Connecting Professional Practice and Education through a Civil Engineering Capstone Project:

Mud Flow Barrier

Abstract

The civil engineering department requires all undergraduates to complete a senior design team project over the course of six months to submerse students into an engineering-firm-type-atmosphere. Facilitators include practicing registered engineers from different disciplines related to the project such as structural, geotechnical, and water resources. The project requires integration and synthesis of acquired knowledge as well as the consideration of alternative solutions, methods, and constraints such as economic, environmental, health and safety, social, political, sustainability, constructability, and ethics.

For the senior design project the university partners with local agencies to provide the senior design team an opportunity to work on real-world design projects. The idea is to expose the students to a real life project, the results of which would be implemented by the agency. This year's project was to analyze and provide the participating agency with an alternate design for its standard rail and timber structure utilized for preventing mudflows from damaging structures below burned watersheds. In an effort to reduce construction time and costs, the Water Resources Division requested the analyses of these standard rail and timber structures to determine whether a more cost and construction effective barriers can be designed to replace these standard rail and timber structures. This has even become more important as the availability of rail on the open market is limited.

This project required hydrologic and hydraulic analysis to determine the possible flow rates and velocities that can impact the structures. The analysis included a structural and geotechnical analysis to determine dead loads, static pressures, and impact loads on both the structure, and the foundation. Once the existing standard was analyzed to determine the factor of safety built into the standard design, alternative designs and/or materials were proposed to reduce cost and construction time. A complete environmental analysis of the project was completed. The project also required evaluation of costs and benefits associated with any developed alternatives.

Over six months, project teams produced a complete technical and non-technical analysis of the project. The analysis included the application of constraints in the final design while holding paramount the safety of the public. Additionally, they prepare a final design technical report including memoranda, computations, drawings, specifications, and cost estimates. Written and oral reports are presented to a panel of faculty and representatives from industry. All students are required to participate in the presentation. The panel includes a number of registered engineers who ask follow-up questions and provide students with feedback on technical merit of the report and presentation.

The students and the project were evaluated in a value engineering type environment by five Professional Engineers who scored the students on incorporating realistic constraints such as social, health and safety, economic, sustainability, ethical, environmental and political. Additionally, the students were evaluated on their techniques and skills for engineering practice.

Section I: Project description

Introduction

For a number of years, the university's senior design team (Team) has had the opportunity to partner with local agencies to work on real-world design projects. These projects require coordination between the Team and the agencies to develop the scope of work, timeline, and deliverables. The ultimate goal of the class is to provide the agencies with the necessary documents that will enable an informed decision on the project based on all applicable engineering areas.

For this year's project, the Team partnered with a public agency (Agency) to review their current practices regarding the design and construction of mudflow barriers. The Agency's Water Resources Division requested an alternatives analysis of mudflow barrier designs to replace the existing design. The project required the application of practices related to hydrology, hydraulics, geotechnical, structural, and environmental engineering. In addition, the Team learned how to coordinate efforts to work within a specified project timeline in order to provide a quality product.

Background

The Agency currently utilizes a standard rail and timber barrier design (**Figure 1**) to prevent damage to downstream structures from increased mudflows resulting from burned watersheds. While the structures have been successful in preventing damage from debris flows, the assembly and construction time is lengthy. Rail ties must be welded offsite and in some cases heavy equipment is needed. Additionally, the structure is difficult to construct in areas that are not easily accessible. The current drainage system works for most of the debris, but fine sediment easily escapes the structure. Maintenance of the structure is expensive and often difficult for machinery to access.

In an effort to reduce construction time and cost, the Agency requested that the Team provide an analysis of no less than three mudflow barrier designs. The project required the Team to analyze the constructability, costs, environmental challenges and operations and maintenance related to each design. The designs also had to withstand minimum serviceability requirements with respect to detention and loading. The three alternatives presented as viable barriers include a cantilever, a braced cantilever, and a flexible wire mesh system.

Figure 1. Photograph depicting rail and timber mudflow barrier

Scope of Work

In order to successfully manage the project, the Team worked with the Agency to develop a scope of work. The scope of work identified 5 tasks to be completed by the Team. These tasks would provide the Agency with the information required to make an informed decision regarding a potential change in the barrier design. For each task, a technical memorandum was submitted for review and comments. **Table 1** lists the tasks and the number of hours allotted for each.

Table 1. Tasks and Allotted Hours

Task	Hours
1. Preliminary Investigation of Potential Designs	200
2. Feasibility Analysis of Potential Designs	450
3. Final Design of Barrier Alternatives	450
4. Detailed Cost Comparison of Alternatives	100
5. Final Report and Presentation of Recommendations	200
Total Hours =	**1700**

Task 1 – Preliminary Investigation of Possible Designs

A Preliminary assessment of possible designs was required in order to reduce the scope of later tasks. The assessment included research of various types of mudflow barriers used historically by the Agency as well as additional literature research of potential alternatives. The Team also met with vendors who presented their barrier designs. Once potential alternatives were formed, a high-level assessment was conducted to reduce the alternatives to 5 potential designs. Feasibility was analyzed with respect to accessibility, constructability, and maintenance after a flood event. The Team also looked at the availability of materials and the lead times required obtaining them. Each of the alternatives were scored and ranked based on the above criteria, and the top five designs were retained for further development. At the end of Task 1, *Technical Memorandum# 1* was submitted to the Department of Public Works for review.

Task 2 – Feasibility Analysis of Potential Designs

The purpose of Task No. 2 was to reduce the remaining 5 potential designs and elect the best three options which would be carried through to the next phase of the project. In order to determine the potential structures for final design, a detailed analysis of the 5 alternatives was conducted. The analysis looked at the benefits and constraints of the alternatives and ranked them based on specified criteria. The areas of analysis considered include:

1. Operational benefits and constraints
2. Maintenance requirements
3. Regulatory requirements
4. Reliability concerns
5. Special environmental considerations (the CEQA/NEPA assessment is conducted in the preliminary design phase)
6. Health and safety issues
7. Capital cost estimate
8. Life cycle cost of project alternatives

After determining all the above categories, all alternatives were presented and only three designs were retained for further development. At the end of Task 2, *Technical Memo 2* was submitted to the Department of Public Works for review.

Task 3 –Final Design of Barrier Alternatives

Concurrently with Tasks 1 and 2, a geotechnical analysis of the area was conducted. Utilizing the geotechnical information and minimum load requirements, a structural analysis was completed and the team selected a design for each alternative. Final drawings were created detailing all needed dimensions for construction. Features included in the final drawings include column and beam sizes, connection details (i.e. bolt sizes), wire diameters, gate openings, material type, anchors, and foundation dimensions.

At the end of Task 3, *Technical Memo 3* was submitted to the Department of Public Works for review.

Task 4 – Cost Comparison

Task 4 required the team to prepare a cost estimate of the three designs. In order to normalize the costs, a materials list was calculated for a 15 foot structure, for a tributary width of three feet (per design specifications). The materials list was determined based on the drawings prepared in Task 3. The prices used to calculate the cost were obtained from Public Works Cost Book and other sources. In addition to the three alternatives, the Agency's specifications and Rail and Timber Barrier drawings were used in order to calculate the structure cost. The alternatives were then compared based on the costs for a 100 foot length structure as shown in **Figure 2**.

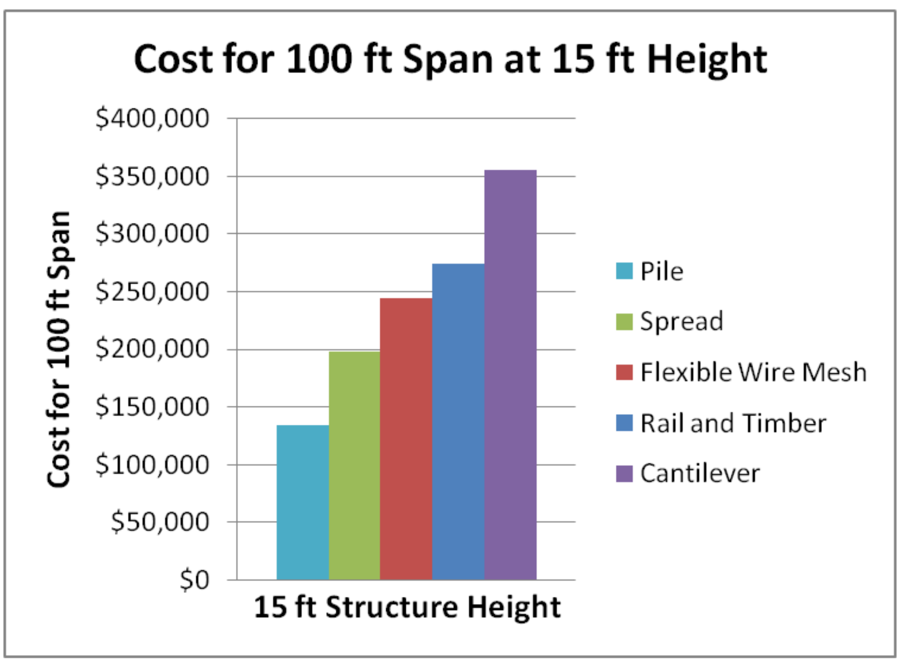

Figure 2. Cost for each alternative and current rail and timber barriers for 15 ft height

Task 5 –Final Project Report and Presentation

After conclusion of the analysis and design portion of the project, the Team was required to develop and submit a Final Report. The report included key information from the previously submitted Technical Memoranda. Additionally, a final presentation of the findings and recommendations was made to a panel of faculty and representatives from the industry. This panel included a number of registered engineers that asked follow-up questions and provided the students with feedback on the technical merits of the report as well as the professionalism of the presentation. All students are required to participate in the presentation.

Conclusion

Based on the available data, the barrier design that best met the requirements of the Agency was a pile design. This design met all of the strength and safety requirements. In addition, the alternative is simpler to construct and maintain than the current rail and timber design. Lastly, the pile design proved to be the lowest cost than any of the alternatives. As a result, the Team recommended the pile structure for future mudflow barrier installations. This design is able to meet all the design criteria established by the agency and meet all health and safety standards.

Section II: Collaboration of faculty, students, and professional engineers

Over the six month duration of the design class, engineering faculty and four practicing registered engineers from three different disciplines worked in collaboration with the students to develop and implement a project plan. The team included one structural engineer responsible for assisting students utilize building codes for their analysis and conduct structural analysis using SAP 2000 to analyze impact from mudflow. Students also received great assistance from a geotechnical engineer in understanding the geology needed to support their design. These activities provided the students with leadership opportunities, hands-on engineering experience, and a chance to meet and work with practicing professional engineers.

The facilitating engineers also gave periodic lectures and assignments in their respective areas of expertise. In addition to the technical lectures, faculty provided practical lectures on project design and organization, cost estimation, report writing, legal issues including the California Environmental Quality Act (CEQA), and presentation skills. The practical lectures provided the opportunity for the professional engineers to share examples from their personal experience that demonstrated the importance of each topic.

Another requirement for the course was that each student develop a portfolio to be used for job interviews. Registered engineers from the school faculty assisted students in preparing resumes and other documents for the portfolio.

A liaison from the Agency, also a registered civil engineer, was very involved in the process as well. The liaison visited the school for the initial scope of work presentation, and later addressed the class regarding personnel issues and career development. At each stage the Agency reviewed and commented on the Tech Memos and the senior design team would adapt the reports as necessary to address these concerns.

Through these many avenues students gained insight as to the value of experience and professional registration.

Section III: Benefit to health, safety, and welfare of the public

This year's senior design class provided an opportunity for students to work on a project that directly affects the public's health, safety and general welfare. The rail and timber barriers that the agency had been using had proven successful in preventing damage from mudflows, but construction and O&M considerations required changes to the design. The Agency needed a design that could be installed quickly and easily maintained to ensure its effectiveness after multiple rainfalls.

This project stressed the importance of codes and minimum requirements for design and safety; a flawed design could potentially lead to loss of property or life. In addition, the Team analyzed the designs to ensure that they met the requirements of CEQA. In each phase of the project, the health and safety of those that the barriers would be protecting was a major consideration in advancing various designs.

Section IV: Multidiscipline and/or allied profession participation

Every instructor in senior design was a professional engineer encouraging the desirability to students for licensure. The practitioners have accumulated over 120 years of combined experience among them in environmental, hydraulics, hydrology, structural, and geotechnical engineering. Design issues from all of these areas arose in the completion of this multidisciplinary project. Instructors brought their experience to the classroom and worked closely with students and guided their paths throughout the entire six months. They introduced students to techniques regarding analysis and design that moved engineering theory in practice.

Section V: Knowledge or skills gained

Students obtained knowledge in various fields as part of this design project. In additions to knowledge of traditional debris flow structures, students learned how to design the latest in technology, namely flexible wire mesh structures. Additionally, students were exposed to geological or geotechnical engineering issues and processes in regards to burned watersheds, and health and safety implications to this phenomenon. A visit to watershed and multiple mudflow barrier sights gave students insight to the variation in channel dimensions, mudflow impact to barriers, and maintenance process and accessibility issues.

In addition to the knowledge gained in standard engineering practice, the students gained valuable skills in project organization and design, cost estimation, report writing, and presentation/public speaking. Students had to work as a team, both among fellow students and with facilitating engineers, in order to prepare deliverables in a timely manner. Students also gained knowledge of applicable building codes; local seismic, wind, and geological conditions; building materials; and the provisions of CEQA.