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Coordinating Field Trips for Design Courses

Prof. Scott A Civjan P.E., University of Massachusetts, Amherst

Scott Civjan is a faculty member at UMass Amherst where he has taught a wide variety of undergraduate and graduate courses over the past 20+ years. He has 4 years of consulting experience between obtaining his BSCE from Washington University in St. Louis and his MS and PhD in Structural Engineering from the University of Texas Austin.

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Abstract

An instructor's experience is presented on how they effectively plan and execute field trips of construction sites as part of a senior level design class. The focus of the paper is on structural and geotechnical components of construction, though the recommendations are applicable to a wider tour scope of topics and classes. Clearly defining the purpose and goals of the field trip, coordinating with construction managers and others involved in the project throughout the planning and tour, and organizing the activity are all important to providing a meaningful experience that addresses the class learning objectives. A range of examples are presented of tours that have been conducted to demonstrate specific learning opportunities available at construction sites. Photos are provided in order to show the range of topics that have been included in this class, but the overall planning and organization would be applicable to any construction site field trip.

Introduction

The use of field trips has been shown to be an effective method of teaching so long as the trip is planned and implemented effectively (1-3). Field trips to construction sites for design classes can directly relate class assignments to real structures, giving students a perspective on the interaction between disciplines (owner, architect, construction managers, sub-contractors and engineers), and boosting confidence of engineering students. However, to maximize their potential, tours should be implemented with purpose and relate directly to class material. While students are often excited to just get out of the classroom and see design calculations realized at the construction site, the opportunity for much deeper learning can take place if properly planned and executed. This has been reported for both engineering curriculum field trips (3-5) as well as field trips for younger students (2, 6-8), with many of the general recommendations to improving the learning experience similar for all levels of education and age groups. These resources typically state the importance that a field trip is clearly linked to the curriculum (2, 6-8) through thoughtful activities leading up to and after the trip. Preparation should include pre-visits by the instructor to the site, clear communication with the hosts and preparation of the students for the trip (2, 5-8).

A field trip to tour a construction site tour has an inherent link to civil engineering design class curriculum. However, planning and integration of materials by the instructor can increase this connection and improve learning opportunities. In order to be most effective, construction site tours need to have a clearly defined purpose, directly relate to the curriculum and communicate information effectively. These goals are difficult to accomplish if the faculty member is not directly involved in the planning and guidance of the tour. Too often faculty members feel uncertain about the site conditions or design experience, and therefore place the responsibility on a construction manager or alumni to develop the tour content. These individuals may be similarly uncertain of leading a tour to engineering undergraduates, or have misconceptions of what is covered in the curriculum. This can lead to tours being ineffective at linking issues back to curriculum and providing inconsistent content from year to year.

The purpose of this paper is to provide some guidance that can be used to plan and implement field trips for civil engineering design classes. Specific photo examples of tours and highlighted features are then provided to show the range of topics that have been included in a Design of Steel Structures class. These specific examples are intended for faculty teaching classes with similar content, but the overall planning and organization recommendations would be applicable to any construction site field trip.

Defining goals and objectives

Mason (1) reviewed 43 studies on the effectiveness of field trips at the university, secondary and elementary education levels. Though most of the included studies related to science activities and many compared field trips as a substitute instruction for class or laboratory instruction, the author concluded that

> *Virtually all results indicated that field work should be used in conjunction with, or supplementary to, other methods of instruction.*

The recommendations stated by McLoughlin (6) are a good starting point for any field trip. Specifically, the field trip should be planned such that students

> *actively seek out information that makes them think, compare it to what they already know, internalize new information, and question what seems problematic.*

Thus, a good starting point is to determine how the field trip could supplement a class and how to engage the students in the visit.

As an instructor, the first question to ask is "what are the goals and objectives" of a field trip to a construction site. Setting up a field trip can take a significant effort, and can be frustrating if the purpose was not met, or seem superfluous if the students or instructor feel like it did not relate to the class. First start with a broad based list of goals that would be ideal for your class. These should be fine-tuned with the characteristics of the specific tour site to see what is realistic and what would fit into the time frame for the tour. Once these goals are laid out, specific objectives can be defined for the tour and discussed with those that will be collaborating.

Specific questions to ask are:

- What can be learned at the field site that cannot be conveyed in class?
- What are the key takeaways you want your students to have?
- How can you most effectively organize the tour to reach those goals?

The answers to these questions will rely heavily on the class that is being taught and the background of the instructor. In addition, the time for the tour and what is available at the field site are variables that may be partially out of the control of the instructor. It is recommended to start with a more fluid tour initially, assess what worked and what didn't and then add more components in future visits.

As an example for a Design of Steel Structures course, a field trip can provide the following context beyond classroom experiences:

- Show how individual design components are incorporated as part of an entire structure
- Provide visual representation of physical components assumed in design , such as connections being pinned versus fixed, brace connections
- Provide physical examples of scale of textbook/class examples
- Demonstrate the construction process, including temporary bracing, plumbing of a building, sequence of construction, etc.
- Define the role of construction manager, field inspectors, engineer, architect and owner
- Demonstrate BIM modeling software and how it is used in real time on a construction site
- Personalize engineering design through students internalizing whether they could see themselves contributing to a structure such as the one being visited

The students could then take away the following:

- Specific new understanding of steel design concepts and details
- Awareness of the many disciplines and roles involved in steel design and construction
- Awareness of how their class design calculations are used in developing a new building
- Increase comfort in being on a construction site and interacting with other disciplines

Based on these goals, specific objectives for the tour could include:

- Introduction of members of the construction team and define their roles
- Provide a general overview of the project including cost, schedule and purpose
- Demonstrate BIM modeling
- Provide a guided schedule of the tour with specific items to be shown (composite deck and slab, typical connections, lateral framing system, temporary supports, foundations, unusual features, architecture mock-up, etc.)

Coordination before the field trip

Several months before the semester starts a series of inquiries about upcoming construction projects should be sent out to find a primary contact. Examples of likely collaborators are those in charge of facilities planning at the University (or other universities if you know of construction at those schools), general contractor or construction management companies working in the area, companies (engineering or contracting) that come to career fairs, and alumni working in relevant companies. The author has found the first of these to be the most consistent collaborators due to a series of construction on campus over the past 20 years. However, all of the others are informally approached throughout the year by stopping by the campus career fairs and seeing alumni or others in the design and construction industry throughout the year.

Clearly stated objectives increase the likelihood that a primary contact will recommend an appropriate project for the field trip. It is important to remember that the field contact does not know what you are looking for, and in many cases does not have a background in the field of study you are teaching. Therefore, it is important to remember that this is a collaboration, not a time to ask them to take care of everything for you. It is surprising how often a faculty member does not feel comfortable in the field so defers to the contact, while the contact is not comfortable with the subject matter. It is also essential to remember that the site representatives have essential information that you want them to impart to your students and can provide all kinds of insight into mistakes that engineers often make, construction issues and the perspectives from the field. Discussions at this early stage to define the site characteristics and time commitments being asked for are essential to a productive tour.

Sit down with your primary contact. Talk through your list of objectives and see what is possible with the sites they have and the time frame you are expecting. Discuss the time commitment you are asking for and whether they or the construction manager of the site would be the best person to be the primary contact.

Meet with construction manager and do a walk-through of the site with them. Ask lots of questions. Get a full sense of what the construction schedule is and what would be seen for a tour scheduled at different times in the semester. Gage their availability to co-lead or lead the tour and interest. If you are looking for any other items that they may be able to provide, such as BIM models, scheduling, or coordination to get other people at the site for the tour find out what is possible. Keep in mind that each of these topics may require others to attend the tour and therefore an increasing time commitment from the general contractor or others. Make sure to ask about safety concerns and requirements. Typically, tours at the end of the day after the workers have left (4PM-5PM) are ideal from a safety perspective, and may be required by the site managers. Being inquisitive and responsive to safety concerns can go a long way toward establishing a positive working relationship. For instance, it is often not realistic for all students to own work boots for a tour. In fact, those that don't have them may be the ones who would benefit most from being on site. Therefore, finding out whether any heavy duty closed shoe will suffice. An example that the author has used is where one contractor required steel toed work boots for all attendees and one student ended up borrowing boots from a friend, ending up with a much more hazardous condition (the shoes were about 3 sizes too large) than if they had worn their own shoes. This example can be used to explain the need for some leniency in requirements. Obtain a copy of any safety waiver that students would need to fill out so these can be brought to the site already completed. Find out whether safety vests and hard hats are required (they almost always are) and the maximum number of students that can go on a single tour (usually 15-20 students at a time) (Figure 1). The latter item will define how many tours need to be scheduled for the class. Determine whether safety equipment needs to be provided by the instructor or is available at the site. Typically it must be provided, and alumni and companies associated with the department are often willing to make donations toward these student learning opportunities. Also confirm whether there are any weather restrictions on the site tour. In general

the author has found that they can occur in almost any weather so long as some decking is in place to shelter the tour.
After this meeting, plan a short follow up meeting to schedule the tour(s) and talk through what your expectations are. Find out any restrictions and talk through what will be shown on the tour. Determine whether the tour will be co-led or primarily led by the instructor or construction manager with the other there to add context and answer questions. The author has found it to be very advantageous to lead the tour himself (with significant construction manager input) in order to specifically relate things to the class, but for the first few years the tours were construction manager led or co-led until the author was more comfortable leading the tour.

The instructor should contact the site a week prior to the tour to confirm the tour times and dates, and also to check that there are not any significant construction schedule issues that will change the content of the tour.

The class content should include as much context as possible prior to the field trip. The instructor should make a point of tying class discussion or assignments to the field trip activity (i.e. "this is difficult to visualize, but should be clear when you see it on the field trip", assign the design of a specific member that can be pointed out on the field trip, etc.). This should include giving students at least a passing knowledge of the scope of the construction project so that they are somewhat familiar with the site. The more that the field trip activity can be introduced as a supplement to course curriculum rather than an isolated additional learning experience, the more directly the connection can be made by the student to class materials. Statements of expectations related to safety and professionalism during the tour should also be conveyed.

Figure 1: Tour group sizes (Photos used by permission)

Coordination during the field trip

To keep everything organized it is helpful to send a short instruction list to students before they come to the field trip. The purpose is a reminder of proper attire, to bring a completed waiver form, designate the specific meeting place and to highlight the expectation that they arrive a few minutes early so that the tour can start on time.

Once arrived it is important to go over safety instructions, including the importance of wearing hard hats, safety vests and goggles at all times, staying with the group, and noting any hazards that might be encountered. All site or other personnel that will be on the tour can introduce themselves, give an overview of the project and explain their role in the project.

If there are any sections of the tour that will take place in the office trailer (such as discussion of BIM modeling or scheduling software) these are ideally done at the start of the tour when everyone is gathered to get safety gear and leave any belongings that aren't brought on the tour.

During the tour, make sure that site personnel are engaged and answering questions, adding comments, or giving prepared information. It is often easy to overlook something as you walk through, so having them engaged in reminding you of items that you want shown is important. It is best to continue through a prepared route of a site rather than backtracking. This is a time to let experts be experts. Get the site personnel to explain things that are specific to the site, typical roles of contractors and engineers during construction, advice they would like to impart on students, etc. Students benefit from hearing different perspectives on what is important to other disciplines during the construction process. Make sure that you provide as much context as possible for how work the students are doing in your class relates to the actual structure. The type of content that each person provides on the tour should be determined before the actual site visit, but be free to improvise as things come up.

Be wary of timing. It is easy to get caught up talking about a specific item and run over your allotted time, or rush through a site if you haven't thought out what you are trying to convey. Since some people may have scheduled for the stated tour length and it is very difficult for individuals to leave the tour (they will likely need to be escorted out by other site personnel), do your best to end on time. Generally, the author has found that a one hour tour is sufficient for a typical site, but longer if BIM/scheduling are demonstrated, or if the site has unusual features that need more explanation.

Examples of learning opportunities

Specific examples of construction tours that have been taken for a Design of Steel Structures course are provided in this section. Example structures will be shown with brief samples of unusual features that can be highlighted during a tour. This will include example references to design class topics (steel design, concrete design, geotechnical design) based on past tours. Effective building types and stages of construction should be matched to course specific objectives. Examples will allude to steel and concrete design classes, geotechnical and foundation aspects, site conditions, finishing trades and BIM modeling. Samples of past tours are posted on the class web site, and can be referenced by students who are unable to attend.

For this specific class students are working with the construction documents (structural and architectural drawings) specific to the structure and many of the homework problems are specific to determining the loads or member designs specific to the structure being toured. The students therefore have a fairly good understanding of the structure at the time of the tour. Additional information on how the field trip is integrated into this specific class is discussed in Civjan (9).

However, the field trip would be effective so long as the students are given context of how the design problems they have worked relate to the field trip. For example, making sure to highlight members of similar size to those that students have designed, connections similar to their design assumptions, etc. Due to construction schedules the tours have been as early as the third week of the semester, or as late as two weeks from the end of the semester. The author's opinion is that the ideal time for a field trip is approximately half way through the semester. At this point students are familiar with the design of some specific members, but are still seeing some components before they have done any design on them. This allows them to have confidence in asking questions during the field trip, but also use the experience to inform class discussions and designs later in the semester. However, the driving force is the stage of construction, with it being better to tour at the appropriate stage of construction rather than at a specific time in the semester.

Tours have been found to be much more effective when the structure is not too straightforward. For instance, a one story structure with regular framing was used once. For students with construction experience it was simpler than jobs they had already worked on and other students did not seem to gain confidence that the structure related to more complex ones. In addition, the roles of the different disciplines were very well defined and did not have much interaction on the project that could be discussed. Structures shown in Figure 2 have been very effective. These have a level of complexity that lends itself well to giving students a sense of the breadth of knowledge that they will obtain as well as aspects that the students may think are beyond their abilities but can be related to information they have gained through their classes. A level of complexity also leads to the need for BIM modeling and changes in the field that can be discussed to highlight the continuous iterations that are part of a design and construction project.

Figure 2. Example structures of moderate complexity (Photos used by permission)

The ideal stage of construction for a tour depends on what should be shown. For the Design of Steel Structures course it is ideal to tour when most of the steel is still exposed, but after some of the floor slabs have been placed, with exposed decking and shear studs viewable in others (Figure 3). Foundations are typically still visible at this stage of construction as well. On larger projects waiting until the latter stages of decking is advantageous as other parts of the structure may already have some of the cladding or finishing trades starting work which allows students to see additional stages of construction process. A follow up tour can be very interesting if there is significant mechanical and electrical components to the structure, especially if little of this work was visible on the original tour.

Standard items to point out are pinned versus fixed connections and how they are distinguished by flange continuity (Figure 4), braces and their connections (Figure 5), column splices (Figure 6) and composite slab details (Figure 7). The process of completing connections can be explained more easily when some floors are complete and others are still being plumbed. Temporary bracing (Figure 8) can be explained in reference to the construction process.

Figure 3. Ideal stage of construction for steel design course (Photos used by permission)

Figure 4) Pinned and fixed connections (Photos used by permission)

Figure 5) Braces and their connections (Photos used by permission)

Figure 6. Column splices: similar members (left) dissimilar members (right) (Photos used by permission)

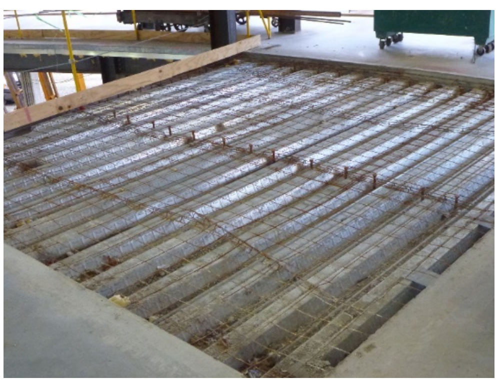

Figure 7. Composite slab details (Photo used by permission)

Figure 8. Temporary bracing (Photo used by permission)

Foundations can be in different states of construction, but pointing out spread footings (Figure 9), boxouts in slabs (Figure 10) and column bases supported by basement walls (Figure 11) can give students a sense of the foundation considerations required in typical detailing. When deep foundations or other geotechnical features are included they are usually no longer visible, but can still be explained at the site.

Figure 9. Spread Footings (Photo used by permission)

Figure 10 Boxout for baseplate (Photo used by permission)

Figure 11. Perimeter column baseplate (Photo used by permission)

Aspects of steel design that are not typically covered in class but can be pointed out in some structures are ways that straight members are used to develop a curved façade (Figure 12), curved members and how they are produced (Figure 13), true "pinned" connections (Figure 14), fireproofing variants, or the galvanized framing with cast connections used in an exposed structure (Figure 15).

Figure 12. Curved façade framing (Photo used by permission)

Figure 13. Curved roof members (Photo used by permission)

Figure 14. Pinned connection connections (Photo used by permission)

Figure 15. Galvanized members with cast (Photo used by permission)

The introduction of other trades and how issues such as mechanical, electrical and plumbing (MEP) systems and subcontractors interact with the construction schedule can be shown if the project is large enough to overlap this activity in another section of the building, or if the tour is later in the construction process (Figures 16). In addition, the modifications to steel required for HVAC can be shown as planned (Figure 17) or field fixes (Figure 18) and discuss how this affects designs. Non-structural wall framing trades may also be present and a discussion of how this is isolated from the structural framing can distinguish how structural elements relate to design assumptions and are distinguished from non-structural framing (Figure 19).

Figure 16. MEP coordination (Photos used by permission)

Figure 17. Coordinated HVAC design (Photo used by permission)

Figure 18. Field fix for HVAC (Photo used by permission)

Figure 19. Non-structural wall framing (Photos used by permission)

Architectural features are very important to highlight, as many consulting conflicts between engineers and architects arise from a misunderstanding of how designs from the two disciplines interact. It is ideal to take a tour after architectural mockups have been constructed as these provide an insightful view into the cladding to structural steel interactions (Figure 20), though later in construction the specific cladding construction can also be insightful (Figure 21). In some tours perimeter structures have even progressed to the point to allow views of roofing components (Figure 22).

Figure 20. Architectural mockup examples (Photos used by permission)

Figure 21. Cladding construction examples (Photos used by permission)

Figure 22. Roofing components (Photo used by permission)

Major design issues can also be highlighted when a structure is a renovation, or built in close proximity to other structures or roadways. These can include requirements to isolate new construction from an existing building in order to designate the addition as a separate structure (Figure 23). This discussion can also include vibration monitoring in adjacent structures and work schedules to not inconvenience occupants of those buildings. More specific to the geotechnical provisions are soil stabilization techniques that might be required to not disturb structures or roadways when excavations are performed. This can include soldier piles infilled with timber lagging which can also include soil anchors and waler blocks spanning between soldier piles for deeper excavations (Figure 24), or secant piles to minimize construction vibrations and noise (Figure 25). When these are not possible a raker system may be used (Figure 26), in this case angled back inside the construction site. Tunnels for access or utilities may require large trench supports (Figure 27).

Figure 23. Isolation of new structure from existing structure (Photos used by permission)

Figure 24. Soldier piles and lagging with soil anchors and some waler blocks (Photos used by permission)

Figure 25. Secant piles (right side) (Photo used by permission)

Figure 26. Raker system (Photos used by permission)

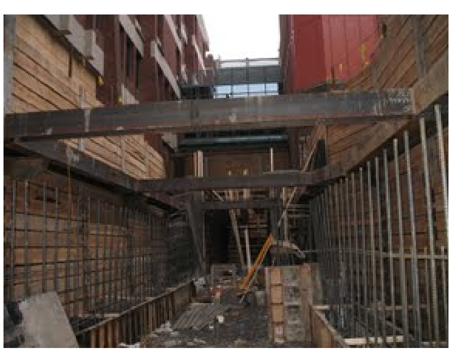

Figure 27. Trench supports (Photo used by permission)

For the Design of Steel Structures class the focus should be on new construction and modern detailing in order to relate directly to class. However, when a project also includes a significant renovation or retrofit to an existing building this can provide for a wonderful opportunity to highlight why design and construction methods have changed (pointing out riveted connections, old proprietary floor systems, abatement of lead paints and asbestos), ways of upgrading lateral force resisting systems, and the design uncertainties inherent in working on older structures with incomplete as-built drawings (if construction documents are available at all). These types of tours have consistently brought out the need for structural engineers, contractors and architects to work together to develop solutions to changing design considerations throughout the construction process. Examples have included adding completely new lateral resisting systems (Figure 28), underpinning existing structural systems (Figure 29), and modifications to existing foundations (Figure 30). The latter required the addition of micropiles and casting of integrated spread footings with associated reinforcement to increase the existing pier capacities.

Figure 28. New steel LFRS (Photo used by permission)

Figure 29. Underpinning of existing wall (Photo used by permission)

Figure 30. Existing foundation with new micropiles (left) and completed footing (right)

(Photos used by permission)

Earlier or later tours can also be very useful. Figure 31 shows an example where site preparation, reinforced concrete foundation work and concrete pumping were observed, while later tours have pointed out the finishing trades, extensive MEP in laboratory structures, and architectural finishes (including architecturally exposed steel members).

Figure 31. Site work and concrete foundations (Photo used by permission)

Feedback

In late 2019 an anonymous on-line survey regarding this class was sent out to all alumni from the past 22 years who had taken the course. The response rate was 21 % of all students who had been enrolled in the course. The purpose of the survey was to obtain an overview of student preparation for their careers and/or graduate school and is reported in Civjan (9). There were 109 responses to the survey question that asked alumni to rank the field trip of construction site experience from 1 (not effective) to 5 (very effective). The average score was 4.26, with several written comments specifically highlighting the construction tour and noting the advantage of using "real life current examples" and "real world experience" context of the class. This result was encouraging and matched the author's subjective review of the experience and comments on individual year end course evaluations.

Conclusion

Construction tours can add significantly to in-class learning. By seeing the actual components that students are designing in the class they can internalize the learning process and gain a better understanding of how their assignments relate to an actual structure. In addition, being physically on the construction site and hearing multiple perspectives on the construction and design process is extremely effective at making students aware of the impact of design assumptions on the overall project, and giving them an understanding that design requests from the field are not arbitrary but usually made with the intent of providing a better finished product.

The examples provided are from a variety of tours given over the past 20 years and are not expected to be included on any one tour. The purpose is to stimulate thought on how getting students into the field could add value to your class and develop a focus on what would be most beneficial to observe. These examples can be used to find appropriate sites to tour and take the intimidation factor out of planning these activities, whether the instructor has significant field experience or feels trepidation at the thought of being on an active construction site.

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