

Innovative Final Year Design Project-International Experience Makes a World of Difference

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Abstract

The Department of Civil Engineering at the University of Calgary is proud to be a leader in multi-disciplinary design education in Canada by bringing many facets to design education including internationalization. This design education produces many contributions to university, industry and society by developing innovative design solutions. This paper explains the novel approach adopted for the final year civil engineering design course in 2002/3 using the largest urban renewal project currently underway in Europe, which the students the opportunity to develop designs. The concept, structure, challenges, contributions and the successful outcome of the civil engineering design course are also explained in the paper.

1. Introduction

The design engineering process is clearly critical to the economic well being of any developed country. The value of a product (or process, or system), its efficiency, environmental impact and consumer appeal are all determined by design [1, 2]. The Department of Civil Engineering at the University of Calgary is a leader in engineering design undergraduate courses. The final year

civil engineering project course is geared for multi-disciplinary design.

The largest urban renewal project currently underway in Europe was the buzz of excitement and learning for final year civil engineering undergraduate students and their academic advisors in 2002/3. The students had the opportunity to design a major portion of the urban renewal scheme as part of their final year design project of the engineering curriculum. Sixty-three University of Calgary (U of C) civil engineering students celebrated what could be the largest class project of its kind anywhere in Canada – a design proposal for a full-scale urban renewal development in Lisbon, Portugal. This is the first time in the history of civil engineering education, not only at the U of C but also anywhere in Canada, that a group of students designed a real international project that provided many challenges and successful outcomes before they graduated from university. This paper highlights various aspects of this design course and the successful outcomes of the design engineering education.

2. Concept of the Final Year Design Course

The final year civil engineering design course is multi-disciplinary with various specialities in civil engineering involved. The scope of this team design project is to apply engineering design and project management principles to prepare a multidisciplinary design and bid document for a real civil engineering project. Students are expected to consult with local industry and professors in the Department. Every year, two teams of approximately 30 to 35 students prepare final design drawings and a report and then present these deliverables to a committee comprising of representatives from the Department and industry. Proposals should document and discuss the project development, design and execution plan with an emphasis on the technical, human resources and business aspects of the project. It includes all civil engineering design aspects: environmental, geotechnical, hydraulics, materials, structural and transportation, and preparation of project management issues including design and contract documents, specifications and presentation of competitive bids. In the last seven years the Department has selected the following real engineering/construction projects:

1. Highway 22 in Calgary (1997/98).
2. U of C student residences (1998/99).
3. 96th Avenue airport link road, Calgary (1999/00).
4. Airport land development, Calgary (2000/01).
5. West Campus development at the U of C including new children's hospital (2001/02).
6. Alta de Lisboa urban development project (2002/03).
7. Pine Creek waste water research park, Calgary (2003/04).

3. Design Project for 2002/03: Alta de Lisboa

Alta de Lisboa ("uptown Lisbon") in Lisbon, Portugal is the largest urban renewal project in Europe. It was developed by SGAL (Sociedade Gestoria da Alta de Lisboa), an international consortium in Lisbon, Portugal. Alta de Lisboa is situated on the northern boundary of Lisbon

and spreads over approximately 300 hectares. It is one of the last remaining, large, undeveloped areas in the city. This project was initially conceived as a new city within the capital, replacing shantytowns. When completed in 2015, the city will have 20,000 multi-family units, including 3,500 social housing units. At present, 200 million Euros are spent annually on this project, which was started eight years ago.

This project is close to Lisbon airport and major city highways, including the Segunda Circular Ring Road, the North/South Axis road, the Lisbon Inner Ring Road (CRIL) and the Lisbon Outer Ring Road (CREL). The development includes housing, shopping, green spaces, city amenities and office space. A complete transportation network has been designed for Alta de Lisboa, creating optimum conditions for access to all points on its boundary.

Alta de Lisboa will also have two stations on the Campo Grande extension (Girassol) line of the Lisbon Metro. Wide pedestrian walkways have been included with links to green spaces, occupying some 70 hectares in all, a quarter of the total area. The area will include six crèches and pre-school units, twelve primary/junior schools and three high schools, after-school centres, day centres, homes for the elderly, youth centres, churches, two fire stations, a police station, and two strategically located municipal shopping centres. There will be 36 children's playgrounds, four swimming pools, four sports pavilions and 20 sports fields.

The scope of the student project was limited to "Area 5" of the development as shown in Figure 1 which is approximately 12 hectares in size. The master plan for this specific site calls for 2.4 million square feet of development, including a shopping centre, office space, hotel, and residential uses, as well as public amenities and underground parking for 5000 cars [3].



Figure 1: Alta de Lisboa Project Site with Area 5

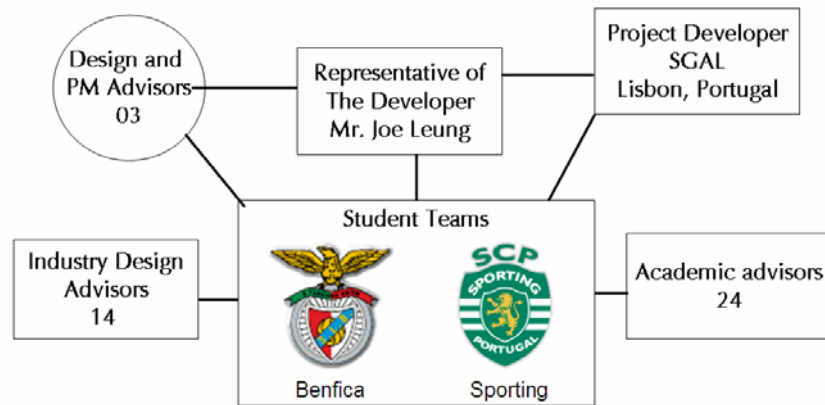


Figure 2: Organization of the Final Year Design Course

4. Course Structure and Terms of References for Designs

The two student teams were subdivided into sub-groups. They were named “Benfica” and “Sporting”, the top two Lisbon teams in the Portuguese Soccer league. The sub-groups consisted of at least one group looking at each of the following aspects: transportation, environmental, project management and infrastructure, geotechnical, and structural. Each of the two teams appointed a management committee consisting of the overall project manager and one member from each of the sub-groups. This committee was responsible for overall management of the team's activities and ensured liaison between the sub-groups. Each team was responsible for its own work schedule, including the organization of progress meetings

and shared work sessions. Students were encouraged to consult with their principal academic advisor, local industry and professors in the Department. In both semesters professors and invited guests presented lectures relating to the project. The students had to submit several deliverables/reports throughout the academic year that included:

1. Development Plan and Report: At the end of the first semester each team was required to present a report of its development proposal summarizing its solution to the problem, including layout of the components. The specific components in this mid-year report are description of the problem, alternative solutions considered, rationale for solution selected, description of solution, layout including preliminary designs and drawings, management structure, preliminary schedule

- and cost, risk analysis index, description of relevant regulations, and environmental issues.
2. A mid-year team presentation (approximately 50 minutes for each team) based on the development plan and report.
 3. A final report consisting of three main components – final design brief, detailed design, and drawings.
 - Final design brief - Executive Summary; Introduction; Design Criteria; Particulars of Design/Analysis; Schedule and Cost Estimate; Environmental Impact Assessment; Risk Analysis; and, Recommendations (or Conclusions). The Design Criteria included the design standards and technical references used by each of the sub-groups, the particular design criteria adopted, particulars of the design/analysis, a summary of the rationale behind the various design decisions, etc.
 - Detailed Design: Each sub-group of the two design teams prepared a detailed design of their design discipline. The students were asked to explain the design criteria used, the assumptions made, the materials used and the overall design methodology.
 - Drawings: Original drawings related to the designs.
 4. A final team presentation (approximately 75 minutes for each team) based on the final design report at the end of the academic year.

The grading was based on a number of aspects that included a clear introduction to the project background, objectives and scope of the project, quality of the deliverables based on the terms of references, design considerations and issues, analysis of the final design and alternatives, design details, originality and innovation, research, and style and format of the report.

Twelve students and four academic professors visited Lisbon in early September of 2002 to explore the site conditions and the expectations of the developers. Another 12 students and four academic professors visited Lisbon again in May 2003 to present the design proposals to the project developers.

There are various key stakeholders in this design course. Figure 2 shows the organizational structure of the design course. The key stakeholders for the student groups are:

1. Project developer SGAL from Lisbon, Portugal.
2. Developer's representative – Mr. Joe Leung, a senator from the University and currently a board member of SGAL.
3. Developer representative's design and project management consultants from industry (BKDI Architects, and Earth Tech Canada).
4. 24 academic advisors from the University of Calgary – this includes professors and post-doctoral fellows.
5. 14 industry design advisors from various consulting/governmental organizations in Calgary (Stantec Consulting, The Cohos and Evamy Partners, Read Jones Chistoffersen Ltd, Riddel Kurczaba Architects, DC Dechka Consulting, UMA Engineering, City of Calgary, Husky Energy, Southwest Trapp and Associates, Jacques Whitford, EBA Engineering, AGRA Foundations, Graham Construction).

The academic professors from the Department of Civil Engineering developed the terms of reference for each of the project's design components. The students had the opportunity to seek advice from numerous consulting organizations as mentioned above. The students took advice from both the academics and industry when they designed the technical and project management components. The developer's representative and the design consultants also provided the scope and timely advice for the architectural and engineering design elements.

Building design considerations as part of the terms of reference for "structural engineering design" for the office/apartment/hotel/retail centre design are given below.

- building layout, height, lateral extent, overall shape
- movement – people/supplies (staircases, elevators, deliveries)
- roof (basic shape and structure)
- floors/ceilings
- exterior wall cladding (with an emphasis on dead load assessment and wind load distribution rather than aesthetics, including climate and local practice)
- basic building structure
- selection of foundation type (with geotechnical group)
- selection of structural materials and structural system, considering local practice

- connections of services from one location to another.

The following are the components the students were asked to include in the structural design:

1. Building structure and loads - layout of columns, beams, and slabs, load paths for dead, live, wind, earthquake loads, and any special loads.
2. Structural analysis (either 2-D or 3-D computer analysis for the various load types and effects of vertical and lateral loads).
3. Design of components for the building (with emphasis on how to design the different elements of the structure, including overall size and reinforcement requirements for the entire structure).
4. Detail design by selecting at least a dozen different components such as columns, beams, and slabs.
5. Design of typical foundations with the collaboration of the geotechnical group.

Similarly, terms of references (TR) were developed by the academics for the other engineering design areas and for project management. For example, transportation TR include the following:

1. Traffic study of existing Lisbon layout.
2. Transportation Impact Assessment for Area 5 considering proposed development, scope of the study, existing traffic conditions, trip generation, modal choice, distribution and assignment, future traffic conditions, transportation network impact, provisions for alternative modes, internal site layout, parking provisions, road safety, environmental and impact of traffic.
3. Geometric design.
4. Pavement design.

5. Designs for “Alta de Lisboa”

The two competing teams – Benfica and Sporting - submitted design and project management solutions which were beyond the expectations of the academic terms of references. Figure 3 shows a sample of design activities/deliverables and the innovations of one of the teams.

6. Contributions and Highlights – Students

Following are various contributions and highlights from the undergraduate final year students’ point of view [5]:

- Real life experience in dealing with an international client: The students were challenged to meet the expectations of a real client who financed the project. Because of the real nature of the project, the deliverables had to be shared with the real client and the students had to prove that the deliverables were good value for the money invested by the client/developer. This also provided the students with an opportunity to show that they are capable of working for international clients.
- Real life experience in designing a portion of the largest urban renewal project in Europe: Because of the real nature and complexity of the project, this was a unique opportunity for the Canadian students to show their strength in designing a major portion of a real project in Europe.
- Challenges of dealing with culture and language issues: Almost all the documents received by the students were in Portuguese. This was an additional challenge for the students. Students had to learn the attitudes and practices of the Portuguese designers in addition to dealing with communication barriers mainly due to language issues. The student felt that the learning experience was enhanced during the design course because of this exposure to a new and different culture and the opportunity to incorporate solutions into culture.
- Sharing the design expertise with Lisbon design professionals and developers: During the academic year, the students had the chance to work with the developer’s chief engineer in Lisbon who not only provided the scope and compatibility of design choices for Lisbon but also the design expertise with regard to specific design issues. The students spent several full days with developer’s chief engineer, touring the entire development site and visualizing the first-hand construction experience both completed and underway. The students also had to satisfy the developer’s representative in Calgary and his design team. Progress meetings were held between the students and this team and the student presented their ideas and received feedback to improve their designs. In May 2003, the students presented their final design ideas to the project developers, and had the opportunity to respond to questions raised by the developers.

Transportation Engineering

Key Activities

- Pavement Design
- Parking Design and Details
- Trip Generation and Distribution
- Model Split
- Microsimulations

Key Innovations

- Traffic Simulation Used to Model Transportation Patterns
- Porous Pavement Used in Pathway Designs
- Use of Pigmented Asphalt

Geotechnical Engineering

Key Activities

- Geological Interpretations
- Soil Assessment
- Foundation Design
- Temporary Shoring
- Permanent Retaining Structures

Key Innovations

- 3-D Modeling Analysis
- Volumetric Calculations
- Use of Shoring as Formwork

Project Management

Key Activities

- Schedule and Estimate
- Risk Analysis
- Bid Document
- Contracting Strategy
- Organization of the Project

Key Innovations

- Simulation Based Schedules and Estimates
- Structured Risk Analysis Framework

Structural Engineering

Key Activities

- Architectural Design
- Slab, Beam and Column Design
- Site Layout
- Earthquake Simulations

Key Innovations

- Use of Stud Reinforcement
- Use of Foamcrete (Cellular Concrete)
- Use of fibre reinforced polymer

Environmental Engineering

Key Activities

- Rooftop Garden Design
- Parking Drainage Design
- Stormwater Networks
- Water Quality/ Quantity Assessment

Key Innovations

- Intensive and Extensive Green Roofs
- Vegetative Filter Strips

Figure 3: Key Design Activities and Innovations of One Student Group [4]

- Opportunity for 40% of the students to visit Lisbon, to meet the project team, and to experience Portuguese history and culture: As mentioned in section 4, 24 students (40% of the class) visited Lisbon and met the project team. They also had the opportunity to explore Portuguese culture and history – which is an added advantage to undergraduate students in addition to their design experience on foreign soil. Needless to say, they also had the chance to tour Lisbon and the surrounding area.
- Opportunity for the students to develop innovative design, construction and project management concepts with the help of advisors and the project developers: This was a unique opportunity for the students. The students were asked to learn from experienced design professionals in Calgary, to transform their ideas into reality and to submit the design ideas to project developers. The students received both academic advice and professional advice, which in turn helped them to develop innovative design solutions.

7. Contributions and Highlights – Academics and the Department

Various contributions and highlights from the academic staff and the Department of Civil Engineering are outlined below [5].

- Developing terms of references for students to design the project by investigating state-of-the-art techniques, and tools and processes suitable for Lisbon: This was a real challenge for the academic professors in the Department. Before they could develop the terms of references for each design discipline, they had to become familiar with the Lisbon conditions. The applicability of innovative design solutions to Lisbon were also considered when TR was developed by the students. As an example, project management TR required a suitable contracting strategy and the students had to research various contractual conditions and strategies that are typically adopted in Lisbon compared to similar ones adopted in Canada. Another example is the use of microsimulation which transportation TR requested. This is a new technology for Lisbon.

- Sharing design concepts and dealing with the design professionals and the owner's team from Lisbon: As mentioned under Section 6 of this paper, academic advisors also had to support the students designs (if they were acceptable to the academic advisors) when they were submitted or presented to either the developer or the developer's team. Various discussions occurred between them and the academic advisors especially when the designs included new thinking, innovation, or unfamiliar design concept for Lisbon. The use of flat slab in structural design is one such example.
- Establishing contacts with the civil engineering program at the Technical University of Lisbon: During the first visit to Lisbon, the academic advisors had the opportunity meet with the civil engineering academic staff at the Technical University of Lisbon to establish future opportunities.
- Becoming a leader by developing the most innovative design course with an international flavour and the first department to internationalize the final year design course: Rarely does a Canadian or any other academic institution offer an international final year design project that emphasizes technical, human resources, business, project management, and civil engineering design aspects including structural, environmental, geotechnical, water resources, materials, transportation and construction. With this year's design course, the Department of Civil Engineering became a prominent department within the University of Calgary and Canada by bringing innovation to the way the course is run in addition to internationalization of the design course. This also raised the profile of the University by improving the calibre of design engineering education in Canada.

8. Conclusions

The civil engineering final design course using the international project “Alta de Lisboa” provided unique opportunities to increase design education in Canadian universities. Designing a project like this one provided the engineering students with real world experience and understanding that meets and enhances both their learning needs and their inquiry skills. A city like Lisbon has different architectural and

construction regulations, a different culture and history, and a different business culture. The students taking part in this project had to learn to deal with all these challenges.

The Portuguese developer obtained perspectives on advanced technical and design thinking in return for sponsoring this project. The students gained an opportunity to be immersed in an international, real-world experience that will be invaluable to their development of design analysis and critical thinking.

This design education and internationalization is an approach that produces a win-win relationship for the University, industry and the international business community by working together to develop innovative solutions. The Department of Civil Engineering at the U of C is proud to be a leader in multi-disciplinary design education in Canada by bringing many facets to design education including internationalization. The Department is currently exploring further opportunities to carry out similar projects in the future.

Overall, this design project provided the students with valuable experience in communication, design and organizational skills that will be useful in any future career in addition to the challenges dealing with a real and international client of a complex project.

Acknowledgements

The authors wish to express their acknowledgements to Dr. Chan Wirasinghe, Dean of the Faculty of Engineering at the University of Calgary for his leadership and idea to use this gigantic project for civil engineering final year design course. The acknowledgements are also extended to Mr. Joseph Leung, U of C Senator and Vice-President of the Marquis

Developments Ltd for arranging the project requested by our faculty Dean and his continued support, SGAL and other affiliated organizations for sponsoring, the 2002/3 civil engineering final year graduates for their commitment and dedication, and all the industry and academic advisors for their guidance to successfully deliver the final year design project described in the paper.

References and Bibliography

- [1] Yellowley, I, Venter, R.D., and Salustri, F.A. "The Canadian Design Engineering Network [Cden/Rcci]: Sharing Engineering Design Educational Tools Within Thirty Three Schools of Engineering In Canada", To be appeared in the *Proc. of the 8th World Conference on Continuing Engineering Education*.
- [2] Salustri, F.A., Britton, M.G., Proulx, D., Venter, R.D., and Yellowley, I. (2001). "Cden/Rcci: A Canadian Network To Enhance Design Engineering Education", *Proc. Of International Conference On Engineering Design Iced 01 Glasgow*
- [3] Burgener, Peter (2003). Lisbon Development of Affordable Housing Tests U of C Students. Newspaper article published in the Calgary Herald on May 28, 2003.
- [4] Chiu, Sarah (2003). International Experience Makes a World of Difference. An Internal Magazine, Department of Civil Engineering, University of Calgary.
- [5] Ruwanpura, J.Y. (2004) "International Experience Makes a World of Difference", Presentation made at the 9th Consortium for North American Higher Education Consortium (CONAHEC) conference, Guadalajara, Mexico.