Structural Engineering | Part 1

Beyond the Otherness between Art and Technique

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I would like to begin with a question: what is engineering? Paraphrasing Wikipedia's definition, "Engineering is an applied science that uses scientific principles to design and construct machines or vehicles, devices or circuits, buildings or infrastructures, plants or systems, programs or algorithms and other elements necessary to achieve one or more objectives, such as exploiting the natural resources available to man or solving a problem. It is an activity of using knowledge for something practical, and its objectives include the design, development, maintenance, repair, and/or improvement of equipment, materials, and processes".

It is clear therefore that, taken as a whole, engineering is a science (or discipline) that covers decidedly broad and articulated areas. Over time, this multi-disciplinarity has created several distinct branches, each of which further differs in terms of themes and methods. The following is an (incomplete) list of the main engineering practices that have developed their own distinctive identities:

- Environmental Engineering (Agricultural, Climate, Geoengineering, Mining);
- Civil Engineering (Structural, Construction, Hydraulics, Transport, Seismic, Geotechnics);
- Management Engineering (Economic, Financial);
- Industrial Engineering (Aeronautical, Aerospace, Chemical, Mechanical, Naval);
- Information Engineering (Automation, Computer Science, Electronics, Communications).

In the context of Structural Engineering (the writer is a veteran civil structural engineer) the following definition strikes a strong chord: "Structural Engineering is the Art of moulding materials we do not wholly understand into shapes we cannot precisely analyse, so as to withstand forces we cannot really assess, in such a way that the community at large has no reason to suspect the extent of our ignorance."

This quote is often attributed to Dr A.R. Dykes and is apparently from the President's Address he delivered in 1976 to the British Institution of Structural Engineers. Irrespective of the details, I believe it accurately captures the essence of the challenge that all engineers (including structural engineers) face every day: even if part of the job is preventing the public from suspecting the extent of the engineers' ignorance, the engineers themselves must acknowledge their own ignorance and bear it in mind during the daily practice that drives their choices and decisions.

In fact, to live a life full of wonder (both as a human being and as a structural engineer) also means having doubts, asking questions, and accepting that you do not know everything. Having only certainties robs you of the ability to savour the taste of discovery and to develop and improve your skills.

As William Shakespeare wrote (Hamlet, Act 4, scene 5) "We know what we are but know not what we may be", and we can certainly become much more than we are: all we have to do is listen with the intellectual humility that creates empathy and understanding.

Engineering (structural, specifically, but also the other branches) is about solving problems or at least limiting their effects for the benefit and advantage of the community at large — for example, the search for safe responses by structures to seismic actions so that quality of life hopefully improves.

Achieving this obviously requires commitment and responsibility starting with the available information, data, events and experiences (that sometimes require interpreting in the light of specific stories); considers the objectives; and then uses judgement to find solutions. That judgement should seek and include knowledge, intuition, integrity, foresight, trust, and the ability to discerningly assess the available information and the needs to be met, and then create solutions through inspiration, artistic and logical thinking, and decision-making, combined with the essential ability to work with (and for) others to reach shared solutions in a clear and synergetic manner.

It is for this reason that Dykes' definition and the fact that it begins with "...Art..." resonates so strongly with me: in my opinion Structural Engineering cannot do without Art — both in the strict sense as the ability to generate emotions by giving shape to unique "structural" works, and in a general sense as a "way of acting".

Now to turn to the other parts of that definition: "...moulding materials we do not wholly understand into shapes we cannot precisely analyse, so as to withstand forces we cannot really assess...". To understand materials requires application and experimentation because each responds according to its own characteristics and these have been deciphered over the past decades precisely because of the need to use the materials in specific, responsible and sustainable ways.

The analysis of form and shape today allows the most complex geometries to be investigated with high reliability and an adequate level of confidence thanks to modern virtual prototyping tools.
And finally, with regard to the forces "we cannot really assess", today we have numerical methods as well as calculation and verification methods that consider the randomness of the forces' actions, and apply appropriate factors to their characteristic values, which are also a function of the probability that the forces combine favourably or unfavourably, again with their characteristic values.
Among numerical methods, an example is computational fluid dynamics which makes it possible to assess the actions induced, for instance, by wind on structures, as well as fluid-structure interaction. Over time, the calculation and verification methods have migrated from the deterministic sphere (for instance the method of admissible stresses) to the semi-probabilistic or probabilistic spheres (such as the limit-state method) and have also moved into the regulatory context.

Virtual prototyping

In industrial production, each new product undergoes the same basic cycle: first, it is designed, then a (physical) prototype is built and tested, leading, if necessary, to modifications and updates of the prototype itself. At each step, indications for a new iteration are obtained. This standard process is generally slow and, since physical prototypes must be constructed, expensive.

When it comes to designing a completely new product, the modus operandi can become even more onerous: after extensive practical tests, the physical prototype is virtualized — a phase that until some time ago involved bringing the prototype right back to the drawing board for subsequent production.

A current solution to these problems is to use virtual prototyping right from the design stage. Virtual work environments offer innovative tools for simulation and interactive visualization of the product from the earliest, preliminary stages of development, thereby offering the attractive prospect of optimizing time and costs while increasing quality and reliability.

Where virtual prototyping shortens the design-validation-fabrication path in industrial production, in Structural Engineering it cannot be disregarded unless one limits oneself to designing and creating simple systems where pre-packaged handbooks and tables are sufficient.

A "special" structure is in fact already a prototype, but one that cannot be tested only in reality. On the contrary, if not properly studied using appropriate methods, specific functional characteristics could be lost or the structure or its important parts could be lost or collapse.

Virtual prototyping therefore constitutes an essential resource in seeking the structural forms to be moulded, particularly for Conceptual Structural Design, which does not apply Structural Engineering's rational methods at the end of the design process merely to verify the feasibility and static/seismic safety of the morphological choices previously defined by other means, but rather applies them at the beginning of the design process of structural morphogenesis.

The finite element method

The overall path that governs virtual prototyping within the sphere of Structural (and Civil) Engineering uses specific calculation methods to assess the correctness and robustness of the design solutions adopted. One of these that plays a fundamental role is the Finite Element Method (FEM) and it has become one of the most versatile approaches for solving structural problems using automatic calculation.

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FEM is well known as a numerical technique for finding approximate solutions to problems described by partial differential equations by reducing them to a system of algebraic equations. The discretization phase of the method corresponds to the transition from a problem posed in the continuous, endowed with infinite degrees of freedom to a problem defined in the discrete and characterized by a finite number of degrees of freedom. This requires one to generally renounce the determination of the exact (analytical or closed-form) solution of the initial problem in favour of an approximate solution, which must include appropriate discretization and suitably chosen shape functions of the elements used to represent the structural continuum. Subdivision is, therefore, a delicate phase and should be conducted with the competence and experience progressively gained in using FEM.

Thus, a model that could pass for "trivial" (due to the use of beam elements with an "exact" formulation) still has to be implemented by duly considering the assumptions made (and justified in relation to the actual behaviour of the simulated system) when critically evaluating the results following the calculation.

Design and FEM analysis

"Mechanics is the paradise of mathematics because it is here that the fruits of mathematics are reaped. There is no certainty in science if mathematics cannot be applied to it, or if it is not related to it." — Leonardo da Vinci.

Unquestionably, Structural Mechanics is also rooted in this Mechanics, since it underlies the development and study of numerical methods and theoretical models that can describe, with relevance to reality and based on relationships drawn from both mathematics and physics, the state of stress and deformation of the structures that form the resistant part of a manufactured article (civil, industrial, or aeronautical construction).

Obviously, FEM as summarized briefly above must be classified as part of the methods for determining the mechanical-structural response of the planned structure, which must not disregard aesthetics if it is to be harmonious. Aesthetics is not something separate, independent, successive; it is not a time that comes afterwards to adorn the technical realization, but is symbiotic with the structure, defining its lines and being defined by the balance between the built and surrounding environments.

This is how Mathematics and Form, while remaining distinct, intertwine in the ingenious ability to innovate and combine Architecture, Engineering and Art. And it is why some structures are bold, aesthetically beautiful, and iconic, while others, untroubled by a spirit of research, remain anonymous and devoid of their own identity. Contextualizing works with respect to the environments in which they arise stems from the wisdom with which projects capable of maintaining a healthy, balanced link with these environments (natural or previously defined by human intervention) are conceived.

This is the case, for instance, with bridges and viaducts that become landscape enhancements and works of art when they are designed using criteria that consider their environmental impact as well as the relative load conditions experienced in service and during the temporary installation/launching phases.

The way in which bridges, viaducts and overhead crossing works generally are conceived to pass over a continuous intermediate uninterruptible impediment (defined as a natural constraint e.g. a sea, lake, river, or valley) or an objective one, such as a transport or service network e.g. railway, motorway, or power line can play a decisive role as early as the preliminary drafting stage of projects.

The final elevated structure (bridge or viaduct) is realized by raising segments prefabricated on site or in the workshop, or by launching the structure, assembled in the area behind one of the two abutments, forward from the rear. Obviously, both approaches require specific structural analyses to be conducted with dedicated FEM models developed specifically to study the behaviour of the structure during the temporary assembly phases.

A special technique was conceived by Studio Ing. Romaro[1] and the Italian company Cimolai for launching the deck of the Chavanon Viaduct in Messeix in France (built and installed by Cimolai and inaugurated in 2000, see Fig. 1): they used main cables and pendants to advance the deck itself Tarzan-style, with the deck head passing from one pendant to the next.

[1] Studio Ing. Romaro no longer exists having been absorbed into Cimolai, first as Romaro Engineering, and then being merged completely into the acquiring company.

Fig. 1. Chavanon Viaduct, opened in 2000.

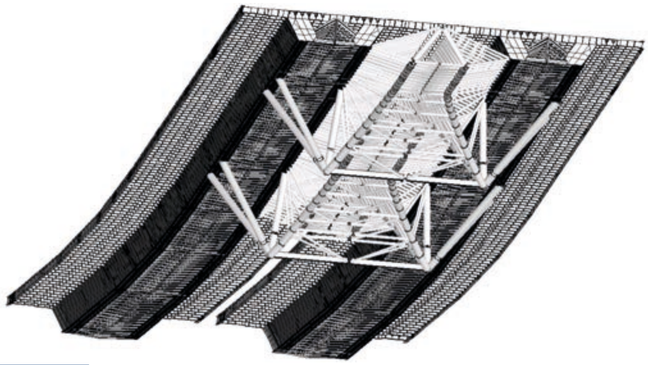


Fig. 2. Portion of the FEM model of a viaduct deck with a central reticular structure.

FEM models were used extensively to study the technique because the behaviour of the main cables had to be analysed for conditions that differed to their intended purpose/behaviour for regular operating conditions.

Needless to say, FEM models are used to study temporary conditions such as launching and also more broadly for designing works in relation to their operating conditions, particularly if the works are structurally innovative and require the support of advanced design, calculation and verification methods. Fig. 2 shows a portion of a FEM model relating to the deck of a viaduct.

In this context, it is worth remembering EnginSoft's heritage as an asset to draw upon for developing innovative and sustainable projects due to the significant role it has always played and continues to play in the field of numerical simulation. Moreover, in the field of Structural Engineering, EnginSoft's dedicated team, active since 1989, has always taken advantage of the evolution of calculation methods and virtual prototyping to help professionals and companies adopt them as an everyday system rather than tools for episodic use. This has led to collaborations with prestigious companies such as Studio Ing. Romaro and Cimolai, which have also made use of EnginSoft's skills and knowledge to design, calculate, and realize works of outstanding importance all over the world, demonstrating yet again that Italian engineering needs fear no comparison.

With this in mind, here is a brief review of some of the works in which these teams were involved.

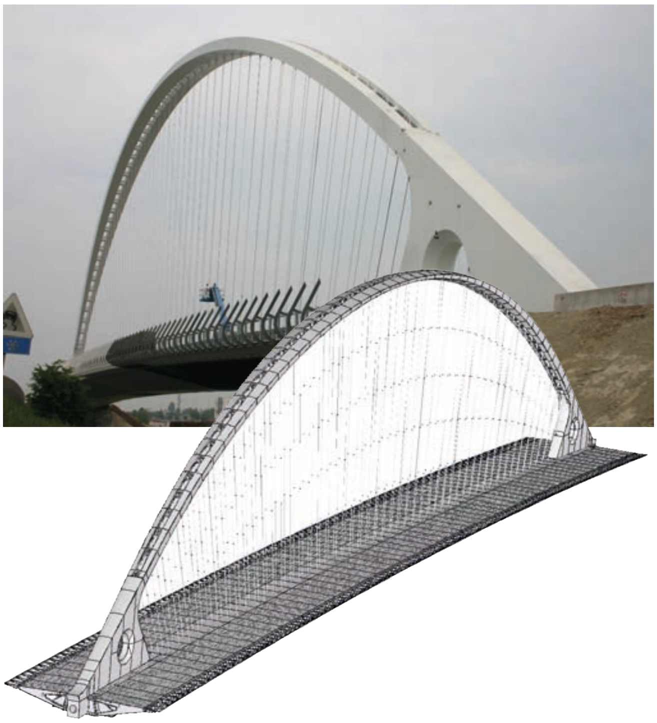


Fig. 4. FEM model and view of the Flyover Bridge over the A1 Motorway and the High-Speed Railway in Reggio Emilia in Italy.

The Padua East Viaduct (Darwin Bridge) in Italy, built by Cimolai, is approximately 540m in length and uses monolithic piers with decking. In the summer of 2005, EnginSoft developed a FEM model (with beam and shell elements) representing the viaduct as a whole (see Fig. 3) to study its behaviour: firstly, to evaluate the sensitivity of its response to variations in the stiffness of the foundations (modelling the interaction with the soil by means of user-defined beam elements), and secondly, to identify better solutions (including those relating to vibration and fatigue behaviour) compared to the basic design.

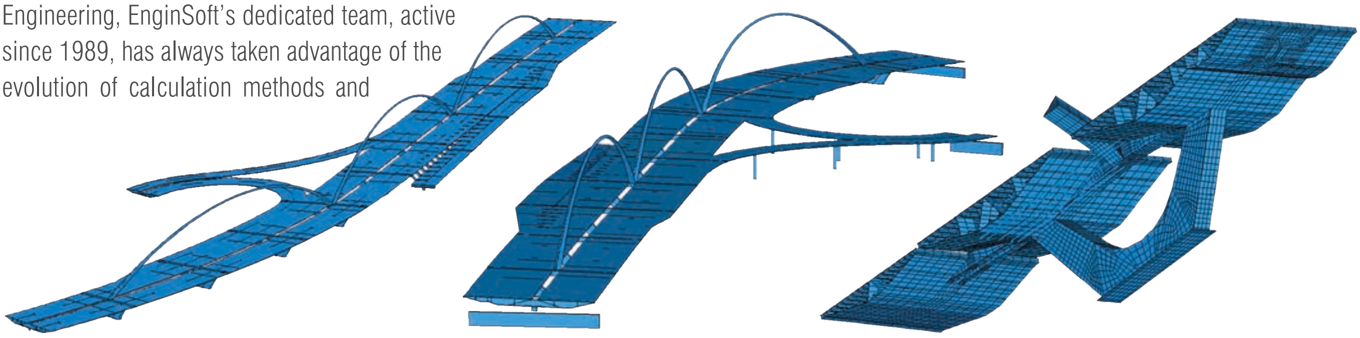


Fig. 3. FEM model of the Darwin Viaduct in East Padua in Italy.

The A1 motorway and high-speed railway flyover bridge in Reggio Emilia in Italy, completed in 2006 and discussed in the EnginSoft Newsletter No. 3, 2006. This arch bridge has a deck span of 220m suspended by stays, and an arch height of 50m from the deck level. An overall FEM model of it was developed (with beam, shell and cable elements) to determine the generalized tension and deformation levels under operating conditions using geometric non-linearity analysis, as an in-depth study of the arch stability which is crucial for the safety of the designed structure. Obviously, detailed FEM models were also performed to structurally optimize the connections of the stays (pendants) to the arch.

The Bridge of Strings in Jerusalem in Israel, built to carry the city's surface metro system, designed by the Spanish architect Santiago Calatrava and built/installed by Cimolai. The bridge was inaugurated in June 2008, about two years after the completion of the modelling, analysis, calculation, and verification activities undertaken by EnginSoft in collaboration with Studio Ing. Romaro and Cimolai. This cable-stayed bridge has a 140m-wide curvilinear deck, supported asymmetrically by stays that converge on a 120m-high steel pylon.

Given its structural complexity, an overall FEM model was developed for this bridge using beam, shell and chord elements (see Fig. 5) for the purpose of revisiting certain design aspects. Using geometric non-linear analysis, the levels of generalized tension and deformation under operating conditions were determined, and an in-depth study of the pylon's stability and the assembly and tensioning sequences of the stays supporting the deck was conducted.

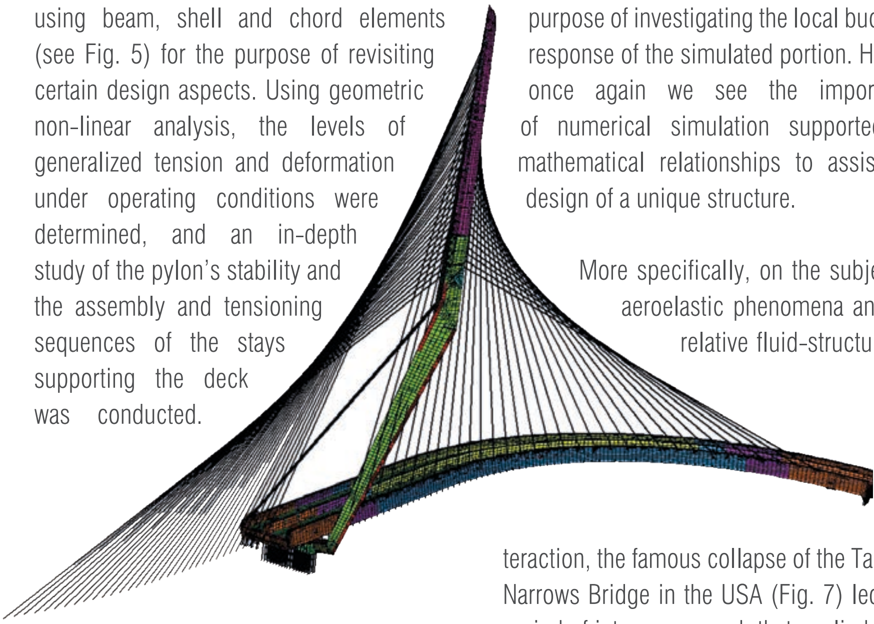


Fig. 5. FEM model of the Bridge of Strings in Jerusalem in Israel.

Detailed FEM models were also performed to adequately investigate the stress levels at the foot of the pylon and to optimize the connections of the stays to the pylon.

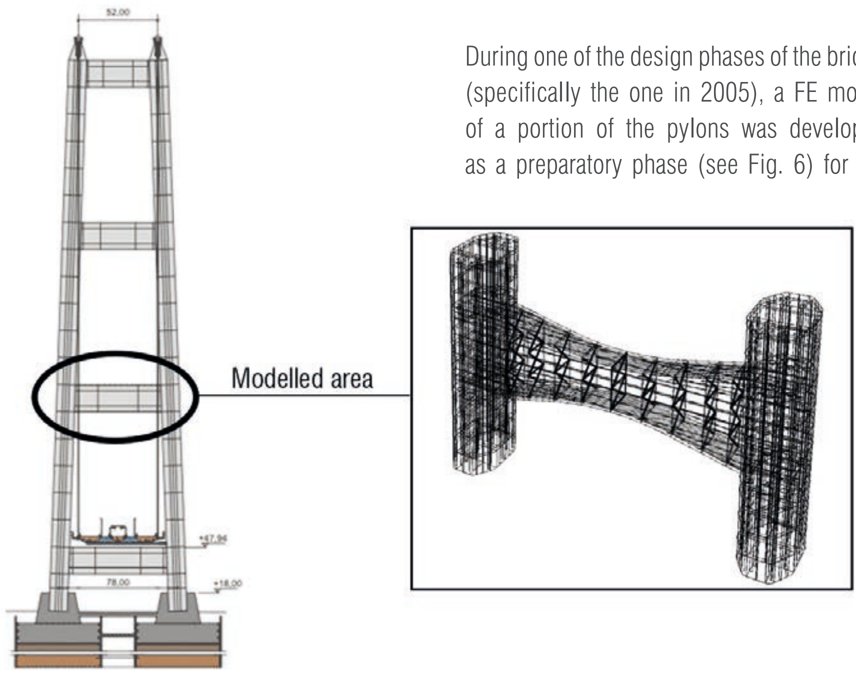
In terms of bridge design, the proposed bridge over the Strait of Messina off the southern tip of Italy is a gigantic challenge and certainly a distinctive one in terms of technical expertise and knowledge of the structure-environment interactions (not least of which the aeroelastic phenomenon) that affect the feasibility of this unprecedented work.

During one of the design phases of the bridge (specifically the one in 2005), a FE model of a portion of the pylons was developed as a preparatory phase (see Fig. 6) for the purpose of investigating the local buckling response of the simulated portion. Hence, once again we see the importance of numerical simulation supported by mathematical relationships to assist the design of a unique structure.

More specifically, on the subject of aeroelastic phenomena and the relative fluid-structure interaction, the famous collapse of the Tacoma Narrows Bridge in the USA (Fig. 7) led to a period of intense research that applied aeroelasticity to Civil Engineering to study the behaviour of a deformable body immersed in a moving fluid and the relationship between the forces exerted by the fluid and the deformations and displacements of the body.

One of the most dangerous aeroelastic phenomena is flutter, given its catastrophic effect. It consists of oscillations of progressively increasing amplitude of the bridge deck that occur at a certain critical speed of the incident wind. These oscillations can lead to structural collapse, as was the case with the Tacoma Narrows Bridge.

For this reason, "autofinanced" benchmarks were conducted to validate the 2D-3D approach adopted to predict the critical flutter velocity of suspended bridge decks, resulting in a satisfactory approximation



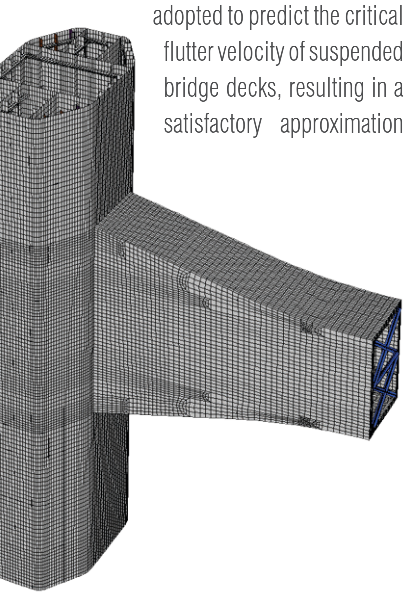


Fig. 6. Bridge over the Strait of Messina: FEM model of Pilone-Traverso region.

Fig. 7. The Tacoma Narrows Bridge in torsional oscillation on the morning of 7 November 1940. (from https://www.unirc.it/documentazione/materiale_didattico/599_2010_264_7525.pdf)

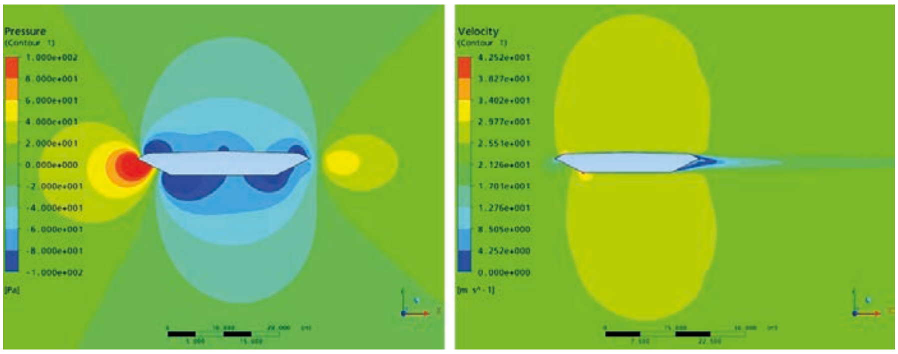


Fig. 8. 2D CFD model of a section of the Storebælt Bridge: pressure and velocity field.

between the declared and calculated critical velocity values. In the benchmarks developed between 2010 and 2011, two bridges were referenced: the Storebælt or Great Belt Bridge in Denmark and the Strait of Messina Crossing Bridge between Sicily and Calabria.

Using CFD (computational fluid dynamics), 2D models were implemented and solved (see Fig. 8) of the deck (of the Storebælt, specifically) immersed in fluid. A variable angle of attack of the fluid section's relative velocity was associated with the fluid, and for each value of the angle and using a k-ω SST turbulence model, the lift (CL), drag (CD) and moment (CM) coefficients were calculated. These were subsequently used to solve the dynamic equilibrium equation:

$$M\ddot{x}+C\dot{x}+Kx=F$$

and determine, in the time domain, as the relative fluid-deck velocity and the value of the damping increase (this last of 2%, 3%, 5% with respect to the critical damping), the dynamic response, in terms of displacement $x(t)$, of a 3D model representative of the bridge under investigation (see Fig. 9).

The wind speed for which the solution diverges (i.e. increasing vertical displacement and/or increasing rotation of the bridge's midsection — see, for example, the graphs in Figs. 10 and 11) constitutes the critical speed at which the flutter phenomenon occurs.

Obviously, a good design matches a critical velocity value greater than the wind speeds that were historically recorded and/or can be predicted at the site.

In Structural Engineering, FEM models are also developed during design definition for special structures whose functionality, strength and robustness must be considered in conjunction with the search for aesthetically "fascinating" solutions.

In addition to the installed conditions, which are characterized by loads resulting from the self-weights accidental actions, wind, earthquake, and impacts, the assembly/installation phase is important for these structures. If designed competently, time can be saved on execution while also achieving the necessary safety for the workers involved in realizing the works.

The term "special structures" is used here to refer to those structures that are truly special in terms of morphology or size (large structures), using steel as the main material. Thus, we refer to structures that have little to do with the context of traditional civil construction. Such is the case of the roofing structures of stadiums dedicated to pedestrian sports or, in the Olympics, to athletics. It is also the case of structures to support and protect telescopes (such as the Extremely Large Telescope (ELT), which operates in the visible and infrared spectrum, or the Čerenkov Large Sized Telescope, which operates in the gamma-ray spectrum); or of protective structures such as the encapsulation of Reactor 4 of the Chernobyl Nuclear Power Plant.

Similar to the collaboration on several bridge projects briefly mentioned above, EnginSoft's structural engineering team supported Cimolai in the engineering development of several significant special structures, contributing technical knowledge and numerical simulation experience derived from its efforts in the field since the almost pioneering days of virtual prototyping applications. At the same time, the team's

Fig. 9. Deformations of the Storebælt Bridge as the wind speed changes.

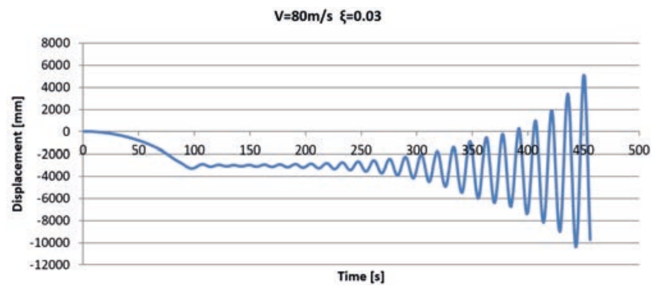


Fig. 10. Deformations of the central section of the Messina Strait Bridge at wind speeds of 80m/s (about 290km/h) and structural damping equal to 3% of critical damping.

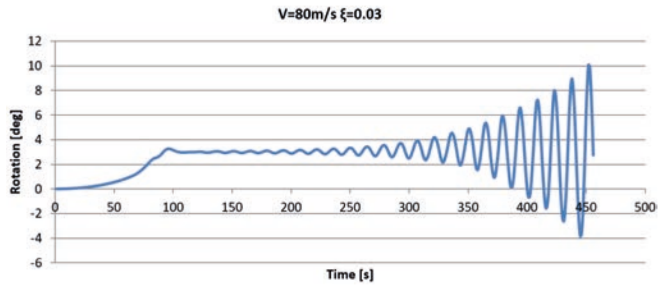


Fig. 11. Rotation of the central section of the Messina Strait Bridge at wind speeds of 80m/s (about 290km/h) and structural damping equal to 3% of the critical damping.

synergies with the expertise, skills and design knowledge of Cimolai's managers/technicians helped to achieve the objectives with assured quality and within satisfactory timeframes.

Below we briefly describe some of the works to whose realization EnginSoft and its dedicated team made a significant contribution.

First and foremost is the roofing of what became the **Olympic Stadium in Athens** for the 2004 Olympic Games, designed by Spanish architect Santiago Calatrava and constructed by Cimolai using an innovative assembly sequence. EnginSoft contributed analytical supervision to the development of the overall FEM model of the roof (see Fig. 12) and directly developed detailed FEM models and specific numerical analyses of key areas of the roof structure such as its four ground supports (the so-called "shoes", one pair of which is fixed to the ground and the other is movable to allow structural "breathing" and to avoid unwanted internal stresses — Fig. 13 shows the FEM model of a fixed "shoe"); and the four connection regions between the torsion tube and the arch (in which the arch push is absorbed by the arch);

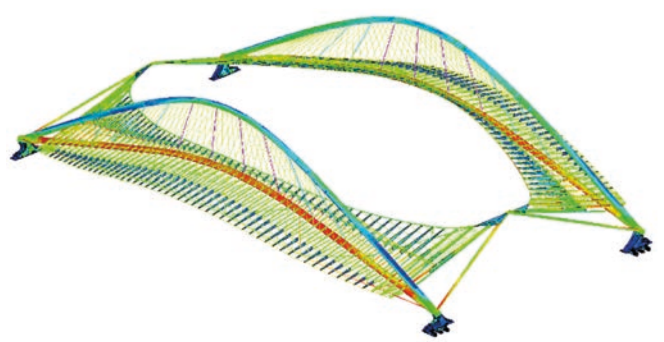


Fig. 12. FEM model of the roof of the Athens Olympic Stadium (2004 Olympic Games).

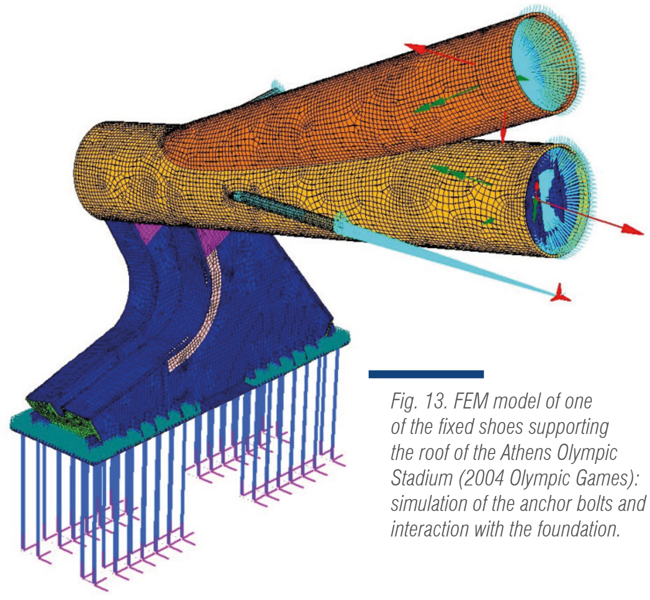


Fig. 13. FEM model of one of the fixed shoes supporting the roof of the Athens Olympic Stadium (2004 Olympic Games): simulation of the anchor bolts and interaction with the foundation.

and the two main connection nodes of the east and west halves of the roof or by the bolted joints connecting the ashlars used to construct the arch.

The **AVIVA Stadium in Dublin,** inaugurated in 2010, apart from hosting football matches, is a temple of rugby. This is only to be expected in Ireland where the game of the oval ball, imported from England in the second half of the 19th century, is played by more than 255 clubs. The state-of-the-art facility replaced Europe's oldest sports ground, Lansdowne Road (dating back to 1872). In 2007, EnginSoft produced an overall FEM model (Fig. 14) of the roof structure of the stadium (built by Cimolai) primarily for the purpose of independently verifying the sections of the members drawn from earlier preliminary calculations. Naturally, normative verifications were conducted for the design load conditions to be considered, including those arising from wind actions, which were obtained from tunnel model tests due to the roof's shape.

After assessing the general level of use of the members, some optimization of the structural efficiency, defined as the relationship between performance and weight, was performed in compliance with the regulatory requirements (EN 1993-1-1 and EN 1993-1-8).

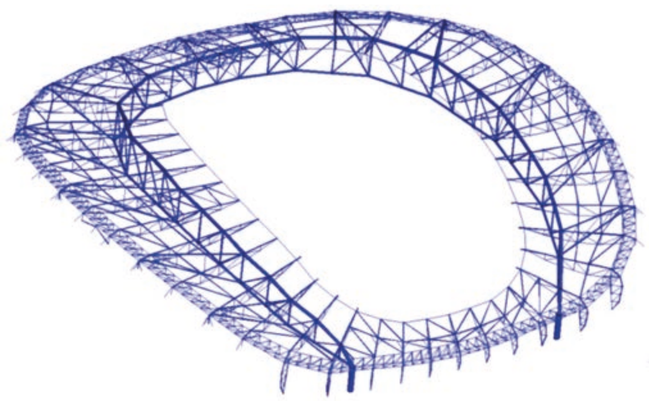


Fig. 14. FEM model of the roof of the AVIVA Stadium in Dublin in Ireland used for rugby and football.

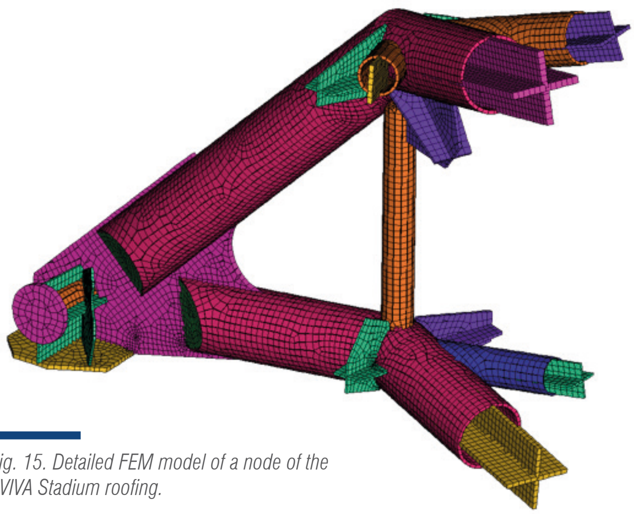


Fig. 15. Detailed FEM model of a node of the AVIVA Stadium roofing.

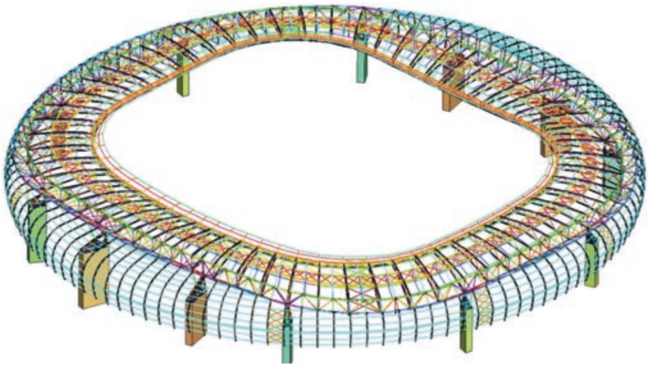


Fig. 16. FEM model of the roof of the Soccer City Stadium in Johannesburg in South Africa (2010 FIFA World Cup Final).

This was achieved by the iterative use of an automatic verification routine that updated the profile sections based on the structural responses, adjusted the properties of the members within the FEM model, provided instructions for re-running the analyses, and then used the new stresses to perform the necessary stress and stability checks. Investigations of localized stress situations at the nodes were conducted by means of detailed FEM models (see example in Fig. 15).

With regard to developing routines and/or verticalizations, and particularly for subjects that may require normative verification, FEM models implemented with commercial software must frequently be supplemented with procedures that allow the search/processing/synthesis of all useful/sensitive data for identifying the levels of functionality, safety and reliability of structures that are far from trivial. These virtualizations, implemented almost daily by EnginSoft not only in Structural Engineering, undoubtedly constitute additional value to complete products (commercial software) that sometimes lack post-processing tools.

In 2007, EnginSoft also created the full FEM model of the roof structure of **Johannesburg's Soccer City Stadium** built by Cimolai for the 2010 World Cup in South Africa (see Fig. 16). After completing the model with all the design load conditions necessary to qualify the structure's behaviour during its operational life, structural analyses were performed to determine the stresses used for code checks

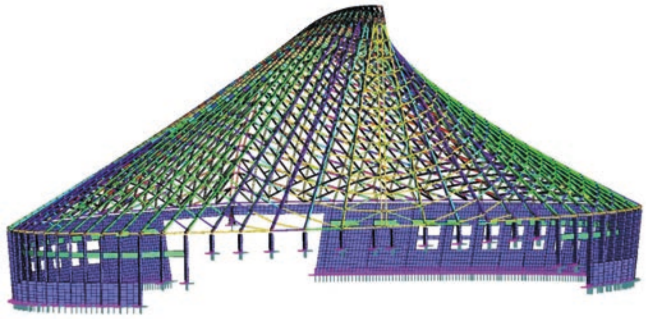


Fig. 17. Multipurpose sports complex in Tor Vergata in Rome in Italy: FEM model of one of the two roofs.

and conducted using automatic verification routines, implemented in accordance with both DIN 18800 and EN 1993-1-1. Once these routines had been tested, all of the constituent members of the structure were checked for all design load conditions. Calculations and verifications were supplemented with numerical analyses on detailed FEM models of some critical areas characterized by intersections of members and the presence of bolted connections.

Another significant contribution from EnginSoft in 2008 concerned the engineering of the two roofs of the **Tor Vergata Multipurpose Sports Complex in Rome in Italy**, designed by Santiago Calatrava and built (actually only one of the two) by Cimolai. These roofs were generated on ruled surfaces and characterized by families of nodes with topologically equal but dimensionally different geometries. Once the overall FEM model was finalized complete with the reinforced concrete support walls of one of the two roofs (see Fig. 17), structural analyses were performed for all the design conditions foreseen for ULS (Ultimate Limit State) and SLS (Serviceability Limit State) to determine the stresses to be used for the normative verification according to EN 1993-1-1 for members and EN 1993-1-8 for welded

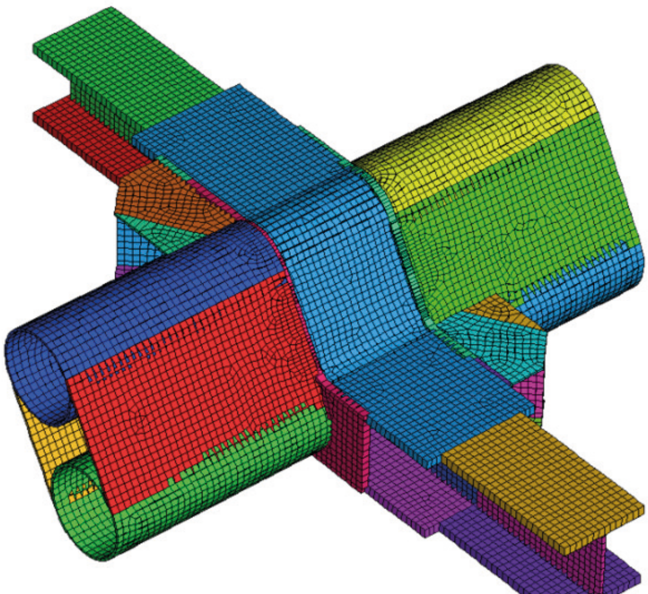


Fig. 18. Multipurpose sports complex in Tor Vergata in Rome in Italy: Parametric FEM model of a node.

and bolted connections. The bolted joints were dimensioned according to two different stress transfer mechanisms, namely the friction mechanism for SLS conditions and the shear mechanism for ULS conditions.

To finalize the structural control of the entire roof, detailed parametric FEM models of the strut-brace joints were implemented (see Fig. 18) in addition to the overall FEM model, in order to obtain topologically "equal" but dimensionally different geometries.

In essence, the notable parameters were obtained by operating on the actual dimensions of each node within the same family/type, resulting in virtual prototypes on which the stress parameters relevant to that specific family were obtained. This was done after having performed an envelope of the stress parameters relevant to that specific family (identified, for example, by a specific interval of the angle between the plane containing the axes of the two struts and the planes containing the axes of the braces or even by a specific interval of the distance between the working points on the axes of the two struts).

The virtual prototypes were then used for numerical analyses, also in material non-linearity (according to Annex C of EN 1993-1-5) to evaluate and validate both the stress fields and, for nodal regions characterized by gross structural discontinuities and therefore by stress peaks with values above the proportionality limit, the associated plastic deformations were also evaluated and validated.

Conclusions

The ability to develop advanced designs is undoubtedly proportional to the skills acquired in using software (programs/calculation codes) dedicated to implementing FE models and to executing the numerical analyses necessary to evaluate the relative structural responses.

In this sense, software can improve productivity, accuracy, and efficiency, as well as enable complex and innovative projects to be tackled. However, being familiar with the software may not be sufficient. In

fact, a common mistake in interpreting the predictions of a FE model is to not consider the limitations of the model — no matter how complex and complete it may be.

This may sound trivial, but every model is based on assumptions that impose limitations on its scope of applicability. If the assumptions and formulations underlying the prototyping/simulation process are not robust and relevant, the results will only support inaccurate or even unsupported solution scenarios. In other words, apart from aspects related to so-called artificial intelligence (which in any case only responds on what it has "learnt" and does not understand creativity and empathy), the model will return as a function of the hypotheses and theories on which it is based. If these are inaccurate or imperfect, or if the model lacks representativity, the computer can only react accordingly. From this point of view, a university professor of Automatic Calculation of Structures (namely Stefano Odorizzi, President of EnginSoft) told me in 1979 that computers are a school that trains humility.

This is why Structural Engineering requires the constant acquisition and deepening of technical-theoretical skills to which knowledge of calculation software becomes an effective complement. It goes without saying that continuous learning accompanied by a healthy curiosity and a determined desire to move beyond one's personal comfort zone are essential to maintaining a high level of skill, to overcoming challenges, to identifying solutions, and to providing answers to ever newer and progressively stimulating questions.

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