

**AC 2009-2487: COURSE CONTENT AND OUTCOME OF CONSTRUCTION
TEMPORARY STRUCTURES**

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COURSE CONTENT AND OUTCOME OF CONSTRUCTION TEMPORARY STRUCTURES

Abstract

The changing construction environment demands more advanced use of temporary structures for economy and safety. The planning, design and construction of concrete formwork systems are completely the responsibility of the general contractor and their hired sub contractors. As such, most accredited construction management and engineering programs offer course work related to concrete formwork. Teaching this class is not the same as like teaching other standard structure classes. The contents, objectives and format of this class are more likely different. Few ABET and ACCE accredited programs offer this course to teach structural design principles and construction process of temporary construction structures such as formwork. In some instances, course instruction emphasizes theory and abstract concepts rather than clarify structural principles and/or their applications. Questionnaire survey was conducted last four semesters at the end of each semester. Based on the survey, it is found that problem solving and decision making skill has been improved significantly regarding temporary structures. On the other hand, they are not that happy with the text. The outcome of this paper can be useful to other architectural/ civil/construction engineering and management faculties in developing and teaching this course from which students can learn state-of-the-art of temporary structures and their applications.

Key Words: Temporary construction structures, Construction, Structures, Fromwork, Learning outcome.

1. Introduction

Today cast-in-place concrete is integral part of all large commercial buildings either those are framed from structural steel or reinforced concrete. With the advent of economically feasible, higher and higher strength concretes, many of the large building concepts that used to be reserved for structural steel are now being designed and built with reinforced concrete. The decision on whether to construct the frame of a building out of reinforced concrete or structural steel inevitably comes down to a question of money and productivity.

In a concrete building, the architect/engineer is responsible for the size, strength, shape and appearance of the structure. However, the planning, design and construction of the materials used to temporarily support these structural components are the responsibility of the general contractor and their hired sub contractors. In fact, there are quite a number of large general contractors across the country who choose to self perform the structural concrete work, which includes the formwork, so that they can better control and drive the construction schedule and make little more money. Given the fact that cast-in-place concrete is gaining in popularity, and many large general contractors choose to self perform this work, most construction engineering and management programs recognize the need to educate their students about concrete formwork. However, with the ongoing pressure to cut units within most programs, and the

migration away from pure engineering based curricula, the challenge becomes how to most efficiently teach formwork design without having to spend the majority of the class time bogged down in the details of the engineering designs.

Recent studies have been found that 40% to 60% of the cost of concrete work for the building construction is for the formwork (ACI 347 report). The collapse of a temporary structure during construction involves a high risk of serious injuries, deaths and substantial property loss. A clear understanding of the design and construction of temporary structures is a critical function not only for the designers but also for developers, contractors, suppliers of construction equipment, inspectors and all users of temporary structures. These temporary structures may pose substantial challenges for the contractors since the projects design professionals rarely mention them in the project documents. The lack of clear design, plan and specifications for these structures leaves a large number of choices open to the contractor. Since no typical plan and specifications are used in this area, contractors make serious safety and economic mistakes dealing with these works.

Most construction engineering and management programs in the United States require the students to learn structural design principles. Often the students do not realize the importance of the practical applications of the structural concepts covered in these courses. In many cases, course instruction emphasizes theory and abstract concept. Many students do not understand math-oriented coursework, probably due to their marginal background in analytical skills. Even some students understand the structural courses but they can not visualize the necessity of these classes in their career, and therefore feel it is 'irrelevant'. These same students fail to realize how the structural course can be useful in constructability analysis, value engineering and productivity of the project. In some cases, they can even design and construct some small temporary structures on their own without hiring design professionals and specialty subcontractors. Whenever the student feels the problem is difficult or time consuming, he assumes that it will not be his responsibility, but would hire a consultant or a subcontractor to solve that problem. The benefit of temporary construction structures coursework is that students can apply structural principles to actual construction in the project site.

Temporary structures provide a significant element of difference from the standard structures principles course as taught to architecture/civil engineering or construction majors (Banik 2001). In temporary structure courses, certain loads such as equipment loads are treated as dynamic components instead of as dead load (Hurd, 2005). Other loads such as fresh concrete on concrete formwork systems may vary significantly depending on the placement rate, type of concrete and temperature. Students who are involved with construction should understand these differences to prevent accidents or structural failure.

The main objective of this paper is to highlight the key elements of this course, develop a course outline, and summarize a course outcome based on student feedback.

2. Existing Course

The Construction Management Department of Southern Polytechnic State University (SPSU) has three concentrations- general, specialty and development. The existing course is listed as CM 3260- Applied Structure II at SPSU for the general construction concentration. In addition, some

architecture and construction engineering students can take this course as an elective upon permission of the instructor. The prerequisite for taking the course is statics and applied structure I. In addition, it is expected that the students have been exposed to the basics of techniques and methods and quantity take-off of construction.

3. Research Methodology

At the end of each semester, a course outcome evaluation and recommendation form is given to verify what students learn from this course; how comfortably and efficiently they can use temporary structures, what they may expect from this class and what are the strengths of this class (Appendix A). They were also asked to give their suggestions on how the class may be made more useful to the students for the next semester.

In the last four semesters, this evaluation form was collected. Thirteen related questions were asked. Questions were asked in the simple format like strongly agree, agree, neutral, disagree and strongly disagree. Out of eighty-nine students, seventy eight responds were received. In addition of thirteen close end questions, two open –ended questions were asked to provide list of strengths of the course and in which way the course can be improved in the future.

4. Course Objectives

The objectives of this course are to provide the capability and understanding of design and construction of a variety of temporary structures such as formwork, shoring/reshoring, dewatering, excavation and others. The student will be capable of dealing with temporary construction issues including state-of-the art developments, safety, and relevant legal and regulatory issues. The student will be able to design and analyze these structures in terms of dynamic and static loads, other technical issues, managerial issues and cost/schedule considerations. In addition, the student will understand the roles of subcontractors, suppliers, design professionals, owners, and government agencies in this area. The student will be able to present temporary structures concepts clearly and professionally from both the quantitative and qualitative standpoints.

In brief, the expected learning outcomes of this course are as follows

- Ability to choose right formwork under different conditions.
- Ability to design and construct formwork for a 3-storey commercial building.
- Ability to decide right soil and concrete for any construction based on testing.
- Ability to identify/evaluate soil related problems and take remedial actions.

5. Course Format

The course is designed with a combination of lectures and discussions. The course is offered on a 3-credit hour basis in both fall and spring semesters. Class generally meets twice a week for a total four-hour duration. Since the SPSU construction program emphasized more on building construction rather than heavy civil construction, about 40% to 50% of semester time is spent on design, estimates, evaluation, and selection of formwork, and planning for shoring and reshoring.

Due to the wide variety of temporary structures, guest speakers from the industry are utilized to provide additional industry perspectives and “real-life” components for this course. Some of the guest speakers in the past have been formwork design engineers and project managers, scaffolding contractors, and dewatering contractors. In addition, several field trips are arranged each semester to provide practical insights into the temporary structure construction, and how these benefit the total construction. Project manager/superintendent/design engineer of the site discusses the problems and limitations of the project regarding temporary structures and how they solve those problems with safety, economy and within schedule.

Class discussions may include the pros and cons of various solutions such as one-story shoring and one-story reshoring vs. one-story shoring and two-story reshoring for a four-story building, slurry trench method vs. open sumps for dewatering, and the others. Students realize that decision in temporary structures impact techniques for work, project schedule, and resource allocation. Most of the students of SPSU are working full-time and part-time in the industry, and gain valuable insights for temporary structure construction. Some of them even work with the temporary structure subcontractors. These students also help to extend the class discussions and render them more valuable to the whole class.

6. Course Assignments

The workload for the course is comprised of a number of homework assignments, class work, class quizzes, literature reviews and text readings covering the essentials and varied aspects of this subject area. They need to design the formwork components (beam, column, wall, and slab) by using the structural formulas and using Tables developed by the American Concrete Institute (Hurd). Besides the quantitative homework assignments, students were individually given readings (catastrophic failures) on temporary structure construction and required to provide a combination of written and oral reports in these areas. Since course enrollments are relatively small (about 15-20), homework assignment are given on both an individual and a group basis. One group’s final project is given every semester on formwork construction. After passage of three/four weeks of the semester, each team is given a four-story building plan, drawings and specifications to design, estimates and schedule of formworks, which they are required to complete for the total building project. Planning of the shoring/reshoring, types and use of the equipment, traffic control and others also need to be discussed in the final report. The written report in part requires the production of shop drawings by the student teams because like other drawings, shop drawings do not exist in the contract documents. This is a kind of extensive report to be submitted at the end of the semester and presented in the class. This final project gives students both a “real-world” type experience plus additional practice in verbal and written communications. The emphasis to the student teams is on providing a well-organized and professional document as a temporary structure subcontractor that could be submitted to an owner or the general contractor for their review. Two, sometimes three exams are given during the semester depending on the class progress and student performances.

An example of a more-involved course assignment might be the selection of a concrete formwork system (Banik, 2001). The student would complete their calculations and analysis to make a decision based upon:

- Preliminary assumptions such as type of cement, concrete slump and vibration
- Design details of the completed structure
- Site and climatic conditions
- Type of concrete surface finish required (architectural vs. structural concrete)
- Construction sequence and schedule allotment
- Equipment type, capacity, availability and costs
- Requirements for safety features
- Support for associated temporary structures in addition to formwork as scaffolding
- Methods of concrete placement
- Form removal and form releasing agents
- Effect on other trades such as hoisting or rebar sub contractor

As can be seen, effective course assignments expose the students to many realities in this area. Students should learn that temporary structures must be designed and selected to enhance the efficiency of the construction process. In many cases such as formwork, temporary structures are in the critical path for the project's completion. Thus the best system choice may be a more expensive formwork system requiring higher crane capacity or more use of formwork to reduce the overall building completion time. This system selection means overhead savings for both the general contractor and subcontractors. In addition, the owners save on capital interest costs and improve income from earlier occupancy. Students often criticize structural design components for emphasizing design and de-emphasizing construction issues. Effective temporary structures assignments should provide an integration of both design and construction issues.

7. Student Learning Outcome

The summary of the feedback is presented in the Table 1. Out of seventy seven responds, 42.86% responded strongly agree that course increased their problem solving and decision making skills. About 35% agree and 10% does not agree with the questions. In respect of communication skills about 70% of the respondents either strongly agree and agree that course improved their communication skills. On the other hand, 11% did not agree. About 65% respondents mentioned that they can evaluate soil related problems and can suggest corrective measures. But 22% are neutral on this.

The students' overall response was very positive about the class. They felt that this course improved their communication and problem solving skills, the evaluation skills of different alternatives, and the planning, design and construction skills. They understood how the temporary structures work (about 70%). They answered even affirmatively when some specific questions were asked about formwork and shoring/reshoring. About 43% respondents mentioned that they are not very convinced about the text. 80% of respondents mentioned that the instructor is knowledgeable in terms of course content to teach the class. When questions were asked about the strengths of this class, invariably they mentioned the design aspects of formwork, instructor knowledge, case studies, final projects, and field trips. The students also mentioned that more field trips, guest speaker's presentations and case studies would be helpful for the better learning outcome of this course in subsequent semesters.

Table 1: Students Learning outcome in terms of Percentages.

	Strongly Agree, %	Agree, %	Neutral, %	Disagree, %	Strongly Disagree, %	Total, #
The course improved my ability in problem solving and decision making skills.	42.86	35.06	11.69	5.19	5.19	77
The course improved my ability to communicate my views clearly in temporary structures.	35.62	34.25	19.18	6.85	4.11	73
The course helped me to develop an understanding of the ways in which temporary structures work.	28.21	41.03	12.82	10.26	7.69	78
This course enhanced my understanding of the scientific disciplines and technology relevant to construction.	25.00	43.42	17.11	6.58	7.89	76
I can determine what kind of formwork I should use for my project.	34.21	39.47	14.47	6.58	5.26	76
If a project is a small size, I can design the temporary structures including formworks.	34.62	35.90	10.26	10.26	8.97	78
I can sequence/plan shoring and reshoring during construction.	32.88	43.84	12.33	6.85	4.11	73
I can decide the type of the soil based on testing.	28.21	46.15	10.26	8.97	6.41	78
I can decide the quality of concrete based on several testing.	32.05	38.46	11.54	7.69	10.26	78
I like the Texts.	21.05	35.53	15.79	18.42	9.21	76
I can evaluate soil-related minor problems and their corrections in construction.	28.21	37.18	21.79	10.26	2.56	78
I have some basic ideas related to compaction and stabilization of soil.	30.26	36.84	17.11	10.53	5.26	76
The instructor is knowledgeable about the course materials.	28.57	42.86	12.99	9.09	6.49	77

8. Student Reactions

The reaction of construction students to this course and others (structures, soils, concrete design) is simply due to the lack of interest. Since it is in their mind that they want to be construction managers rather than designers, they don't feel the need to understand temporary structures very well. Some students failed to realize the correlation of a fundamental understanding of construction science principles to execution of the construction project. Sometimes, they felt that temporary structures are difficult for them to understand. The student who has better analytical background appreciates the necessity of the coursework and seemed to the authors they are interested to learn.

9. Course Text and References

There are a great variety of books for the traditional construction courses such as construction management, estimating and scheduling. But only a few choices exist for this course. At the

beginning of teaching this course Handbook of Temporary Structures in Construction by Ratay was chosen as a text, considering comprehensive coverage of the subject area. But this book was not well received by the construction students, mainly due to the concentration of the design aspects rather than both design and construction aspects. Although the book provides comprehensive coverage of the temporary structures, but seem written for professional experienced engineers. Students had difficulty to understand some of the critical aspects of the temporary structures from this book. Another weakness of the book was inadequate coverage of formwork.

Under this scenario, the author selected the book Formwork for Concrete by Hurd as a text. This book covers the selection, design, materials and costs of formwork, including shoring and reshoring. Handbook of Temporary Structures by Ratay was chosen as a supplementary text, and keeping several copies in the library as a reserved books so that students can use them as needed. The major drawback of both the books is the lack of proper homework applications, which are suitable for construction students. Thus the assigned homework problems have had to be developed by the instructor. Several spread-sheets based design problems, developed by the author, helped the students understanding the design process and concepts very well. The spreadsheets served as excellent in-class presentation tools, enabling the instructor to review various design examples without having to get bogged down in all of the rote calculations. Furthermore, because of the relative reviews the examples from the book, the students can concentrate more on the methods and processes, and not get overly focused in on the details of the calculations presented. The benefit from spread-sheets that seems most important to the student is the concept of receiving immediate feedback when solving complicated design problems outside of the classroom.

In addition, Engineering News Record (ENR) and manufacturer's literatures are used in this course. ENR provides a timely and continual source of examples of innovative applications of temporary structures, and highlights the failure of temporary construction structures. Some manufacturers also provide videotapes of these applications, which are used to supplement course literatures. Many subcontractors also share information such as drawings and various calculations of temporary structures provided that sensitive information is eliminated from this course. To cover the soil related problems, the class also introduced the book- Soil in Construction by Schroeder and Dickenson.

10. Conclusions

Temporary construction structures play a significant role in the overall construction project success. Therefore, it is important to include this course as one of the core courses for the construction and architectural/civil engineering programs. Reviews of numerous constructions failures and OSHA fatalities/disabling injuries justify the requirements of knowledge of temporary structures for the construction and engineering students. Available inadequate course instruction materials, while limited in comparison to other standard construction courses, are marginally adequate to provide sound education. The instructor needs to exert more effort to supplement the inadequacy of reading materials, course assignments, and case studies, and to invite guest's speakers. It is always good to develop some design related problems in spread-sheets and show them how to use.

The students' overall response was very positive about the class. They felt that this course improved their communication and problem solving skills, the evaluation skills of different alternatives, and the planning, design and construction skills. Spreadsheets for the design problems were appreciated by the students.

The instructor also needs to change the students' mindset and to make the course more interesting so that students may feel temporary structures are not very difficult to understand and these materials are essentials for the successful completion of the project.

Bibliography

1. Banik, G. C. (2001). Teaching Temporary Structures: Style, Content and Outcome. Proceedings of 2001 ASEE annual conference, Albuquerque, NM, June 2001.
2. Epstein, W. C. and Gilpin V. C. (2003) E-Z Forms 2003: Interactive Spreadsheets for Teaching Concrete Formwork Design, Proceedings of 2003 ASC annual conference, Clemson, SC, April 2003.
3. Field, J. and Carper, K.L. (1996). Construction Failure (2nd ed.), New York, John Wiley & Sons.
4. Hurd, M.K. (1998). Formwork for concrete Sp-6. Detroit: American Concrete Institute.
5. Peurifoy, R. L. (1976). Formwork for Concrete Structures (2nd ed.), New York, McGraw-Hill.
6. Ratay, R.T. (1996). Handbook of temporary construction structures in construction (2nd ed.), New York, McGraw-Hill.
7. Schroeder, W. L. and Dickenson, S.E. Soils in Construction (5th ed.), New Jersey, John Wiley & Sons, Inc.

Appendix-A

Construction Management Department, SPSU
Course outcome Evaluation and Recommendation Form

Course: _____ Semester/Year: _____

Mark an "X" for A= Strongly agree, B= Agree, C= No Comment, D= Disagree, E= Strongly disagree

1. The course improved my ability in problem solving skills.
A _____ B _____ C _____ D _____ E _____
2. The course improved my ability to communicate my views clearly in temporary structures
A _____ B _____ C _____ D _____ E _____
3. The course helped me to develop an understanding of the ways in which temporary structures work
A _____ B _____ C _____ D _____ E _____
4. This course enhanced my understanding of the scientific disciplines and technology relevant to construction.
A _____ B _____ C _____ D _____ E _____
5. I can determine what kind of formwork I should use for my project.
A _____ B _____ C _____ D _____ E _____
6. If a project is a small size, I can design the temporary structures including formworks.
A _____ B _____ C _____ D _____ E _____
7. I can evaluate soil-related minor problems and their suggestions in construction.
A _____ B _____ C _____ D _____ E _____
8. I can sequence/plan shoring and reshoring during construction.
A _____ B _____ C _____ D _____ E _____
9. I can decide the type of the soil based on testing.
A _____ B _____ C _____ D _____ E _____
10. I can decide the quality of concrete based on several testing.
A _____ B _____ C _____ D _____ E _____
11. I have some idea related to compaction and stabilization of soil.
A _____ B _____ C _____ D _____ E _____
12. I like the Text and Course materials.
A _____ B _____ C _____ D _____ E _____
13. The instructor is knowledgeable about the course materials.
A _____ B _____ C _____ D _____ E _____
14. List the strengths of this class:
1) _____ 3) _____
2) _____ 4) _____
15. In what way(s) do you think this course will be more useful to you in the future?