YEAR 1 Integrated Design for Civil Engineers at the Cyprus University of Technology

Designing, Analyzing, Building & Testing model structures

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Introduction

Civil and structural engineering, as the oldest forms of engineering have been a popular career path for many young individuals interested in STEM subjects. A vast majority of students choosing to study an undergraduate course in Civil Engineering usually select it for their love of structures or construction. It is no surprise when asked what they would like to do when they graduate their response is often to build skyscrapers or bridges; both marvels of structural engineering. Some of these students soon become alienated, since the first two years of a 4-year course (i.e. MEng) is overwhelmingly based on engineering science (physics, maths, mechanics and materials), rather than design which has drawn them to the course in the first place. The Year 1 "Integrated Design for Civil & Geomatics Engineers" module at the Cyprus University of Technology aims to keep their spirit high and inspire students for an amazing and creative profession, as well as bridge and find connections with engineering science modules, which are undoubtedly the foundations of Civil and Structural Engineering. This submission describes the Large Integrated Group Design Project (LIGDeP), which is the culmination of the "Integrated Design for Civil & Geomatics Engineers I" module.

Large Integrated Design Project

LIGDeP is an interactive design studio and model construction activity that runs for 6 weeks (average of 6 hours engagement per week) in the second term of Year 1 for the undergraduate courses in Civil Engineering & Geomatics at the Cyprus University of Technology.

Students in groups of 5-6 are asked to first research a real structural typology and then design, analyze and build it as part of an integrated system. The model construction process is conducted using specified materials (scrapped paper, tape, wooden sticks, plastic straws, adhesive etc) with fictitious costs and each group is required to produce drawings, qualitative structural analysis, method statements, bills of quantities, GANTT charts and risk assessments prior to the construction phase. This activity has been running under the supervision of the author and teaching assistants since 2012 and has been constantly evolving to improve the student learning experience. In a sense, this is an indoor and longer "Constructionarium", the successful UK university project in collaboration with the industry, that further includes design, analysis and test elements. The themes for the last 3 years are shown below:

2012 "Road network with bridges": A seamless road network with bridges and constraints on road width, gradients and turns. Each group was responsible for part of the network and one bridge; each of a different specified typology. The network was tested by navigating a 500g remote controlled model forklift around the network in both directions.

2013 "Monorail network with bridges": A seamless monorail network with bridges and constraints on path width, gradients and turns, as well as cost and material use. Each group was responsible for part of the network and one bridge; each of a different specified typology. The network was tested by navigating a 2-car model train of mass 1kg around the network. The test was performed in both directions, by changing direction at the depot (see Figure 1).

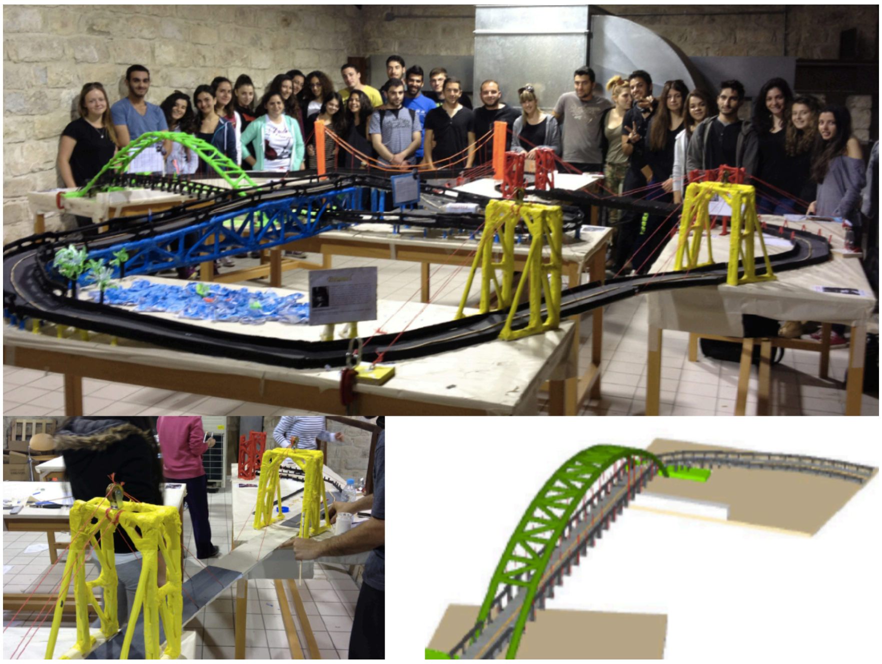

Figure 1: An overview of the 2013 Monorail project.

2014 "Stadia Engineering": Each group had to design and construct a 60,000 capacity stadium in 1:250 scale, of different roof typology. Each group was given specific constraints on pitch size, allowable viewing sightlines and roofs structure and materials. Each stadium was tested by applying downward and upward loads on the roof and checking the mechanical response of the roof to resemble the function of the specified structure. Further checks on sightlines were performed to ensure allowable extreme viewing angles and unobstructed views of the whole pitch (see Figure 2).

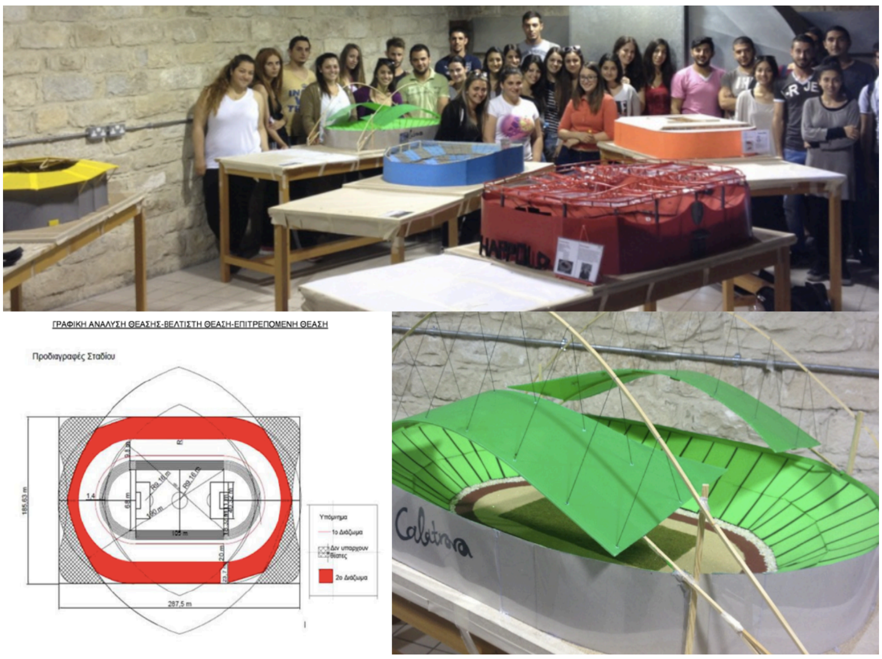

Figure 2: An overview of the 2014 Stadia project.

Activity Description

Each group is named after a well-known engineer and they are asked to find out about his/her biography and landmark achievements. As part of the deliverables, students should pin up a sign with a short biography of their famous engineer (Figure 3).

Figure 3: A sign exhibiting information about the project and prominent engineering figure.

Each student in the group has an assigned role in leading at least one of the work packages of the project. This includes: Project Management, Cost Engineering, Health and Safety, CAD and Drafting, Qualitative Structural Analysis, Method Statements and Construction planning. This does not mean that each work package is undertaken solely by that individual, but rather is the lead in delivering it as part of the whole project. In all cases, there's a shadow lead and at the end of the project a list is submitted, highlighting each student's involvement. The group report takes the form of an A3 portfolio that includes:

- A short research report with bibliographical references, describing the structural typology of their system and explaining how it works.
- Sketches to communicate concept designs, including designs that were not selected.
- Qualitative structural analysis using the Expedition Workshed Catastrophe tool (www.expeditionworkshed.org). When faced with 3-Dimensional structures (i.e. stadium roof), students are challenged to create 2-D equivalent models in Catastrophe or even to create scaled down physical models in order to simulate the response (see Figure 4).
- Initial Bill of Quantities of the estimated material and labour costs, which is revised at the end of the project.
- GANTT Diagram of activities.
- Method statements for the construction phase.
- A risk assessment for the construction phase. Construction in the lab "site" does not start before a risk assessment is performed, a GANTT diagram is drawn and method statements are present in the "Project Diary".

Each group delivers an interim presentation on progress and a final presentation upon the completion of the project. The interim presentation, delivered with 1 or 2 weeks after setting the project is mainly to report on the group building, brief understanding and initial GANTT diagram and risk assessment. It allows the project supervisors to pinpoint any problems in the progress. From there onwards, the supervisor has weekly meetings with different work package leaders who report on their progress and challenges they face. All the leaders are encouraged to present to their groups, since students will be evaluated not only on their own work within the group, but also for their understanding of all the activities of the group. The final presentation, upon the completion of the project, provides some highlights of the design process and a summary of the construction activities.

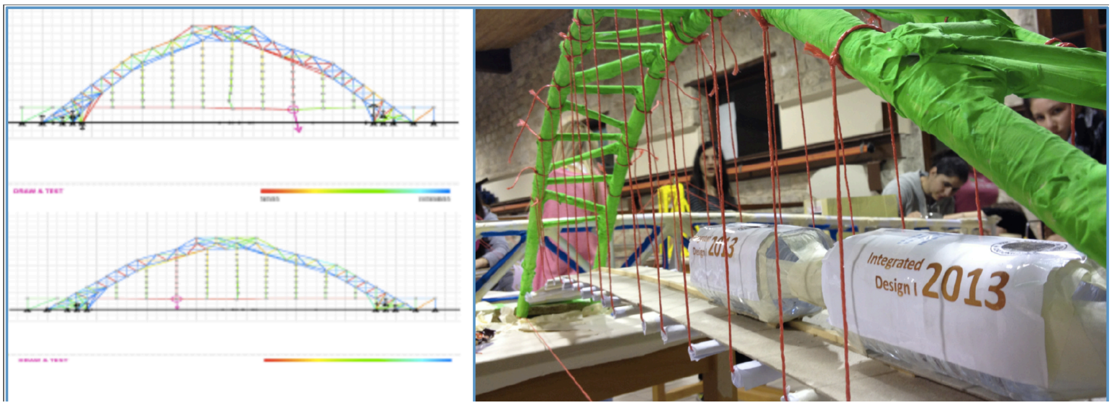

Figure 4: Modelling in Expedition Workshed Catastrophe.

Assessment
The assessment of this exercise is multi-dimensional and its objective is to evaluate student engagement, understanding engineering principles, individual effort, ability to work in a group and the ability to perform certain tasks and deliver the results in a professional way. Students are evaluated for their day-to-day work, the work package they led, the performance of the group exhibited by the deliverables and finally the final presentation and interview. This marking scheme has evolved during the years and the weightings have varied. Nevertheless, the evaluation reflects the aim of the project, by capturing the totality of activities of this project.

Highlights and Resources
Project briefs can be found on www.steliosyiatros.weebly.com/teaching.html
Videos with slideshows from this project can be found in the links below:
- 2012 Project (Road network)
  https://www.youtube.com/watch?v=gTg9QJExb90
- 2013 Project (Rail network)
  https://www.youtube.com/watch?v=ON1zFAJ9CTE
- 2014 Project (Stadia) http://www.youtube.com/watch?v=i1_Z96vkxIA

Improvement to student learning
Prior to this project, all students are introduced to qualitative analysis and modeling through Expedition Workshed's "Push Me Pull Me" and Catastrophe web apps (www.expeditionworkshed.org). Interacting with these web apps, students had the opportunity to boost their own understanding of structural behaviour and challenge their assumptions. For example frequently structural analysis lecturers use the word "pin" interchangeably to describe either a hinged support or a free-to-rotate joint within a structural member. This can confuse students when first introduced. In typical examination papers and worksheets, students are usually asked to analyze different line models but very rarely are asked to model even a planar structure. When such questions were set by the author, a significant number of students, early in their studies would place triangular a "pinned support" at any joint within a planar structure they felt it required a pin. Thus, using the introduction of the Push Me Pull Me web apps and worksheets prior to this project such modelling issues are pinpointed, before we even move to the project. During the project, the modelling

activity brings even further improvement, since the students have to create and analyze one or more 2-Dimensional node-link models that will mimic the behaviour of their three dimensional structures (Figure 5).

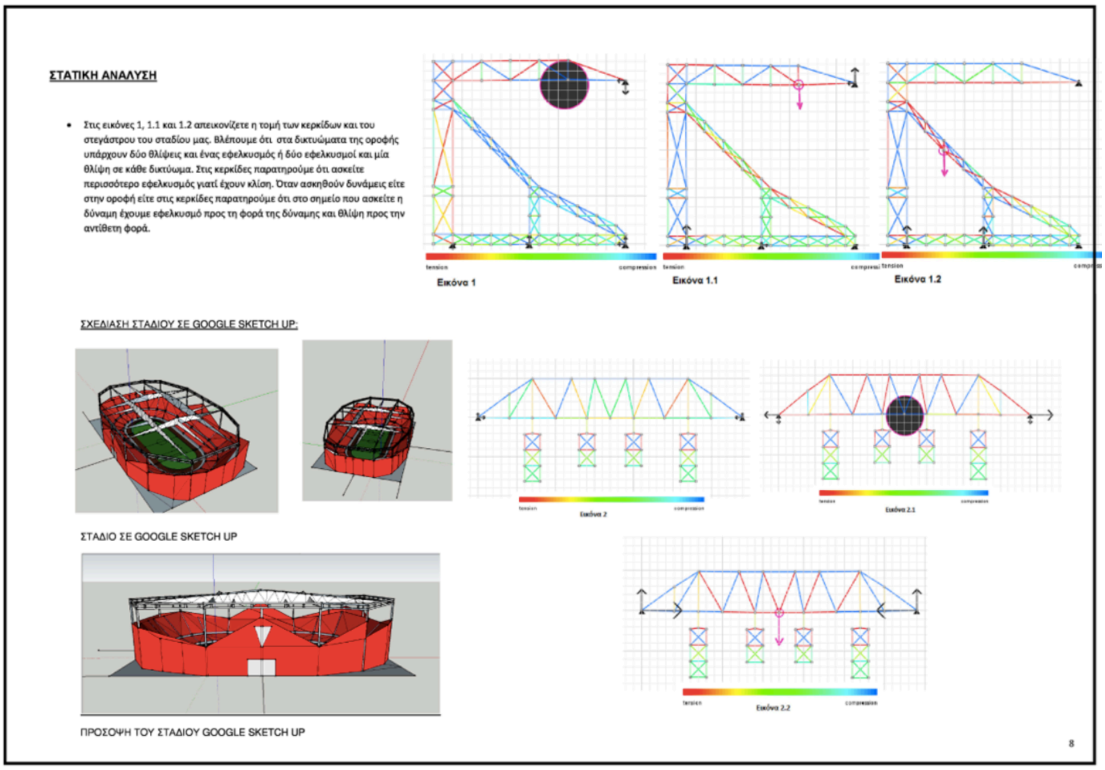

Figure 5: Modelling 3-D structures in 2-D equivalent models.

The current project runs for 3 years now, with requirements changing each year to bring upon improvements in the learning process as well as increasing the difficulty level, since newcomers are always keen to learn from the previous years achievements. For the first year, the scope of the project was a road network with one bridge per group. In year 2 the project changed to a monorail network with heavier payload, while the new cohort was asked to design leaner, more economic structures under stricter guidelines and deadlines. In the 3rd year the project theme changed to stadia, where students were asked to design both the seating bowl structure for a specific capacity as well as the roof. Since the structural problem became in 3-Dimensional, students were forced to test numerous structural models in Catastrophe in order to model their structure's behaviour as closely as possible. What was very interesting is that for the past two years the project has been gaining the interest of "alumni" of the project, coming in the studio and mentoring Year 1 students to face their challenges. Providing these mentoring opportunities to 3rd and 4th year undergraduates, enhances their communication skills as well as their own understanding of structural behaviour. Feedback as communicated to the author by module leaders in structural analysis of later years, has been very positive for the cohorts of the past two years who are project alumni.

The open-ended nature of the project, including its leap into areas that have not been formally taught (health & safety, aspects of construction management, structural analysis etc), allows plenty of room for self-learning and development. What was evident through the duration of the project was that the fear of the unknown (no specified solution a priori) was soon replaced by confidence building through achievement. Even for skill modules that have been introduced in Year 1 (such as technical drawing & CAD), this project offered the opportunity to students to hone their skills in CAD skills as well as experiment with 3D modelling and animations of their structures.

Alumni recall that their experience during the project was stressful, but very rich and rewarding. Anonymous student online feedback over the years rates the module very high (90-100%) with comments such as “The Integrated Design module is one of the most important modules of the 2nd semester because it integrates knowledge from different other modules.” and “the module project brings us closer to the more practical aspects of our future professions”. In personal communications with the author, they frequently mention how working in groups helped them develop their interpersonal skills and that they relate their experiences from this first year project to new material they learnt in subsequent design and construction management modules. The only negative comments would be on the workload, which they rank as one of the most demanding, not only of the 1st year but of the whole course. Indeed the workload to deliver a group project from concept to realization is significant, but manageable. This is probably the first time students have to perform in a group and execute an open-ended project. Students are also inspired and always put a lot more hours to the project (compared to the others modules) as they take ownership of their achievements. Nevertheless, each year every effort is taken by the author to keep the workload manageable in project brief re-designs.

This project sets the scene for the Year 2 Integrated Design Project, a larger conceptual design with technical, environmental and business aspects, similar to the group design project, which is a requirement for the Master of Engineering courses in the UK. Building on the knowledge and skills acquired from the previous years, students undertake to design and size conceptually larger structures, such as airport terminals and other infrastructure, while simultaneously looking at the investment viability in terms of economic and environmental factors. This project is done in collaboration with professional engineers, architects and business consultants.

Conclusion

The students, given a hands-on open-ended project, which they had to own, become highly motivated which was reflected by their dedication and quality of work. Through the initial series of workshops they were introduced to different stages of engineering design and later through the project they had a glimpse of a ‘design-analysis-build-test” project and its constraints, mimicking as closely as possible conditions found on a construction site. The use of Expedition Workshed qualitative structural analysis tools, empowers year 1 students to design basic structures and realise how these deflect, what is tension, compression or bending and appreciate stability. It complements their understanding of structural behaviour, while at the same time allows them to discover the link between what is analyzed and what gets built. By researching the structural typologies, enhances their understanding of structural behaviour and motivates them to develop their mathematical skills in order to analyse real bridges and stadia. Moreover the project introduces aspects of structural design and construction such as serviceability and ultimate limit states, site diary, bill of quantities and risk assessments. This reinforces their existing knowledge and creates greater appreciation of concepts in subsequent structural design and construction management modules. Last but definitely not least, such a project where each student takes a leadership role and ownership of certain tasks as part of a group, builds up their “experience” portfolio (especially placement interviews), hence enhancing their employability condition.

For more information or material please contact Dr Stylianos Yiatros (stylianos.yiatros@cut.ac.cy). The Cyprus University of Technology allows the use of their material with appropriate acknowledgment.