of the assignment criteria would be interpreted. In some cases, the resulting reflections from the students were better because of the misunderstanding. In other cases, the students had to reinterview a practitioner in order to rewrite the submission at an acceptable level.

Conclusions:

The Structural Engineering Practicum at the beginning of the Master’s program at Rose-Hulman Institute of Technology has successfully helped students achieve the course objectives:

- Each of the students gained meaningful structural engineering experience that qualifies for licensure.
- Each of the students interviewed at least three different experienced engineers in order to learn about how to practice structural engineering. Asking questions is an important skill for an effective mentor relationship.
- Based on the quality of the submissions, each of the students has learned decision making processes for various aspects of structural engineering design and business.

The practicum has also proved beneficial to the internship employers and to the program faculty.

- Employers value the experiences that the interns get, but would not typically make it a priority to provide those experiences during an internship.
- The interview process encourages the senior leadership at the sponsoring firm to reflect on procedures and policies that should be reviewed periodically.
- The experiences described by the students provide real world examples that can be used to motivate and educate undergraduates and other students in the master's program.

In order to improve the practicum experience, the faculty are working on the following changes:

- Update the language of the assignments that students needed to resubmit in order to reduce ambiguity.
- Create a forum for students to share their practicum experiences once they arrive on campus for the fall term.

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Appendix: Practicum Assignments

General Information:

The practicum is designed to provide you with valuable experiences to augment the technical skills you will develop through the master's program. To ensure you gain the desired experiences to the desired depth, there are 10 specific topics each with its own assignment.

- For each topic, prepare a written submission that addresses all of the items about the topic.
- Submit one written submission per week.
- The experience required to write about the topic may be obtained directly (i.e., being there), or through interviews with firm members who can describe the experience in detail.

Topic: Business Aspects of Project Management

Address the following:

- Describe the project kickoff process. Does it consist of a formal meeting or is it a gradual ramp-up of personnel?
- What is a labor multiplier? What cost items does it include, and how does it affect what is charged to the client?
- Describe the differences between a lump sum and a time and materials contract. Which is the most common for your firm? Which is preferable to your firm and why?
- How does the firm track the budget throughout the duration of a project? Who is responsible for tracking the budget and making sure that a project does not go over budget (title and position, not name)?
- How are human resources allocated for projects? Does each project manager have a staff that works solely for her/him, or are junior level engineers shuffled between projects as needs arise?
- How are subconsultants selected for a project? Who is responsible for coordination with the subconsultants?
- Describe the design scheduling process? Is it a formal process with many intermediate milestones or more informal?
- Who is responsible for developing and maintaining the project schedule (title and position, not name)?
- Describe the project closeout process. Is there an internal meeting to discuss lessons learned? Is there a meeting or questionnaire sent to the client to assess how the project could be run more efficiently?

Topic: Obtaining a Job for the Firm

Address the following:

- What types of projects does your firm seek? Do you consider the scale of the project?
- What are your major sources of jobs?
- How much consideration is given to the various components that a project has to offer, and how much is given to the potential monetary benefit?
- What are all the considerations that are taken into account before bidding for a job?
- How does the profit margin fit into the bidding process?
- How are these projects advertised or how do design firms get to know about these projects?
- What are the marketing methodologies that your firm employs?
- After learning about upcoming projects, what steps does your firm take to win the project?
- After obtaining a job, what are the key steps before actual design begins?
- After obtaining a job, what does your firm do to obtain more projects in the future from the same client?
- What are some of the challenges to obtaining a project from a private or government entity?
- Identify a major project that was awarded to your company:
 - Briefly describe the project, especially the key components of the project. You can leave out the name if needed for confidentiality reasons. Provide enough information to understand the magnitude and type of project (e.g., 15 story condominium in Florida).
 - Who were the employees (titles and positions, not names) that played key roles in obtaining the project and what were their specific roles?
 - What were some of the key challenges faced in obtaining the project? How were they overcome?

Topic: Client Meetings

Address the following:

- In what situations would a meeting be initiated by the designer or by the client?
- For the example situations described above, who sets the meeting agenda and controls the flow the meeting?
- Describe the differences in meeting content if an owner is present versus only technical personnel (e.g., an architectural firm is the client and the owner of the project is not present).
- Describe the company policy (formal or informal) regarding client contact. Is it a single point of contact or many? Why?
- Attend a client meeting or discuss a recent client meeting with a member of your firm.
 - Briefly describe the project. You can leave out the name if needed for confidentiality reasons. Provide enough information to understand the magnitude and type of project (e.g., 15 story condominium in Florida).
 - Who attended the meeting? Include titles, positions, and affiliations (client representative, representative of your firm, or other entity), but do not include names.
 - What was main the purpose of the meeting (e.g., periodic update, problem on the project, kickoff meeting, design review meeting)?
 - Describe the level of formality and general tenor of the meeting. How would each of these items change based on the purpose of the meeting?
 - Describe methods that the representatives of your firm used to assure the client that the project would be successfully completed? Focus on how challenging situations or difficult questions were addressed.
 - Did representatives of your firm use time with the client (before, during, or after the meeting) to do marketing of other services or for other projects? If so, describe methods used.

Topic: Decisions Made in the Schematic Design Phase

Address the following:

- What is the purpose of the schematic design phase? When does it occur in the design sequence?
- Pick a particular project that has been through the schematic design phase.
 - Briefly describe the project. You can leave out the name if needed for confidentiality reasons. Provide enough information to understand the magnitude and type of project (e.g., 15 story condominium in Florida).
 - Who was involved (titles and positions, not names) and what was each person's role in the schematic phase?
 - How were the principles of sustainable design (economic, social, and environmental) addressed in the schematic phase?
 - What decisions were made in the schematic phase for that project?
 - Pick two key decisions made in the schematic phase. For each decision, address the following:
 - What considerations went into making the decision?
 - Why did the design team ultimately make the choice they made?
- What signals transition out of the schematic phase into the design development phase?

Topic: Design for Constructability

Note: If the firm has not designed a project that fits well with this assignment, work with the firm to identify a project that would have benefited from designing for constructability and address the following as if that project had been designed for constructability.

Address the following:

- Pick a project where design decisions were made specifically to enhance constructability.
 - Briefly describe the project. You can leave out the name if needed for confidentiality reasons. Provide enough information to understand the magnitude and type of project (e.g., 15 story condominium in Florida).
 - Pick two major design decisions made to enhance constructability of the project. For each decision, address the following:
 - Who was involved in the decision (titles and positions, not names)?
 - When in the design process was the decision made?
 - What decision was made and why?
 - What would the "traditional" choice have been?
 - How did the decision impact the project?

Topic: Integration of Gravity and Lateral Systems

Address the following:

- Pick a particular project that has been through the detailed design phase.
 - Briefly describe the project. You can leave out the name if needed for confidentiality reasons. Provide enough information to understand the magnitude and type of project (e.g., 15 story condominium in Florida).
 - Describe the gravity system chosen. You may include sketches if helpful.
 - Describe the lateral system chosen.
 - Explain the process by which designers made sure that members common to the gravity and lateral systems were adequate. When in the design process did that occur?

Topic: How Non-Structural Elements are Integrated into the Design

Address the following:

- Identify major non-structural elements that are typically included in buildings or bridges. What are common integration issues that must be addressed in the design?
- Who are the key players for the different non-structural elements (titles and positions, not names)?
- How are the details of the various non-structural elements communicated between parties?
- At what stage in the design process is the consideration of non-structural elements critical to the design?
- Pick a particular project that includes at least two significant non-structural elements.
 - Briefly describe the project. You can leave out the name if needed for confidentiality reasons. Provide enough information to understand the magnitude and type of project (e.g., 15 story condominium in Florida).
 - Identify the key people (titles and positions, not names) in charge of the non-structural elements.
 - Describe how each of the non-structural elements was integrated and identify any challenges encountered.
 - What are some lessons learned or tools available that help to address integration of these elements?
- If a non-structural component does not fit or has an issue, what is the protocol for addressing the problem?

Topic: Role of the Designer in Creating the Construction Documents

Address the following:

- Describe key differences between design drawings and construction drawings.
- What are specifications?
- At what stage of the design process are construction drawings created and by whom are they created (titles and positions, not names)?
- What constitutes a construction change that must be documented?
- What is the procedure if a designer from this firm identifies changes that need to be made after the construction documents are already sent to the field?
- Are there any cost implications associated with design changes? If so, who is responsible for the cost?
- Pick a particular project that has been through or is currently in the construction phase. Review the specifications and construction drawings:
 - Briefly describe the project. You can leave out the name if needed for confidentiality reasons. Provide enough information to understand the magnitude and type of project (e.g., 15 story condominium in Florida).
 - Identify three key parts of the specifications that were created by structural engineers for this project. What are the parts? What process did the engineer(s) use to draft these specifications?
 - How are changes on the construction drawings noted?

Topic: Quality Assurance Process

Address the following:

- Describe the firm's quality assurance process.
 - Is the process standardized? If not, answer the next two questions based on the typical process.
 - What procedures are followed by designers working on the project?
 - What procedures are used to review the project (i.e., outside of the designers working on the project)?
- Pick a project that had a design flaw identified by the quality assurance process.
 - Briefly describe the project. You can leave out the name if needed for confidentiality reasons. Provide enough information to understand the magnitude and type of project (e.g., 15 story condominium in Florida).
 - What was the design flaw?
 - How was the design flaw detected?
 - How was the design flaw remedied?

Topic: Role of the Designer in the Construction Phase (responding to Requests for Information)

Address the following:

- Who establishes the communications protocol for those involved in the construction work?
- How are errors or omissions in contract drawings dealt with?
- Who reviews and approves working drawings and submittals by the contractor?
- The construction phase of a project begins with a “Project Kick-off Meeting”. What is the essence of the Kick-off Meeting?
- Who are those present at the “Project Kick-off Meeting”? List the job titles of all key participants.
- Identify a project where a contractor wanted to implement a design different from the one indicated on the design drawings:
 - Briefly describe the project. You can leave out the name if needed for confidentiality reasons. Provide enough information to understand the magnitude and type of project (e.g., 15 story condominium in Florida).
 - What was originally designed and what was proposed as an alternative?
 - What was the process by which the contractor proposed the change? What was the process by which the firm decided whether the change was acceptable?
- Identify a project where there was a problem in the field:
 - Briefly describe the project. You can leave out the name if needed for confidentiality reasons. Identify roughly when the design was completed compared to when the problem was identified.
 - How did the contractor notify the design firm of the problem (i.e., communication method)?
 - Who received the communication (title and position, not name)? Why was that person chosen to receive the communication?
 - What request(s) did the contractor make in the communication?
 - What was the design firm’s response? How did the firm member decide on that response?