A COMBINED APPROACH TO ENGINEERING AND ARCHITECTURAL EDUCATION

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Abstract

The majority of students starting an engineering degree in the UK have studied mathematics and one or more of the science subjects with their knowledge assessed through closed book examination. They have little or no experience in applying the subject material to a project brief and, it is this application, mixed with many other considerations, that translates the understanding of science into engineering. Engineering and architecture are both design disciplines so why do we teach them so differently?

Our four year integrated Masters programme in Civil Engineering and Architecture is aimed at those who wish to design structures; the core elements of the programme being Structure, Material and Place. This programme shares its first two years with our other civil engineering programmes. It was apparent that our design curriculum (across all civil engineering programmes) specified many of the expected key design skills but that it was not producing graduates who were agile design thinkers. During the last three academic years strategic investments have been made to improve our design curriculum, encourage design thinking within our students (and staff) and to foster a greater design culture within the Faculty. This paper will describe the rationale for the development of the curriculum and some of the issues encountered in its implementation with reference to recent student outputs.

Introduction

The Faculty of Engineering and the Environment supports a wide range of engineering programmes offered at undergraduate level from civil, mechanical, aero and astronautics and ship science to acoustical, environmental science and audiology. Research is focussed on groups that comprise the sub-disciplines commonly associated with these programmes. The Faculty is recognised internationally for its research across all the subjects and, was assessed under General Engineering (Unit of Assessment 15) in the 2014 Research Evaluation Framework (REF). As a research intensive Faculty, all 193 eligible academic staff were submitted and results from the REF confirmed the Faculty's research as being the most powerful in General Engineering in the UK. Power is defined as the assessed quality and impact multiplied by the number of academic staff submitted. Additionally, the Faculty provided the most powerful submission to the REF from any single institution in the UK, in any engineering unit of assessment.

Many of the investments and curriculum developments described will not be viewed as innovative when compared to architectural or other design focused educational programmes. However, a significant shift in emphasis in the mapping of primary educational objectives at undergraduate level towards integrated design and redirecting engineering laboratory areas away from research use only is highly significant, particularly in the context of the attitudes and behaviours associated with a research focussed community. The changes were necessary to meet the strategic goal of providing world class education in a research led environment in which new knowledge is being created. Careful planning and management of resources was needed to achieve this goal within existing and available infrastructure and resource restraints and they are now providing tangible improvements and outputs that are novel to civil engineering education.

This paper focuses primarily on the development of the MEng Civil Engineering and Architecture undergraduate degree, Faculty of Engineering and the Environment, University of Southampton, the specific investments made during the past three academic years and their relationship and influence on our core MEng Civil Engineering programme. These are described through the illustration of recent projects produced by students enrolled on the programme.

Programme context and structure

In 2009-10, the University reorganised into a new Faculty structure with eight Faculties from the previous structure of three “super-Faculties” and twenty or so Schools. The new Faculty of Engineering and the Environment was formed around the core engineering programmes and Schools of Engineering Science: aero and astronautics, mechanical engineering, ship science, The Institute of Sound and Vibration Research and Civil Engineering and Environmental Science. For administrative purposes, the faculty is divided into four similarly sized academic units of Civil, Maritime and Environmental Engineering and Sciences, Engineering Sciences, Aeronautical Astronautical and Computational Engineering and The Institute of Sound and Vibration Research.

In 2012-13, taking advantage of the new Faculty structure and the synergies between disciplines that it opened up, the teaching of Year 1 was reorganised so as to create cross-Faculty modules delivered over the full academic year. Civil Engineering programmes participate in three of the new modules: FEEG1002 Mechanics, Structures and Materials, FEEG1003 Thermofluids and MATH1054 Mathematics for Engineers. The remainder of the Year 1 programme comprises an amended module CENV1023 Construction Design and Materials with a substantially increased materials science and design content, and a new module CENV1025 Civil and Environmental Engineering Fundamentals. The latter contains basic chemistry and geology for engineers, as before, but with the addition of computer programming, not previously covered in the first year.

Overall, the aim of these changes was to give students access to new skills in design and computing whilst not decreasing the content and intellectual challenge of their core engineering science activities. From 2012-13, requirements for progression were strengthened by making all modules in Year 1 Core subjects. Thus, the module pass mark of 40% must be achieved in all modules. (Previously this was only true for Mechanics, Structures, Geology for Engineers and Hydraulics modules). For all students entering the course from 2012-13 this limits the referrals that they may take on failure of a module to 30 credits in any one year (previously, there was no limit). The development of the Year 1 modules delivered across the full academic year removed the need for Semester 1 examinations and in their place an intensive two week design workshop is undertaken that allows students to gain knowledge and skills in design by tackling a range of problems, culminating in a design project that runs through semester 2. Design communication through hand sketching, diagraming, technical drawing, modeling (physical and CAD) and prototyping is taught as an essential part of the design process as well as for final communication of output.

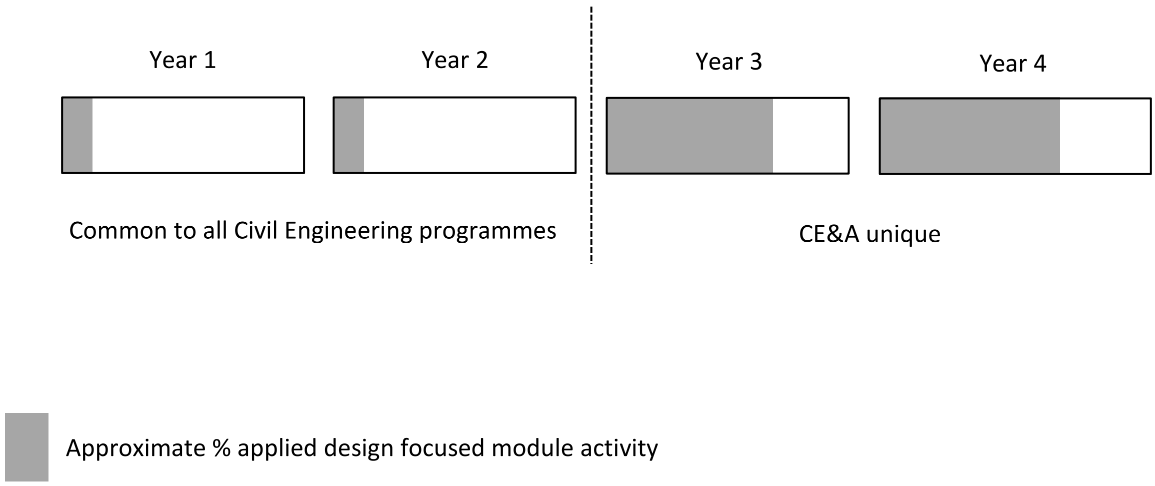

Figure 1. CE&A programme structure (Years 1 to 4).

Inception and development of the Civil Engineering and Architecture programme

The Civil Engineering and Architecture programme was established in 2003 to be a headline programme within Civil Engineering and was targeted to attract high achieving students, particularly those who were design focused, or those who wished to have broad design skills. It was considered that the addition of architectural education content would broaden and enhance the core civil engineering education. There were initial discussions with Portsmouth University, School of Architecture to support the architectural aspects and their integration into the programme. This did not go forward, and a team of three/ four visiting architects taught the architectural modules – no architects were permanent members of staff.

The programme is a four year full time integrated Masters undergraduate Honours degree accredited by the Joint Board of Moderators (JBM). Students graduate with an MEng. This qualification offers the fastest recognised route to becoming a Chartered Engineer. Entry subjects are A-level Mathematics and an A-level in another science subject from Physics, Chemistry, Biology, Geography, Geology, Further Mathematics. The third A-level subject is flexible but it cannot be General Studies, Critical Thinking or Use of Mathematics. Current grade entry requirements are A*AA. Students typically have not previously carried out significant project based work. The programme was titled Civil Engineering with Architecture when first established. However, the programme evolved and was retitled Civil Engineering and Architecture with a substantial design component being common to the educational criteria specified by the JBM and ARB. During 2007 and 2011 a number of students successfully applied to the ARB for Part I accreditation through interview. As a result, in 2011 consideration was given to making an application to the ARB to formally accredit the programme. However, changes to the eligibility criteria resulted in applicants from the programme being barred from ARB Part 1 by interview because it could not be demonstrated that it had sufficient architectural education by virtue of its JBM accreditation. This resulted in a reflection on the future direction of the course. This coincided with the appointment of an architect as a full time Faculty member to oversee and strengthen design based education across the Faculty and estate and technical support investments to improve student design activities across the Faculty generally.

The three following key strategic decisions were made:

1. The design curriculum within the Civil Engineering programme would be supported to the same extent as the Civil Engineering and Architecture (CE&A) programme – inheriting the momentum from the CE&A programme.
2. The 'additional' CE&A modules within Years I and II would be removed so that the programmes had equal credit weighting – Years I and II would be the same for all Civil Engineering programmes.
3. The CE&A programme would focus to a much greater extent on structural design.

The broader Faculty investments in design

A number of strategic investments have been made by the Faculty to improve design teaching and reputation since 2011 to date and include:

- Appointment of new members of staff; Faculty Director of Design Education, Senior Experimental Officer (to lead on design for manufacture), Teaching Fellow to lead design development in mechanical sciences and three additional student facing technicians to run new studio/ workshops.
- Curriculum development with a significantly increased design and manufacture focus.
- The realisation of three 80 seat design studios and associated design workshops.
- Significant investment in an Engineering Design and Manufacture Centre (CNC machinery, additive manufacturing, laser and water cutters).
- The realisation of the Faculty Design Show (including establishing www.uosdesign.org, which acts as the Design Show catalogue and provides a future framework for communication student design activity) and the general increased focus/ communication of design activity across the Faculty.

Significant investments in resource and curriculum have realised tangible design impacts. However, the greatest impact has been the development of a design culture [Fig 2]. Although much harder to define as it involves intangible elements such as pro-activeness, ambition, collective momentum and identity.

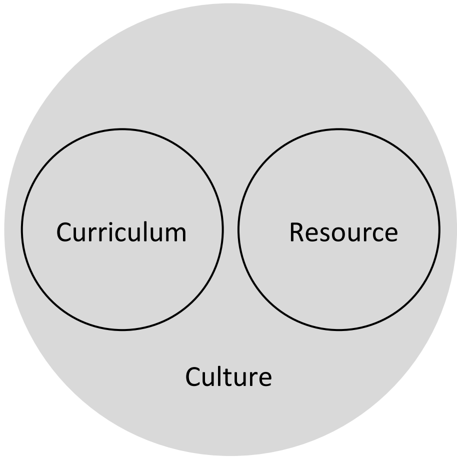

Figure 2. Investments in design.

A decision was made to make all design activities project based. This addresses the key objective to strengthen the focus, structure and clarity of our design curriculum and to increase its meaning and rigour through the development of challenging outward looking project briefs that allow for unique solutions to be developed. These activities should encourage diversity and experimentation. A further critical development was to move assessment away from the individual numerical marking of multiple project components to the assessment of design as an integrated solution, fundamentally focused around core design attributes of innovation, process, communication and impact. The teaching impact objective provided a link to the REF Research Impact Statements.

To further support the design process, events such as interim project reviews using external practitioners, presentations and an end of year Faculty Design Show have all been implemented to fuel positive and competitive participation and increase our student's exposure to a wide range of audiences.

Design modules

The following is a summary of the core design modules across the four years of the design curriculum:

Year 1

CENV1023 Construction, Design & Materials, provides a broad introduction to the 'design process'. A range of design skills including diagraming, hand sketching, modelling (physical and CAD) engineering drawing, manufacturing, as well as personal skills of observation, analysis, communication, and innovation are taught through their application within design and prototyping exercises. It is taught in parallel with adjacent introductory engineering science modules and specifically draws upon structural and material behaviours. Students are prepared for the Constructionarium (a residential field course www.constructionarium.co.uk) through completion of a series of tasks including construction method statements, temporary works design (formwork etc) and surveying and setting-out methods. The Constructionarium forms a core part of our civil engineering programme and an underpinning context to later modules on structural analysis and design, construction management and engineering economics.

Year 2

CENV2028 Design 2 provides students with the opportunity, working in groups between 4 and 5, to design a temporary structure for a site in the Southampton area. They are expected to utilise and further develop the skills and abilities introduced during Year 1. The module builds upon the critically reflective and competitive design environment initiated within Year 1 and offers the opportunity for a 'winning' design, as judged by a professional panel, to be developed further and built at full scale for the opening of the Faculty Design Show.

The completion of Part 2 marks the end of the common design threads that are shared across all civil engineering programmes. Part 3 and 4 of the Civil Engineering and Architecture programme is predominantly design project based (66%) delivered through both individual and group project work.

Year 3

CENV3062 Architecture 3 requires students to demonstrate a greater understanding of the design process, the application of relevant engineering skills and a maturity of judgment. Projects start at the conceptual stage but an emphasis is placed on detailed design, aimed at instilling the importance of refining initial design proposals and the application of specific engineering skills and analysis. CENV3062 Architecture 3 is a triple module (45 credits, rather than 15 credits) and therefore provides the required time for students to develop individual design directions and a resultant ownership of their work.

Year 4

CENV6159 Architectural Group Design Project is run over the first semester and requires students to develop and demonstrate a high degree of design ability within the context of a brief with input from industry sponsors and/or university research. The combined experience and learning gained throughout the Year 1, 2 and 3 modules should be demonstrated. CENV6160 Architectural Engineering Project is a final semester individual design project providing students the opportunity to realise a design solution to a highly technical level that demonstrates the breadth and extent of their abilities.

The following project examples provide a selected overview of recent student project outputs that begin to demonstrate the impact of the recent investments in design.

Figure 3. Year 1 Prototype project installed on site.

This traversing structure [Fig 3] has been designed to span between a column and an adjacent wall. Intentionally sculptural in form, the structure uses the bending characteristics and the associated lateral forces generated by layered plywood struts to retain the structure between the existing built elements. Threaded steel bars connect the struts and allow for adjustment.

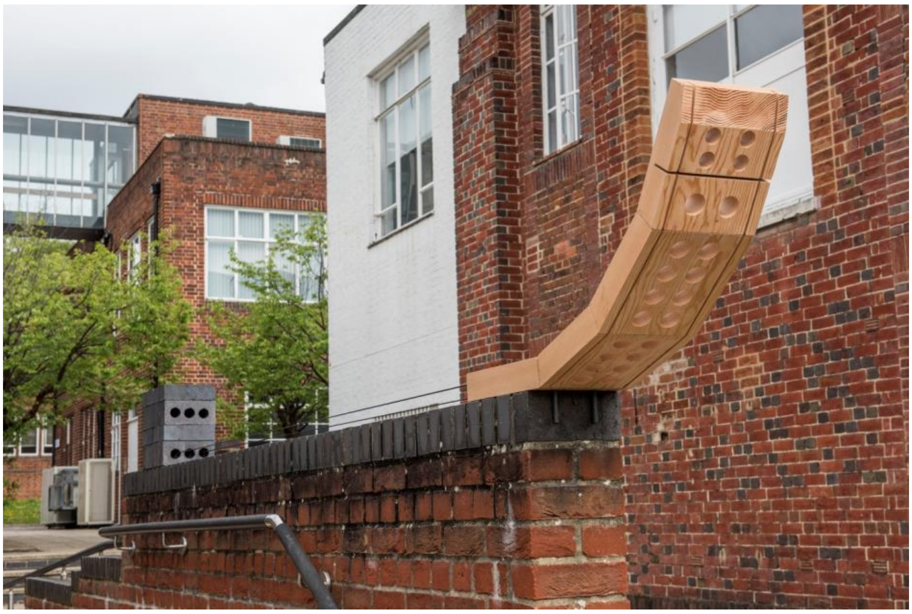

Figure 4. Year 1 Prototype project installed on site.

This lookout structure [Fig 4] was designed to sit on top of, and project from, the end of an existing brick wall. A sectional timber element made from Douglas Fir and perforated to reduce its weight, is held in place by a tensioned cord. The dimensions and geometry of the timber sections are informed by standard brick dimensions. A loose stack of engineering bricks counterbalances the cantilever of the timber through frictional forces greater than the tension forces in the cord and includes a factor of safety for the overall structural system.

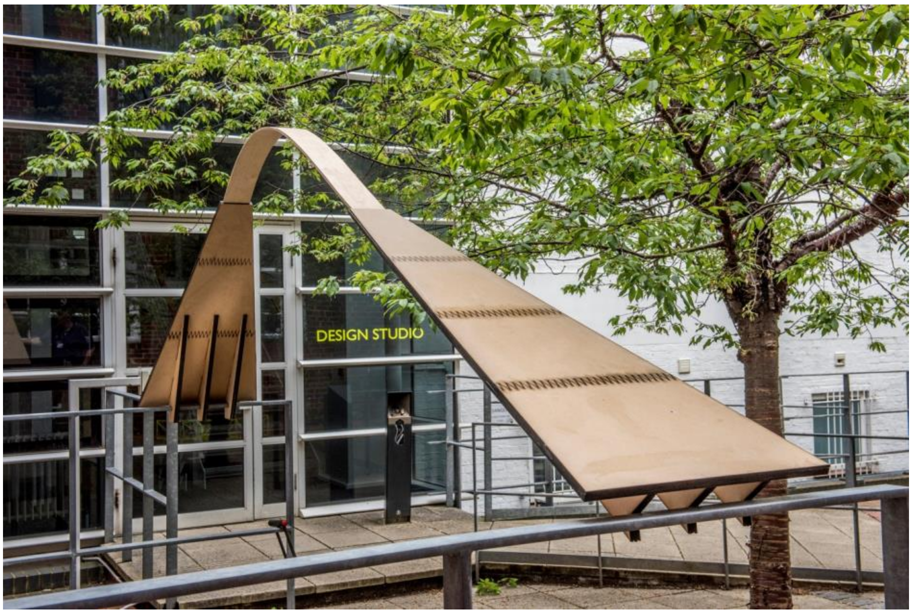

Figure 5. Year 1 Prototype project. Full scale prototype installed on site.

This traversing structure [Fig 5] comprises three sections and has been designed to span between two handrails and to avoid obstructing the existing access route below. Two laminated flared MDF panels provide lateral stability, one rigidly connects to the handrail at a fixed angle, the other rests and pivots on the handrail requiring the central plywood section to bend under the weight of the panel; this results in the overall structural form.

Figure 6. Year 1 Prototype project. Development models.

Figure 7. Year 1 Prototype project. Student groups installing prototype structures for the Final Presentation.

Figure 8. Year 1 Prototype project. Student groups presenting during the Final Presentation.

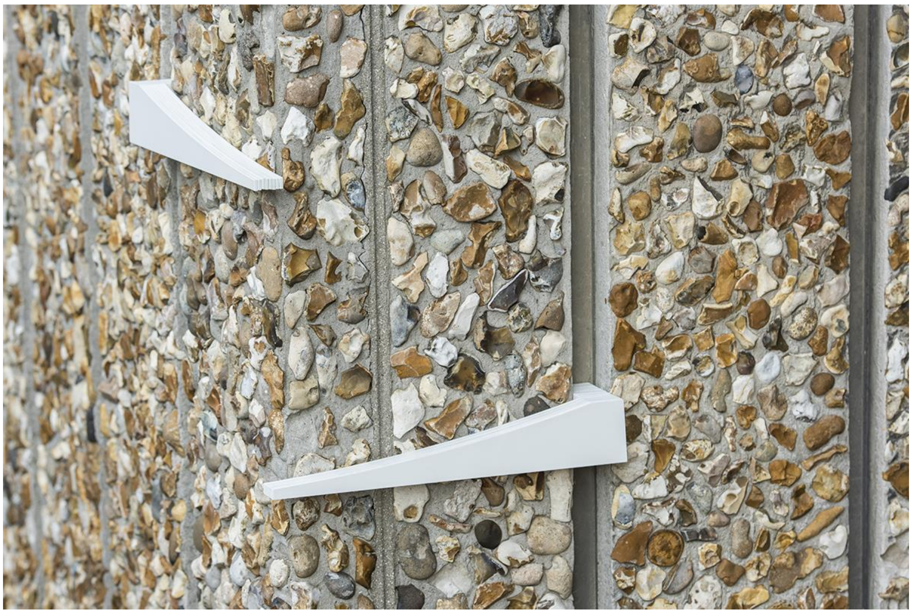

Figure 9. Year 1 Prototype project. Full scale prototype installed on site.

These ascending structures [Fig 9] have been designed to slot into the vertical rebates in a wall and be capable of installation at differing heights. The structures act as levers to create friction forces between the structure and the internal sides of the wall rebates. Constructed from laminated laser cut MDF they are hollowed out internally and have concealed steel weights to create the required friction forces.

Figure 10. Year 2 Concept model; ‘breathing’ pavilion.

Figure 11. Year 2 development models.

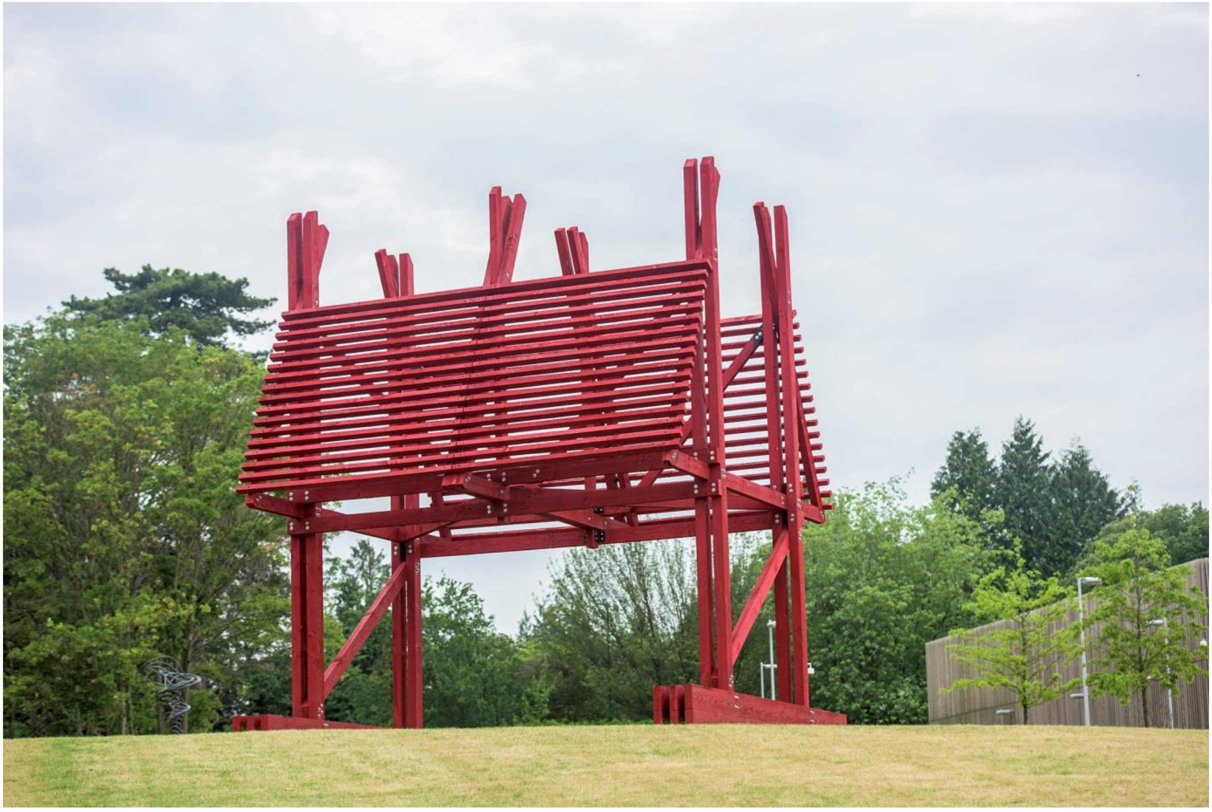

Figure 12. Year 2 full size prototype construction.

This structure [Fig 11 and 12] has been designed and built by a group of second year civil engineering students as part of their design curriculum. The project brief asked for the design of a unique temporary structure for a site adjacent to the medieval walls located towards the southern end of Southampton. The structure was to provide a focal point for visitors and act as a potential catalyst for cultural activities in the area. This structure fits around and masks the view of an unsightly existing footbridge whilst also acting as a celebratory gateway for pedestrians passing under and over the bridge.

The concept design considered a range of factors; the local site characteristics and its surrounding environment, the temporary nature of the structure, form, proportion and the user experience, differing material characteristics and construction process. The production of drawings and scale models and the use of calculation resolved the design through an iterative team working process. The detailed design was developed with support from a professional consultant team and further resolved the structural stability, member sizes, connection details and construction tolerances. The final structure was constructed with the assistance of a local contractor using locally sourced rough sawn Douglas Fir, proprietary galvanised fixings and an ultra-saturated water based red wood stain.

"Having the opportunity to work as a team and alongside professional consultants to develop our own unique design solution, and then to be involved in the full scale construction of our design has been a challenging and rewarding process. We are all very proud of our structure"

Project student team: Aiden Brown; Part 2 MEng Civil Engineering and Architecture, Rosalynde Burchell, Sally Pickard, Jared Tiller; Part 2 MEng Civil Engineering

Figure 13. Year 3 CENV3062 Sectional development model.

Louvered Shell
High Street, Southampton

This project [Fig 13] proposes a cafe and restaurant unit to the south of the archaeological excavations, the utilisation of the existing vault and a wide span structure to protect the excavations from the effects of weathering. A louvered steel cladding unites the elements.

The area to the south of the vaults is excavated to create a submerged structural box housing a two storey cafe and restaurant. Double height volumes are used to create visual linkages between street and basements levels, utilise daylight and create unique and engaging spaces. Sheet piling is installed around the perimeter of the site with reinforced concrete walls cast in-situe to form the internal layout and provide stability for the roof and cladding structures.

Structural analysis carried out to ascertain the likely performance of the existing vault structure suggested that additional loading would be detrimental to its integrity. The proposed concrete slab above and pedestrian walkways are hung from the primary roof beams to avoid additional load being placed on the vault.

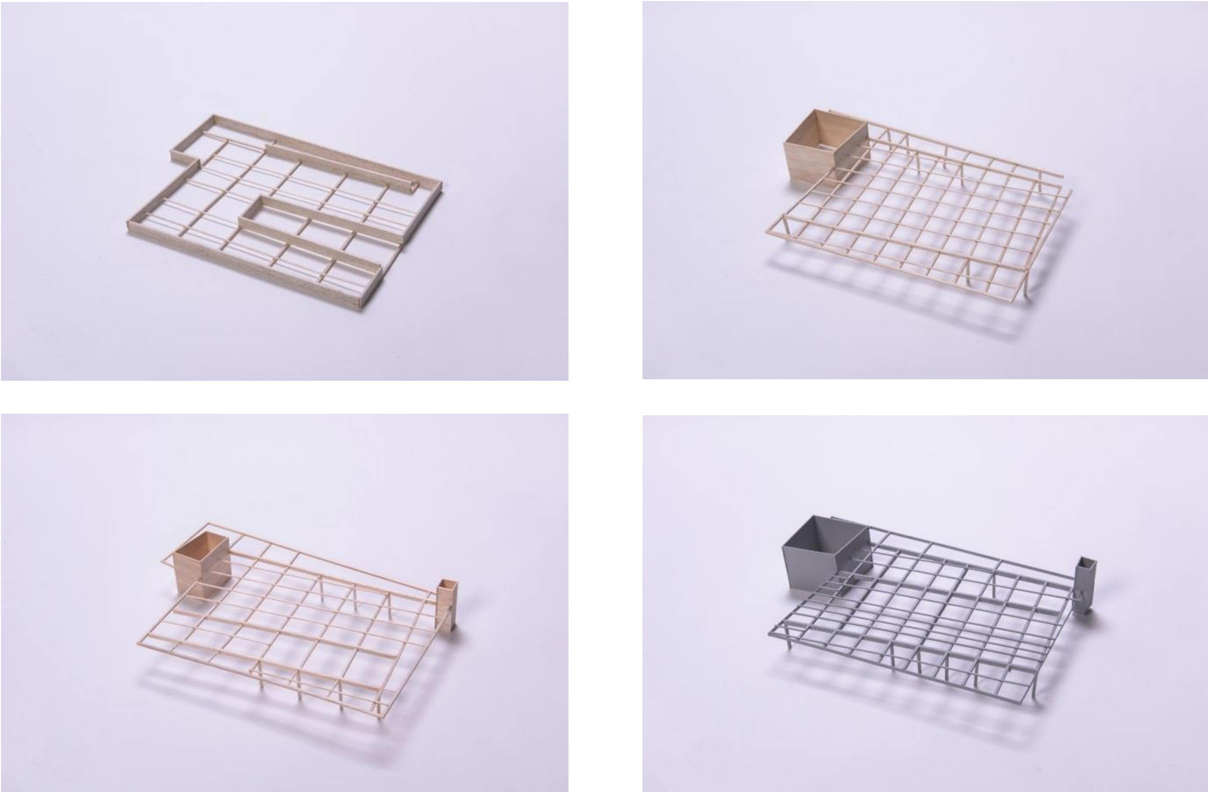

Figure 14. Year 3 CENV3062 development models showing primary steel frame.

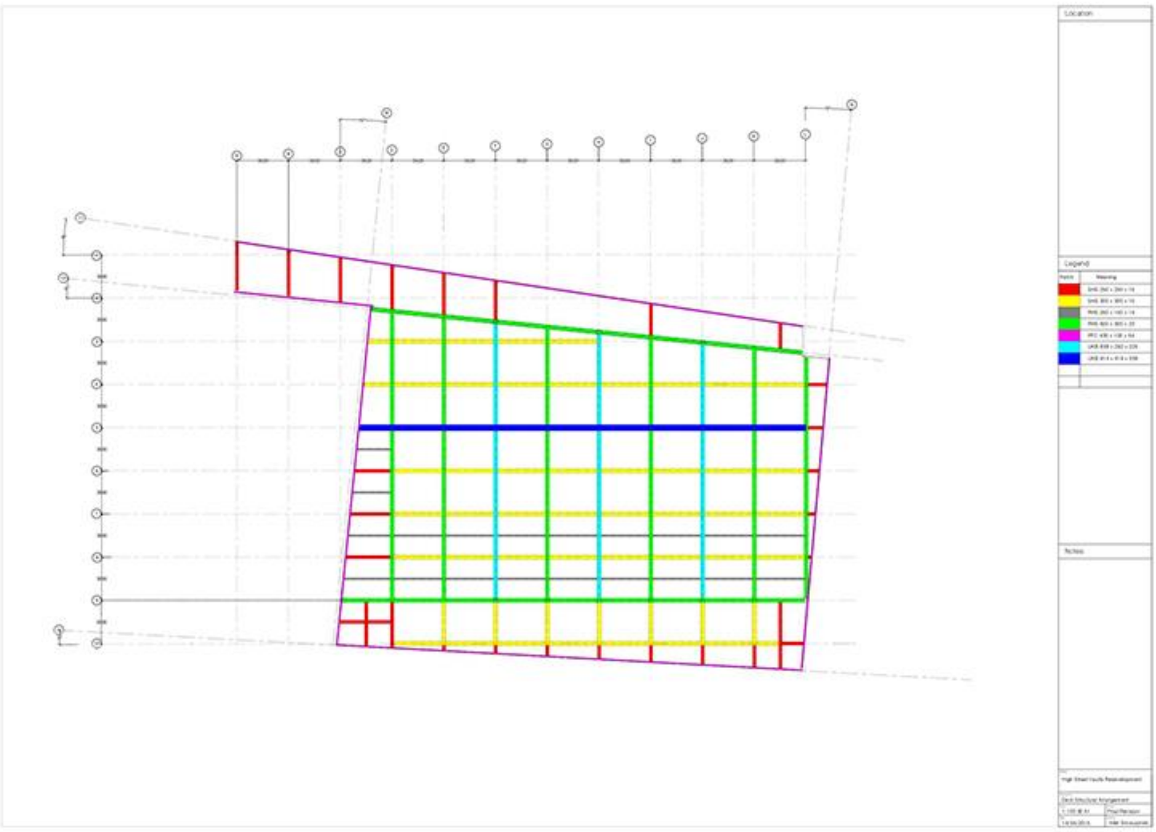

Figure 15. Year 3 CENV3062 beam loading diagram.

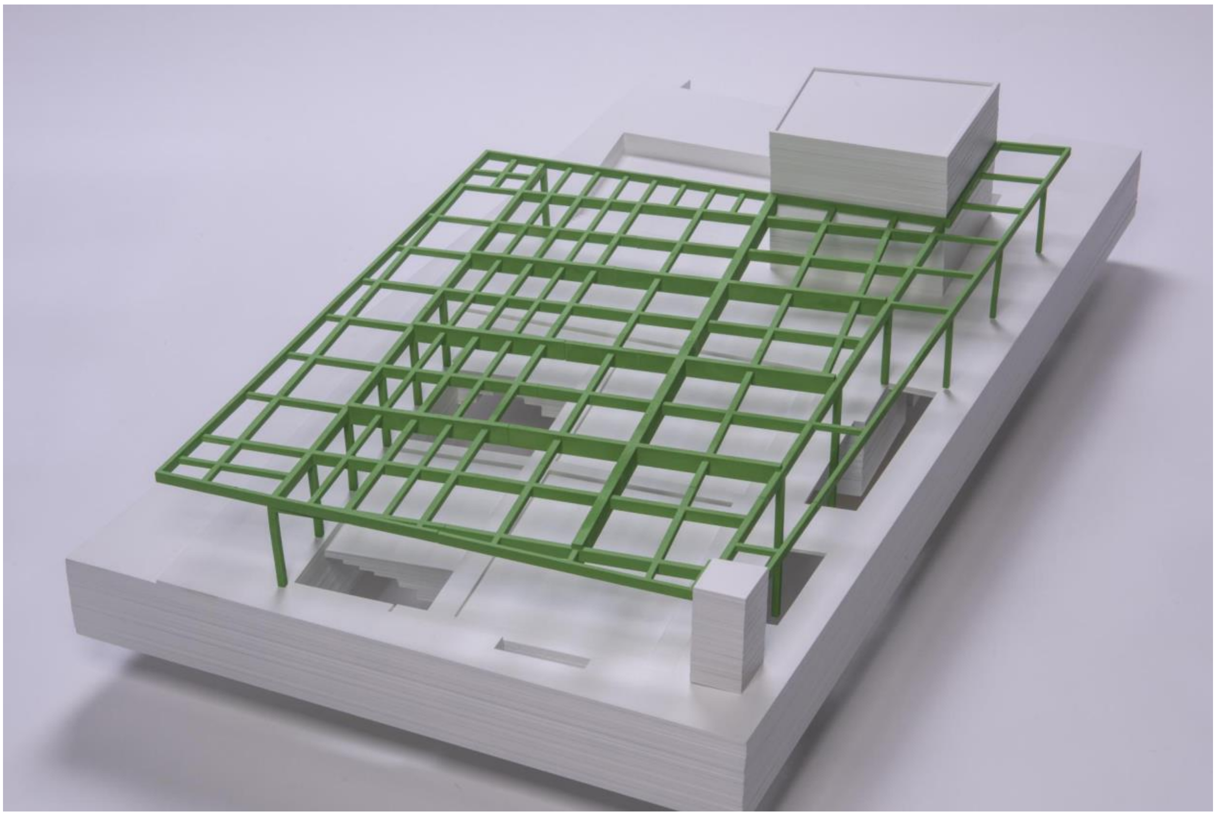

Figure 16. Year 3 CENV3062 Scale model showing site and primary structure (green) of proposed canopy.

Multi- level Plaza
High Street, Southampton

This project [Fig 14, 15 and 16] proposes the extension of the public realm to provide improved access to the basement level archaeological excavations/ vaults and to provide protection against the effects of weathering.

The area to the south of the vaults is excavated to create stepped access descending down to basement level, a plateau midway down breaks down the vertical travel distance and provides an area for external seating in the summer; the steps are orientated south to also act as seating. Sheet piling forms the edge of the area to be excavated and extends around the existing excavations to stabilise the boundaries and reduce identified water ingress issues.

A steel framed canopy structure spans above the existing exposed archaeological excavations, its column loads transfer to the proposed retaining structure and the efficiency of the beam grid has been refined to reduce weight and aid construction. Access onto the southern section of the canopy extends the possibility for the public to experience of the site

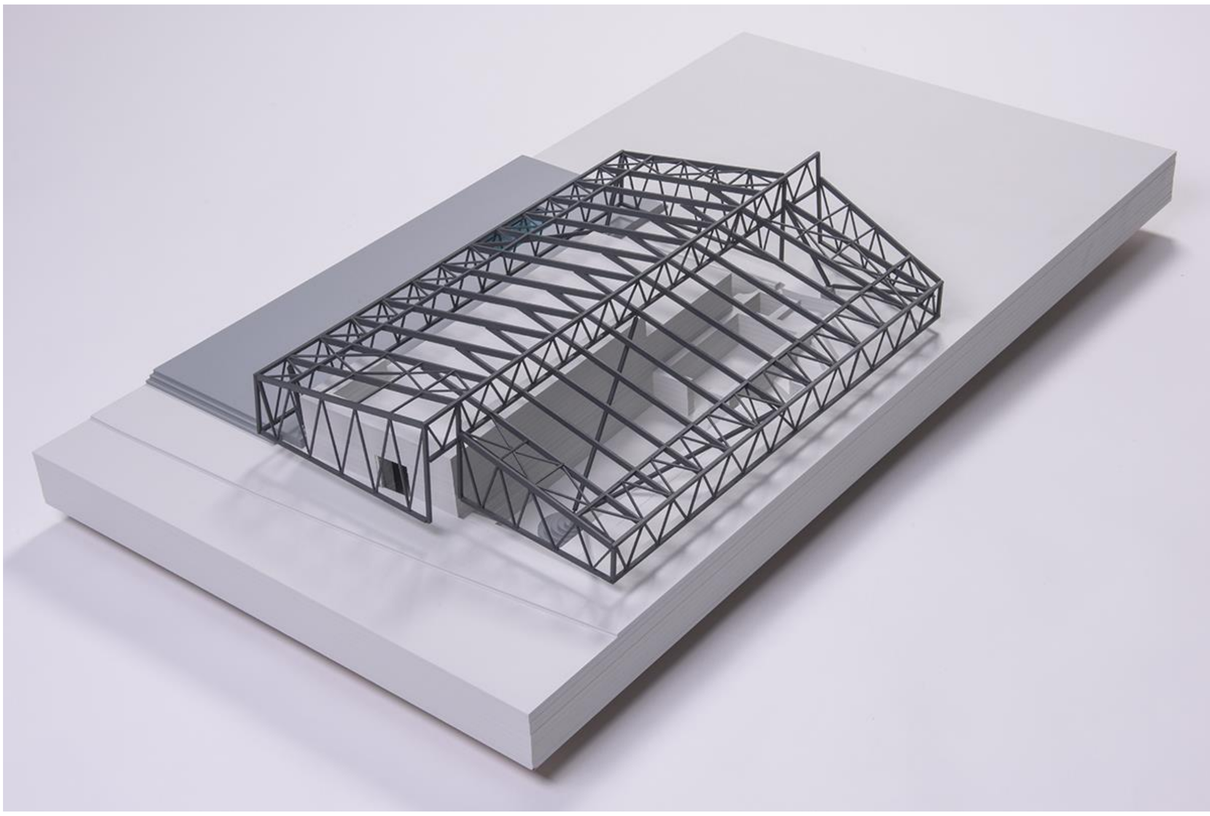

Figure 17. Year 4 CENV6160 Scale model showing the site and proposed structural frame and ground slab.

Canopy
Quilters Vault, High Street, Southampton

This proposed structural design [Fig 17 and 18] results from the consideration of the building's street context (scale, proportion and massing), programmatic requirements (access, circulation and function), site characteristics, structural and material performance, and the construction process.

A steel framed canopy primarily designed to enclose the existing medieval structures and shelter them from the effects of weathering. The structure also aims to increase public interest and cultural focus towards these important archaeological structures within the city wide context.

The external shell of the building staggers in plan and steps in height to establish an exterior mass suitable to its streetscape and to create inspiring volumes internally. These formal shifts provide locations for an entrance and exit and allow for significant glazed openings that maximise the use of natural light. The pitched roof effectively drains rainwater and further breaks down the mass of the building.

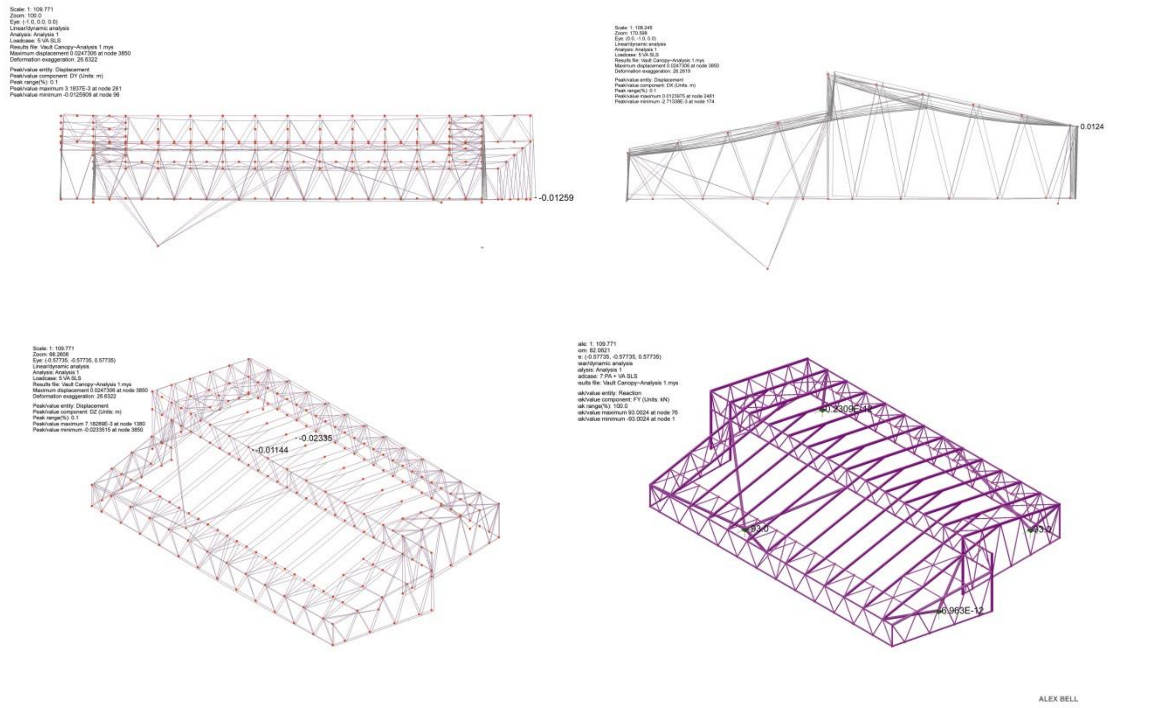

Figure 18. CENV6160 Structural analysis model using LUSAS.

The complexity of the site ground model dominated the location and development of the inclined struts that provide vertical support to the roof structure and provide overall lateral stability. Trusses and bracing elements support spans, provide stiffness and characterise the appearance of the canopy structure. Piles, ground beams, thrust blocks and spanning slabs are used to provide stable foundations that avoid placing load on the existing structures during the lifetime of the building.

The building is clad with horizontal louvers that allow air to freely flow through and for the support structure to be seen as integral to the appearance of the building. The facades are further animated when illuminated at night time. The elevations are hung and stop short the surrounding street surface to emphasise the insertion of a modern structure and the retention of the historic fabric.

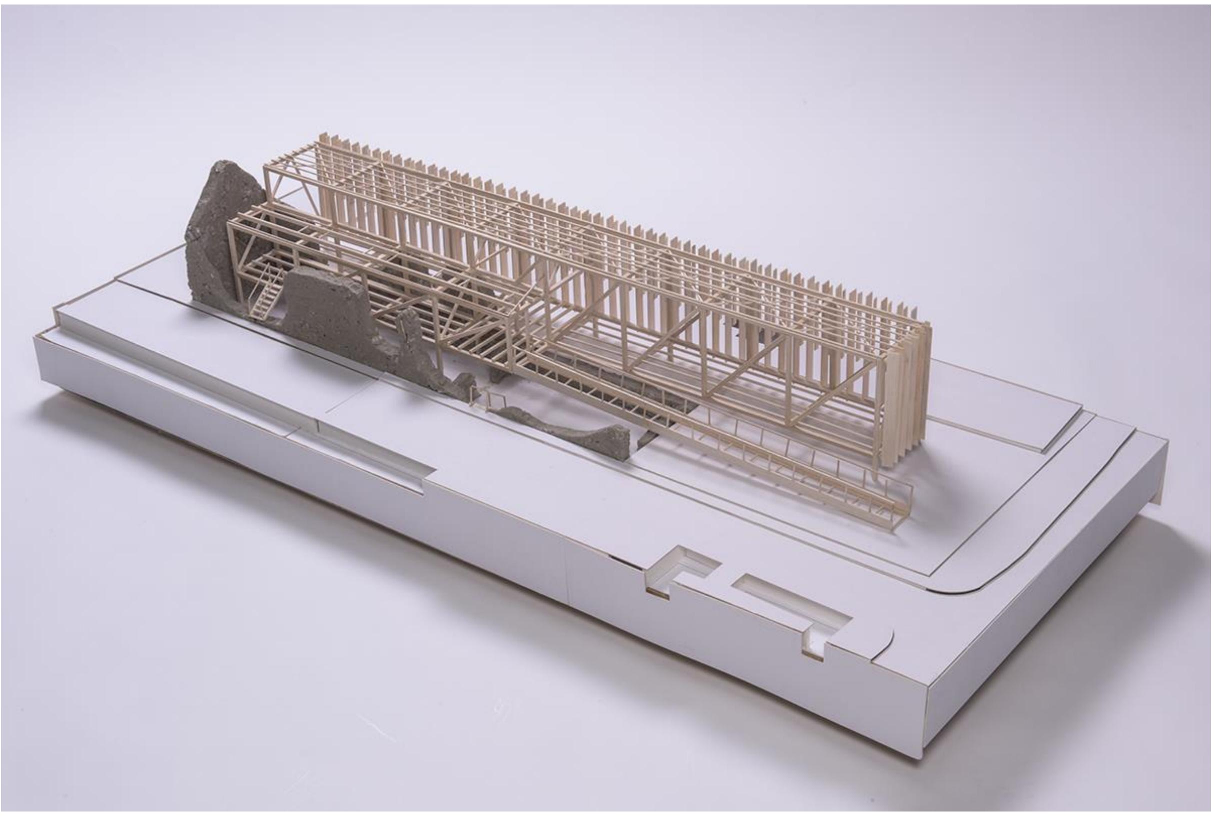

Figure 19. CENV6160 Scale model showing the site and the proposed structural framework.

Canute’s Palace Restaurant
Canute’s Palace, Porters Lane, Southampton

A steel framed and timber clad building designed to partially sit within the footprint of Canute’s Palace [Fig 19 and 20].

An evaluation of the site suggested that building solely within the footprint of the existing building would not support an economically sustainable restaurant and it was not possible to extend using the existing site levels. The floor level of the proposed building is raised (to retain public access to the archaeological remains) and ramped access utilises the existing masonry shell as the main entrance and to locate the kitchens and associated services. The dining area sits adjacent to the northern elevation of the existing structure and faces Town Quay Park. This arrangement results in the north wall of Canute’s Palace being encompassed within the proposed building, acting as a visual break between the front and back-of-house and emphasising the relationship between new and old.

The proposed building extends east towards High Street to achieve a street frontage, maximise park views towards the north, and form a visual boundary along the southern park boundary. A braced steel frame supports this long, relatively narrow form, a column grid and its cross bracing is left visible and proportioned to realise an efficient structure, span underground archaeology and coordinate with functional requirements. The structure is portilised below its ground floor to avoid visually detracting from the view of the enclosed historic wall and removable screw pile foundations transmit the load to more competent strata and avoid placing load on archaeological features.

This project has been developed and communicated using a range of design methods; sketching, technical drawing (Autodesk AutoCad), three dimensional computer modelling (Autodesk Revit), physical model making, hand calculation and computational analysis (LUSAS) to provide a fully resolved structural solution.

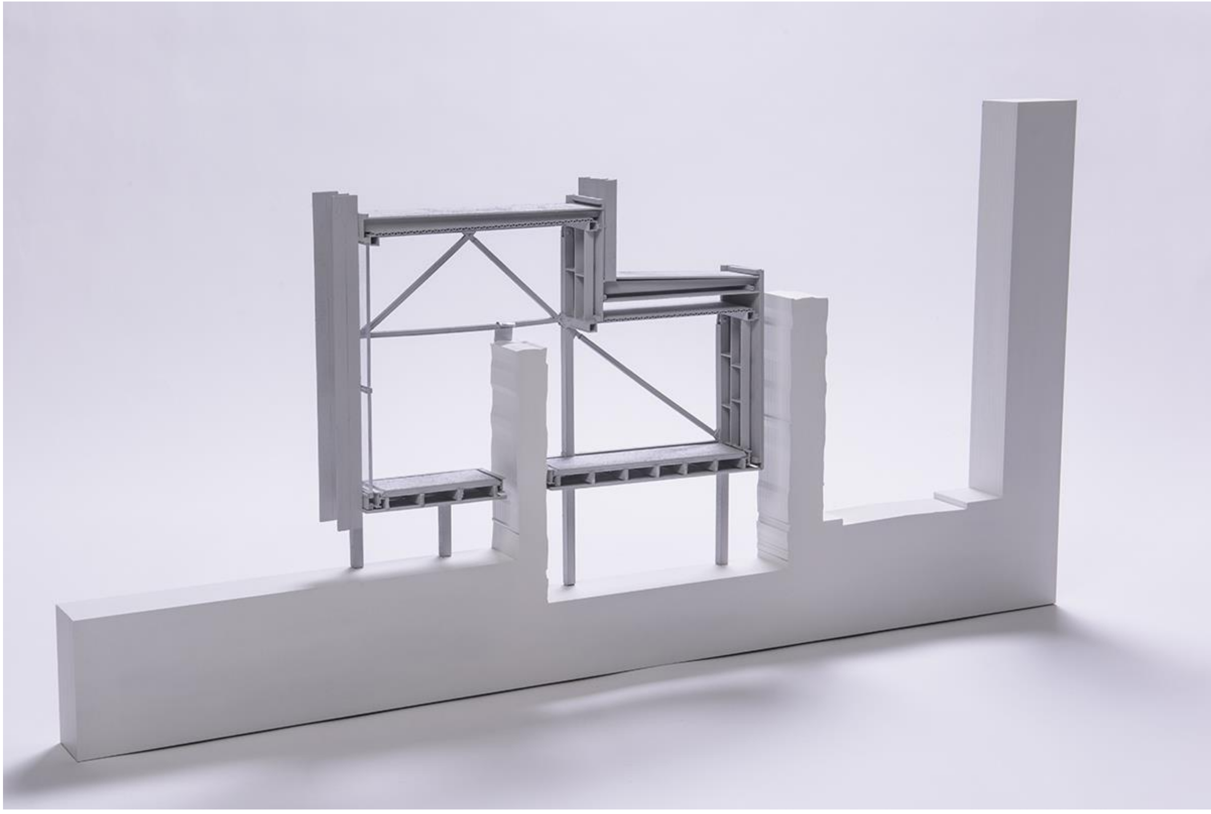

Figure 20. CENV6160 Sectional model.

Conclusion

It is important to recognise that the investments described within this paper are recent (within the last three academic years) and only represent the start of a much wider strategic plan to improve the design abilities of our engineering graduates. As such, the conclusions and reflections are made against limited data. However, it is possible to identify positive emerging trends.

- Students are becoming increasingly independent and proactive in finding solutions. They develop new knowledge and draw linkages between the content of all their taught modules within the context of addressing their design briefs. Craft, skill and judgement of the students is now more significant.
- It is apparent that students now have a greater ability to critically discuss their work. There has been a shift from a predominantly defensive stance when confronted by critical review towards more productive engagement that assesses the advantages and disadvantages of their proposed design solutions.
- Design has moved away from a final proposal to illustrate the aesthetics of an idea towards an understanding that design requires an iterative, critically reflective process and the delivery of a suite of high quality information from which others can understand the proposal.

- The importance of students feeling integral to a programme with a clear identity is becoming more apparent. The increased design opportunities offered within all civil engineering programmes offer ‘ownership’ of unique designed outputs.
- To support the uplift in design ambition, the development of appropriate work space and provision of dedicated technical support has required extensive re-purposing of estate. This was initially met with resistance amongst the academic community but which is now seen as essential to the broader development of integrating design across all undergraduate programmes. Transformative events such as the inaugural Faculty Design Show have been essential in demonstrating to the broader academic community the benefits and uplift in educational attainment made possible by these changes.