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A Retrospective and Prospective View on Teaching Conceptual Design of Structures

Una visión retrospectiva y prospectiva sobre la enseñanza del diseño conceptual de estructuras

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ABSTRACT

The paper begins with personal reflections on the, often underestimated, role and responsibilities of structural designers in the context of sustainability. The integration of the sustainability framework within the construction industry must begin at the Conceptual Design stage, as early decisions profoundly impact the sustainability of the entire project. The paper then introduces criteria to develop a sound structural concept, emphasizing the need to integrate diverse disciplines. While past concerns focused primarily on safety and economy, today's emphasis on sustainability demands a more holistic and multidisciplinary approach. Structural designers must balance and prioritize inherently contradictory criteria to devise an appropiate structural concept. Next, the paper addresses the essential ingredients of a sound Conceptual Design: creativity, experience and knowledge. Education plays a vital role in fostering these qualities. The paper traces the origin and evolution of the course "Tipología Estructural", which was originally introduced by Eduardo Torroja in the 1953-54 academic year. Torroja was a pioneer in teaching Conceptual Design at academic level, integrating diverse knowledge areas and hands-on design experience. His visionary course, which continues today with updated contents and methodology, uses a project-based learning to foster creativity and practical problem-solving skills. This approach prepares students to effectively tackle structural design challenges in the framework of sustainability.

KEYWORDS: sustainable design, holistic approach, conceptual design, teaching, structural typology.

RESUMEN

El artículo comienza con reflexiones personales sobre el papel y las responsabilidades, a menudo subestimadas, de los diseñadores estructurales en el contexto de la sostenibilidad. La integración del marco de sostenibilidad en la industria de la construcción debe iniciarse en la fase de Diseño Conceptual, ya que las decisiones tempranas impactan profundamente la sostenibilidad de todo el proyecto. A continuación, se introducen criterios para desarrollar un concepto estructural sólido, destacando la necesidad de integrar diversas disciplinas. Mientras que en el pasado las preocupaciones se centraban principalmente en la seguridad y la economía, el enfoque actual en la sostenibilidad exige un enfoque más holístico y multidisciplinario. Los diseñadores estructurales deben equilibrar y priorizar criterios inherentemente contradictorios para desarrollar un concepto estructural óptimo.

Posteriormente, el artículo aborda los elementos esenciales de un Diseño Conceptual sólido: creatividad, experiencia y conocimiento. La educación desempeña un papel fundamental en el desarrollo de estas cualidades. Se rastrea el origen y la evolución del curso "Tipología Estructural", introducido originalmente por Eduardo Torroja en el año académico 1953-54. Torroja fue un pionero en la enseñanza del Diseño Conceptual a nivel académico, integrando diversas áreas del conocimiento y la experiencia práctica en el diseño. Su curso visionario, que continúa impartiéndose con contenidos y metodologías actualizados, utiliza un enfoque de aprendizaje basado en proyectos para fomentar la creatividad y las habilidades prácticas de resolución de problemas. Esta metodología prepara a los estudiantes para abordar eficazmente los desafíos del diseño estructural en el marco de la sostenibilidad.

PALABRAS CLAVE: diseño sostenible, enfoque holístico, diseño conceptual, enseñanza, tipología estructural.

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1.
ON THE RESPONSIBILITY OF THE STRUCTURAL DESIGNERS

Sustainability has become a crucial concern in the construction sector, affecting every stage from planning to deconstruction. There is a pressing need for a more rational, holistic and sustainable approach, which necessitates education, personal ethics, and a sense of responsibility. The United Nations report "Our Common Future" (1987) expanded the concept of sustainability beyond environmental aspects to include economic and social dimensions, influencing new generations of construction guidelines and codes.

Despite increased awareness, radical changes are still needed. The urgency of this shift is underscored by the projected 20% increase in the human population by 2050, necessitating substantial investments in infrastructure and housing, particularly in developing countries. This presents a unique opportunity to adopt a new paradigm in construction that focuses on sustainability and ethical responsibility.

One of the primary indicators of environmental impact is the emission of equivalent CO_2 (CO_{2eq}), which measures the global warming potential of all greenhouse gases produced by an activity throughout the whole life of a structure. As a rough estimation, the construction and manufacturing industries are responsible for approximately 30% of these emissions, with the concrete industry alone accounting for about 8%.

Efforts have been made within the construction material manufacturing sectors to reduce their environmental impact. However, concrete and steel have faced criticism for its perceived incompatibility with sustainable practices (refer to The Guardian article "Concrete: the most destructive material on Earth"). This criticism often overlooks scientific assessments showing that efficient structures can have similar CO_{2eq} footprints regardless of the materials used [1]. It is essential for experts to objectively evaluate these claims and guide society toward more sustainable construction practices.

The new version of fib Model Code 2020 places sustainability at its core. Introducing sustainability concepts to designers through codes and specialized literature aims to increase awareness on several fronts: minimizing material consumption, using appropriate materials and construction processes considering local conditions, and creating resilient, adaptable, and durable structures.

Decisions made during the early stages of planning and conceptual design significantly influence the sustainability of construction projects (Figure 1). Early, informed choices can lead to more efficient construction, maintenance, refurbishment, and eventual dismantling or recycling.

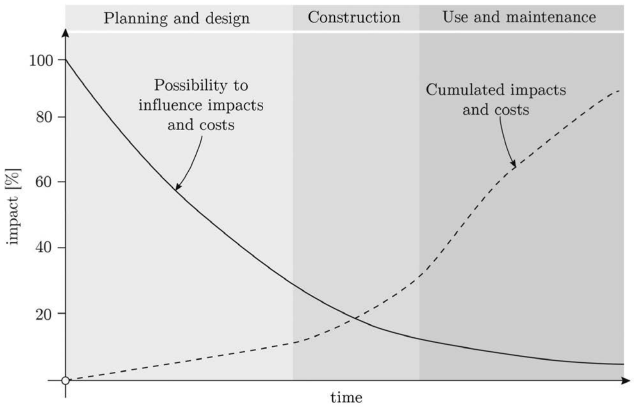


Figure 1. Influence of decisions made during the life cycle versus impacts and costs (qualitative impact of design decisions). European and North American average. Plot reproduced from [1], inspired from [2].

Life cycle energy of a building includes both operational energy (used for heating, cooling, hot water, ventilation, and lighting) and embodied energy (required for material supply, production, transportation, construction, and disassembly). The latter is more related to the work of structural designers because it is strongly influenced by the conceptual design of the structure.

The percentage of operational and embodied energy over the total life cycle energy varies depending on the type of construction and its use. As described by De Wolf et al. [3], buildings have a limited operational lifetime, which results in a significant percentage of embodied carbon contributing to the total environmental impact of the building. Many stadia built in the Middle East have not been used intensively, making embodied carbon the dominant factor in their total life cycle impact. Consequently, the role of structural designers is very important in these buildings. For example, according to De Wolf et al. [3], the material quantity and, therefore, the embodied carbon per seat in the Beijing stadium (3500

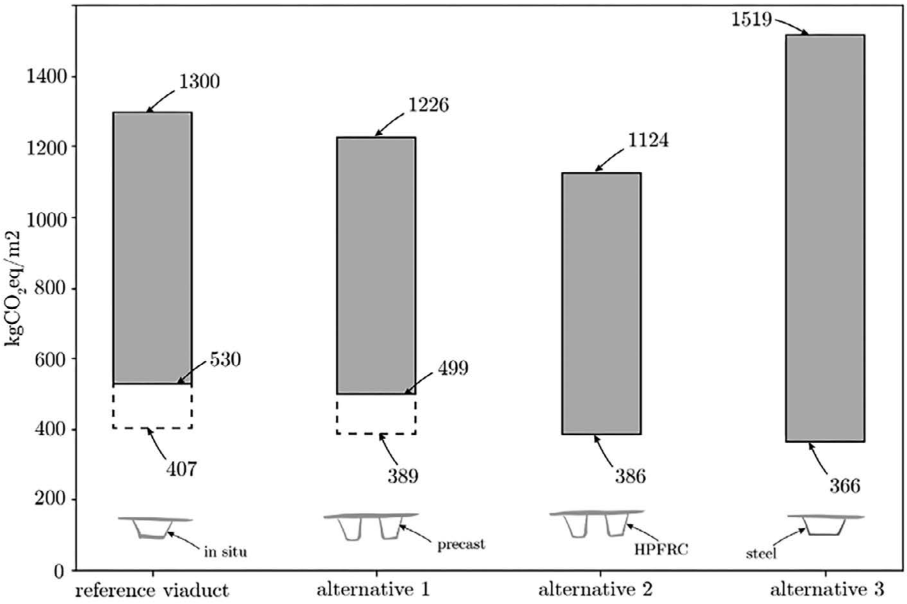


Figure 2. Comparison of CO_{2eq} associated with product and construction stages (A) for the reference viaduct and three alternatives [1].

kg CO_{2eq}/seat) is approximately ten times higher than in the London Olympic Stadium (350 kg CO_{2eq}/seat).

To demonstrate how critical decisions in conceptual design can lead to more sustainable construction practices, Figure 3 illustrates the results of an Integrated Life Cycle Assessment covering stages from A1 to A5 (cradle-to-practical construction) for the Molvizar viaduct (Spain), which serves as the reference case study (for instance, in bridges, nearly 100% of the energy is embodied, being the operational carbon almost negligible). The Molvizar viaduct is a nine-span curved prestressed box girder structure, with a total length of 432.50 m and typical spans of 51.50 m. Its deck consists of two prestressed concrete boxes, each 12.0 m wide and 2.75 m high, constructed using a moveable scaffolding system.

Two scenarios for embodied carbon coefficients (ECC, expressed as kg CO_{2eq}/kg of material) were analyzed: using either the highest or lowest factors for each material to estimate a range of emissions. The deck accounts for 50% of emissions on average, foundations (piles and pile caps) for 30%, and the rest coming from abutments and piers. To explore alternative structural typologies, the following options were considered:

- Alternative 1: Precast U-shaped beams with a reinforced concrete slab.
- Alternative 2: Precast UHPRC U-shaped beams (0.157 min ECC, 0.253 max ECC) with a reinforced concrete slab, based on [4], [5], [6].
- Alternative 3: Steel-concrete box composite deck.

The dimensions were adjusted based on the original viaduct. Alternatives 2 and 3 show higher potential for reducing emissions. In regions allowing slag cement for post-tensioned elements, emissions for the reference viaduct and all alternatives are similar in the minimum scenario (ranging from 366 to 407 kg CO_{2eq}/m², as shown by dashed lines in Figure 2). Alternative 2 demonstrates the best performance with average ECC values, indicating that high-performance materials can reduce emissions by decreasing material quantities. Alternative 3 performs comparably to concrete options with low steel emission values, but higher emissions if using standard steel. Significant differences arise between maximum and minimum ECC values, placing responsibility on designers to select materials that minimize emissions. Availability of low-emission materials, such as slag cement and scrap steel, significantly influences the optimal solution. The choice between full concrete and composite solutions depends on local industry capabilities, aligning with the need for project-specific evaluations based on location and sustainability indicators. Additionally, while the focus was on greenhouse emissions, other sustainability indicators, such as economic and social factors, must be considered. HPFRC-based alternatives have similar or lower costs compared to standard concrete, benefiting from lower transportation and crane costs. Prefabricated solutions across all alternatives enhance worker safety. The impact on local industries, either concrete or steel, and the long-term benefits of innovative materials like HPFRC, are also crucial. Environmental impacts, such as land disturbance from crane use, vary based on site conditions, further emphasizing the importance of location in determining the optimal solution.

The previous example is used also to contextualize the possible impact of structural engineers. A potential embodied carbon reduction of 20% in this case study would lead to save around 1300 tons of CO_{2eq} (calculation based on a total deck area of 5200 m²) which is equivalent to the emissions generated by 1300 Rome-to-New York one-way flights.

However, focusing solely on CO_2 emissions for assessing sustainability overlooks many critical aspects that significantly impact the sustainability of a structure, particularly in bridge engineering. These factors include the precise lo-

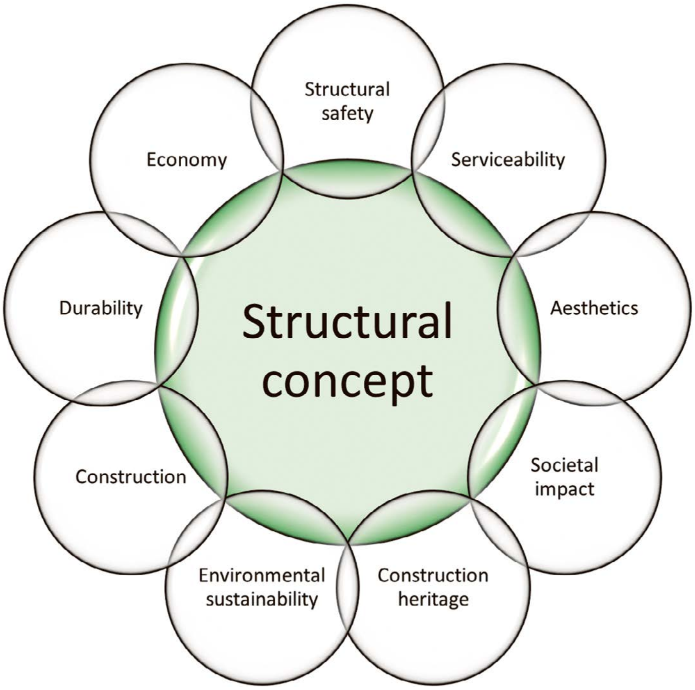


Figure 3. Overview of the criteria to be considered for a sound structural concept (image taken from slides of the Bridge Design Lectures – Prof. Kaufmann at ETHZ – freely available at https://concrete.ethz.ch).

cation, span lengths, structural type, vertical and horizontal clearances, accessibility, and width (with consideration for potential future widening). All these elements are crucial for ensuring functionality, economic efficiency, and both short- and long-term social impacts. Engineers and clients are not always fully aware of the long-term consequences their decisions may have on current and future generations. Therefore, understanding sustainability on a larger scale should take precedence over secondary concerns, such as the materials to be used [7]. For instance, the new Tamina Canyon Bridge in Bad Ragaz is a structural engineering marvel, yet it has a width of only 9.5 meters. One might question how the costs would change if the bridge's width were increased to 12 meters. Given that the construction process can account for 70-80% of a bridge's cost, increasing the width to accommodate future traffic demands would likely have a minimal impact on the overall cost.

The following section addresses the definition of the conceptual design of structure as a holistic approach that goes beyond the traditional approach.

2.

ON THE CONCEPTUAL DESIGN OF STRUCTURES

The previous section has shown that the role (and responsibility) of structural designers is huge, and the most important and effective decisions are made during the conceptual design stage. Conceptual design is the creative process of combining different aspects to develop a holistic solution for a specific engineering problem. It is an iterative process guided by knowledge, intuition, experience and, if possible, creativity.

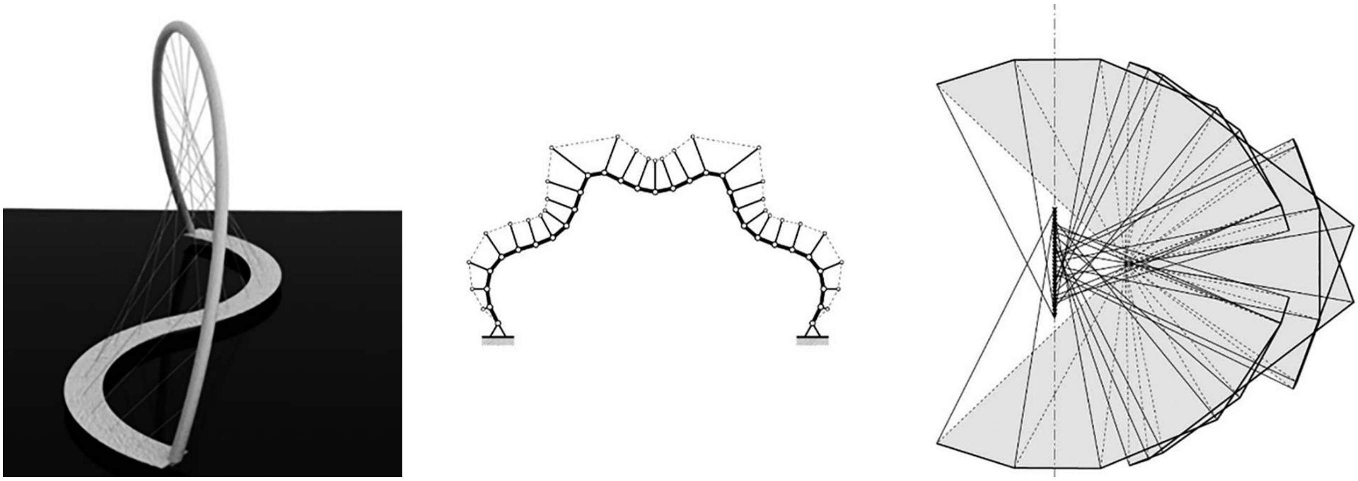
Conceptual design of structures is a cross-disciplinary activity that involve different individual disciplines such as solid mechanics, structural analysis, construction materials, building techniques, etc… [8], as well as the capacity to establish relations among them.

A sound conceptual design is not the result of a sudden moment of inspiration. On the contrary, it is the fruit of a serious, systematic and ambitious work in the search for the most adequate solution to a given engineering problem. Commonly to other creative fields (e.g. architecture, literature, culinary arts, painting, etc), successful processes are context-dependent, experience-based and principle-driven.

Figure 3 illustrates a proposed set of criteria to be considered for generating a sound structural concept. The involved disciplines clearly go beyond the pure technical ones mentioned before. In fact, they extend far beyond the classical structural considerations of safety, serviceability, construction, and economy. Structural engineers may not be experts in every domain, but their broad understanding allows them to integrate diverse perspectives and make informed decisions. Effective communication with specialists enables the team to navigate complex design challenges, ensuring that the final solution is well-rounded and robust.

A holistic approach ideally aimed to maximize all criteria simultaneously is impractical because many of these criteria are inherently contradictory. For example, a concrete mix based on CEM III/C has only one-third the environmental impact of CEM I. However, it also costs 10% more and has lower durability against carbonation compared to conventional concrete.

Evaluating all these criteria using a purely mathematical approach is inconsistent. There are multiple viable solutions, and it is the responsibility of the design team to choose the most appropriate one, prioritizing certain criteria over others.



a) b)

Figure 4. Application of the equilibrium concept to spatial arch bridge supporting a curved deck (a) and free-form post-tensioned curved shapes (b).

3.

ESSENTIAL INGREDIENTS FOR SOUND CONCEPTUAL DESIGN

According to the author, the essential ingredients for a sound Conceptual Design of a structure are creativity, experience and knowledge.

Regarding the first ingredient, creativity, often overlooked, it is insightful to recall Jörg Schlaich's words from the preface of the first international congress on the conceptual design of structures (IASS Symposium 1996): "The overall quality of many structures today leaves much to be desired. The rapid technological progress does not reflect adequately in their variety, beauty and sensitivity. Too often, structural engineers neglect the creative conceptual design phase by repeating standard designs and not sufficiently contributing with [their] own ideas to the fruitful collaboration with architects. Engineers thus often waste the chance to create building culture". Today, 28 years later, the situation has not changed.

The author does not have a clear idea of why this happens, but maybe is a mix of 3 different factors.

- Collaboration: engineers might not be sufficiently involved in the early conceptual phases where creative ideas are generated, leading to designs that lack aesthetic and innovative qualities.
- Education: Engineering education often emphasizes technical skills and problem-solving within established paradigms, sometimes at the expense of fostering creativity and innovation.
- Standards: Building standards restrict innovative design. Applying prescriptive regulations with novel designs can be complex and time-consuming,
- Incentives: There is a lack of economic incentives for engineers to pursue creative designs, in fact, rewards in the industry are often based on construction cost rather than innovation and creativity.

The author questions whether meeting minimum budgets is a cause for lack of creativity, noting that in the past, engineers like Maillart and Nervi demonstrated that their immensely creative designs were, at that time, the most cost-effective solutions. As reported by Kessler [9] in the tender for the Salginatobel bridge, the proposal by the contractor Prader & Cie. (built on the design of Maillart) was based on a lump sum of CHF 135000, 40% less expensive than the average cost of the other quotes. This demonstrate that at least the economic pillar of the sustainability has been always present in high quality engineering.

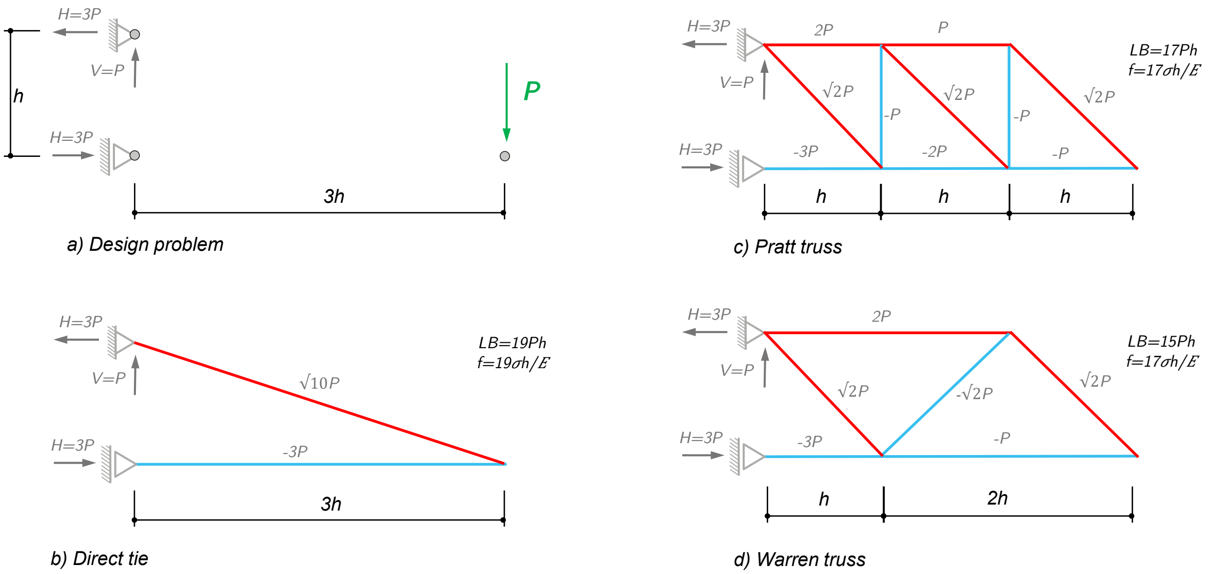
Experience can be considered on two levels: personal experience and knowledge of history.

Personal experience is vital as knowledge from past projects informs decisions, helps avoid mistakes, and allows for proactive issue identification and resolution. It enables designers to recognize best practices, anticipate potential problems, and take a holistic view of projects, which leads to more well-rounded designs.

Knowledge of History is equally important. Learning from past successes and failures leads to better-informed decisions and inspires innovation. For instance, knowing how ancient builders created impressive structures with limited technology can inspire sustainable, low-tech solutions today; examples in this line include the undulating brick walls by Eladio Dieste in the Church at Atlantida (Uruguay) or the water deposit by Eduardo Torroja in Fedala (Morocco). As Hugo Corres states, "When I think I have invented something, it is because I should read again Razón y Ser (the famous book by Eduardo Torroja) [10]," emphasizing that many concepts have already been invented and simply need to be studied and interiorized.

The third essential ingredient is knowledge. As mentioned before, a strong grasp of various disciplines and the ability to interrelate them are crucial. However, the most vital aspect remains a deep understanding of simple, yet powerful concepts associated to structural engineering. Several practical examples illustrate this point.

It is well-known that curved structures are characterized by the critical relationship between their geometry and structural performance. Selecting an appropriate shape



a) Design problem

b) Direct tie

c) Pratt truss

d) Warren truss

Figure 5. Application of Maxwell's Theorem on load paths. Image of the author reproduced from [14].

in the early-stage design of such structures is important for achieving material-efficiency. The definition of the funicular or antifunicular shape (i.e. a bending-free geometry under a specific set of loads) is well-know problem from the past and it has been well-documented in the literature (Huerta 2008). However, a profound understanding of this concept can lead to the development of spatial arch bridges supporting a curved deck [11], as shown in Figure 4a. The result represents an innovative answer to demands on functionality, structural optimization and aesthetics for curved decks, popular in urban contexts. Then, the implementation of this simple yet powerful concept in a parametric and interactive environment allows for the rapid exploration of numerous structural solutions in real time, providing great versatility to the designer during the initial design stages.

Another example of the power of the funicularity concept is achieving axial-only behavior in geometries that deviate from the ideal bending-free shape [12], [13]. This is accomplished by adding forces through an external post-tensioning system, with the layout defined using graphic statics. This method is particularly useful when non-structural design criteria, such as usability, architectural needs, or aesthetics, prevent the selection of purely bending-free shapes. Figure 4b illustrates the application of this methodology to an arbitrary shape. The example, featuring varying degrees of curvature, demonstrates the versatility of the methodology. Specifically, the left figure indicates the arbitrary shape with the applied post-tensioning system, while the right figure shows the corresponding force equilibrium at each node which ensure the pure bending-free behaviour.

A third example is the application of Maxwell's Theorem on load paths, originating from Maxwell's 1864 paper and revisited by Baker [14]. Maxwell's Theorem essentially states that the sum of a structure's tension load paths minus the sum of the compression load paths is equal to a value related to the applied external forces (including reactions). Although the definition of a structural system involves many other criteria, the example shown in Figure 5 (reproduced from [14]) shows its application to a truss for selecting a material-efficient location of the structural elements. Starting with a cantilever configuration (a), three different solutions (b-d) are presented. For each truss layout, the total load path is calculated by summing the products of the tension member forces and their corresponding lengths and the compression member forces and their corresponding lengths. Additionally, the deflection is shown, assuming the structure has equal stresses in tension and compression. From solutions b) to d), the length of the truss elements is reduced along with the deflections. In summary, by altering the truss layout, it is possible to increase the volume of material, resulting in a stiffer structure.

4.

RETROSPECTIVE PERSPECTIVE VIEW: THE LEGACY OF EDUARDO TORROJA AND THE COURSE "TIPOLOGÍA ESTRUCTURAL"

3.1. Historical evolution

Although the importance of Conceptual Design of Structures has been emphasized repeatedly in previous sections, it is not typically included in university curricula. However, in the 1953-54 academic year, Eduardo Torroja introduced a course titled "Tipología Estructural" at the Civil Engineering School of the Universidad Politécnica de Madrid. Initially, this course was offered to fourth-year students and was conducted once a week.

Starting in the 1955-56 academic year, the frequency of lectures increased to four per week. During this period, the course syllabus included the following topics:

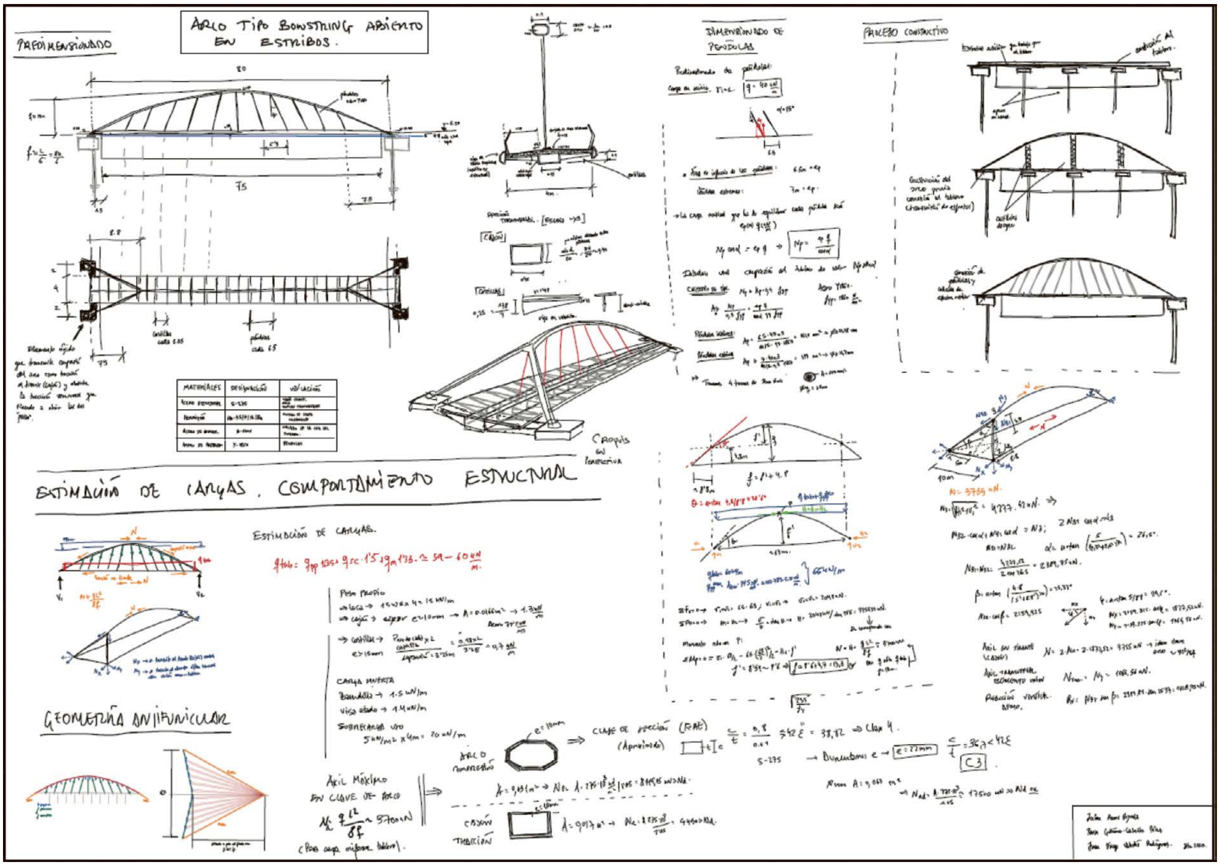


Figure 6. Example of intermediate submission with first design concept and hand calculations for an arch footbridge.

1. General approach to the topic.
2. Basic influence of the tensional phenomenon.
3. Materials: masonry, wood and steel, reinforced and prestressed concrete.
4. The basic elements: column and wall, arch, vault and dome, beam and shell, composite beam.
5. The functional groups of the construction: stories and building, bridges and aqueducts.
6. The static-resistant functionalism.
7. The construction process and its influence on the structural typology.
8. Aesthetic expression. Comments about lines and surfaces.
9. Origin of the structural diagram. The calculation. The project and its organization.

During the academic year 1958-59, Jose Calavera (honorary president of INTEMAC and former full professor at the Universidad Politécnica de Madrid) attended the course of Tipología Estructural and he reminisced on his experience as a student in a recent book [4]: “in fourth year Prof. Torroja taught Tipología Estructural’, his favourite subject. In each class, he would lecture for 20 minutes and then call a student to the blackboard. The class was broken down into three-student teams, each of which was to draft a provisional design. The students were free to choose their partners as well as the subject of the design. When a student representing a team stood up in front of the class to explain their preliminary design, Prof. Torroja allowed no calculating, but asked continually about the depth and width of the members and the structural system”.

In 1957, the first edition of Torroja's book "Razón y ser de los tipos estructurales" was published [10]. The book’s content closely mirrored the course syllabus. Eduardo Torroja passed away in 1961, and Juan Batanero took over the course from 1961-62 until 1983-84, making slight changes to the syllabus. Jose Antonio Torroja, Eduardo’s son, taught the course from 1984-85 until 2002-03. Since then, Hugo Corres has been the primary instructor, with support from the author since the 2012-13 academic year.

The following section is addressed to describe the current organization of the course.

3.2. *Today*

"Tipología Estructural" is an unconventional course where each instructor brings a unique approach to teaching. Due to its complexity, effective teaching of Conceptual Design relies heavily on lived experiences. Currently, "Tipología Estructural" is a mandatory course for all the students enrolled in the Master of Civil Engineering program; this introduces new challenges as it must engage students who may not primarily be interested in structural engineering. However, this challenge also presents an opportunity. Viewing engineering as a creative profession, the principles of conceptual design can be applied across various fields, including hydraulic works, ports, and linear infrastructure.

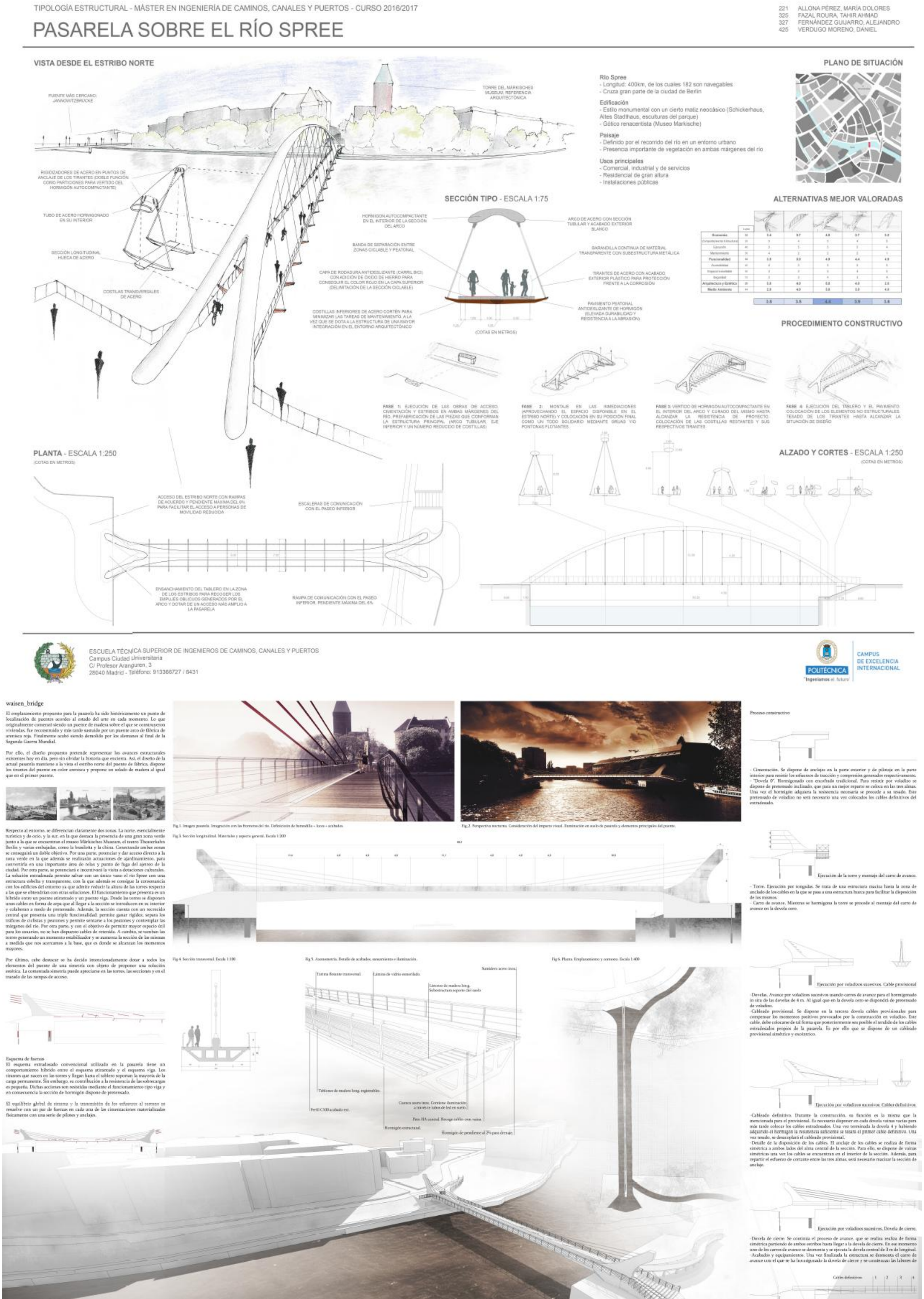


Figure 7. Examples of final submission.

The knowledge acquired in this course can be applied to various structural typologies such as bridges, buildings, residential towers, wind towers, cooling towers, water deposits, etc… For each typology, the course provides:

- Typical dimensions, geometrical ratio and material quantities.
- An overview of applications.
- Dimensioning of main elements.
- Analysis of specific details.
- Considerations about aesthetics and durability.

The course is structured as a project-based learning experience, where students gain hands-on skill in designing structural systems. By the end of the course, students should be able to:

- Define the main structural design parameters and identify constraints and boundary conditions.
- Visualise force flows and explain the fundamental behaviour of different structural typologies.
- Identify the relationships between structural form, internal forces and building.
- Analyse existing structures using appropriate terminology (in both English and Spanish) and objective arguments
- Dimension predominant elements of different structural typologies by hand.
- Have an awareness of material properties and their design potential and limits.
- Critically question structural design concepts of historical and contemporary references.
- Design an appropriate structural system for a given design challenge, considering a wide range of structural typologies.
- Design structures creatively and generate structural forms beyond known typologies.

Lectures are supplemented by flipped classrooms and invited speakers. To foster the interdisciplinary nature of the course, several speakers from various backgrounds have been invited in recent years: Taba Rasti and Pablo Urango on architecture, Fernando Porras on urbanism, Sandro Rocci on roads design, Luis Miguel Viartola on construction processes, Cristina Iglesias on sculptures, and Peter Tanner, José Romo, Borja Herraiz and Carles-Hug Bitlloch on structural design.

Students are tasked with developing a preliminary design for a structural solution to a given problem, which varies each year. There is an intermediate submission where students define the most relevant design criteria, develop several design alternatives, and finally select the proposal to be developed further. Figure 6 illustrates an example of intermediate submission with the first design concept and hand calculations for an arch footbridge.

The final submission consists of an A1-format poster with oral defence describing the develop project. Two examples of these posters are illustrated in Figure 7.

6.
FINAL REMARKS

Structural designers have a huge responsibility in promoting sustainability within the construction industry. The integration of the sustainability framework into structural design requires ethical responsibility, comprehensive knowledge, and a holistic approach, encompassing environmental, economic, and social dimensions. This change must begin at the Conceptual Design stage, as early decisions profoundly impact the sustainability of the entire project.

The essential ingredients for a sound Conceptual Design of a structure are creativity, experience and knowledge. A deep understanding of fundamental structural concepts is crucial for innovation. Concepts like funicularity and Maxwell's Theorem are simple and powerful and should be perfectly know by every structural designer.

Education plays a vital role in this transformation. Eduardo Torroja was a pioneer in teaching Conceptual Design at academic level, integrating diverse knowledge areas and hands-on design experience. His visionary course, which continues today, uses a project-based learning to foster creativity and practical problem-solving skills, preparing students to tackle structural design challenges in the framework of the sustainability.

To conclude this paper, the author recalls an insightful statement by Hugo Corres "Problems should not be solved. They should be avoided." A sound conceptual design of a structure is an essential step in this direction.

References

[1] B. Regúlez, D. M. V. Faria, L. Todisco, M. Fernández Ruiz, and H. Corres, "Sustainability in construction: The urgent need for a new ethics," Structural Concrete, 2022, doi: 10.1002/SUCO.202200406.

[2] N. Kohler and S. Moffatt, "Life-cycle analysis of the built environment. ," in NEP Industry and Environment , Nairobi, Kenya, 2003, pp. 17–21.

[3] C. De Wolf, J. Hogroian, and J. Ochsendorf, "Comparing material quantities and embodied carbon in stadia," in Proceedings of IASS Annual Symposia, IASS 2014 Brasilia, International Association for Shell and Spatial Structures (IASS), 2014, pp. 1–8.

[4] R. Ruiz, L. Todisco, and H. Corres, "Application of high-performance fibre reinforced concrete to precast girders for road bridges: Conceptual considerations and numerical analyses," Structural Concrete, vol. 24, no. 4, pp. 4645–4659, Aug. 2023, doi: 10.1002/suco.202200907.

[5] R. Ruiz, V. Chozas-Ligero, L. Todisco, J. D. Jimenez-Vicaria, and H. Corres, "Experimental characterization of a cost-competitive tailor-made HPFRC mix design for wide application in precast girder of roadway bridges," Structural Concrete, vol. 25, no. 2, pp. 935–955, Apr. 2024, doi: 10.1002/suco.202300550.

[6] R. Ruiz, M. Fernández Ruiz, L. Todisco, and H. Corres, "Shear resistance of prestressed HPFRC beams without stirrups: A mechanical analysis of shear-transfer actions based on detailed experimental measurements," Eng Struct, vol. 306, p. 117711, May 2024, doi: 10.1016/j.engstruct.2024.117711.

[7] J. Romo, "Conceptual Design of Bridges and Sustainability," in IABSE Symposium 2019 Guimarães: Towards a Resilient Built Environment - Risk and Asset Management, Guimaraes: IABSE, Mar. 2019.

[8] A. Mari and J. A. Torroja, "Education of structural engineers in conceptual design: the Spanish experience," in Proceedings of Conceptual Design of Structures, Stuttgart: IASS, 1996.

[9] A. Kessler, Salginatobelbrücke. Buchdruckerei, Schiers, 2011.

[10] E. Torroja, Razón y ser de los tipos estructurales. Madrid: Instituto de la Construcción y del Cemento, 1957.

[11] L. Todisco, H. Corres, A. Pérez, A. Addante, and J. Cañada, "Conceptual design of spatial arch footbridges supporting curved decks," Structures, vol. 33, pp. 1207–1215, Oct. 2021, doi: 10.1016/J.ISTRUC.2021.05.003.

[12] J. Cañada Pérez-Sala and L. Todisco, "Conceptual design of externally posttensioned curved structures for live loads," Structural Concrete, vol. 21, no. 6, pp. 2220–2236, Dec. 2020, doi: 10.1002/SUCO.201900536.

[13] L. Todisco, H. C. Peiretti, and C. Mueller, "Funicularity through external posttensioning: Design philosophy and computational tool," Journal of Structural Engineering (United States), vol. 142, no. 2, 2016, doi: 10.1061/(ASCE)ST.1943-541X.0001416.

[14] W. F. Baker, L. L. Beghini, A. Mazurek, J. Carrion, and A. Beghini, "Structural innovation: Combining classic theories with new technologies," Engineering Journal, vol. 52, no. 3, pp. 203–217, 2015, [Online]. Available: http://www.scopus.com/inward/record.url?eid=2-s2.0-84934279219&partnerID=40&md5=bf0e488ee136d217f958d1a69fcda091