The role of wind in steel megastructure erection

MSc Ing. Alessandro Catanzano [1]

[1]*CTO Santo Engineering Srl, Padova, Italy, Veneto, alessandro.catanzano@santoeng.it*

SUMMARY
In erection design of civil steel megastructures, namely bridges, stadia or mega-roofs, wind plays a particular role due to the trivial change of the shape of the construction, but more precisely due to changes in many fundamentals parameters with unobvious consequences on static and dynamic exposure of the structure during the route to the final service structural configuration, for which the designer has arranged his work.
While the need for calculations and wind tunnel testing for service life is well established, it is far less clear what the erection designer is supposed to do, with companies that have schedules and budgets never aware of the issue and of the risks, full lack of standards and third parties that asks with no rules on the tip of the web contents.
Well-known contemporary structures examples will be reviewed on the matter, still part of the regulatory debate, mostly focused on load-to-check issues, rather than on general but incisive prescriptions, that bring eventually to effective design solutions.

Keywords: wind, erection, megastructures

1. INTRODUCTION

When erection, heavy transport and heavy lifting science approaches to megastructures, namely long bridges, stadia with special erection issues, or very large roofs, handymen, last-minute professionals and free advisors disappears. An erection design of a megastructure could easily overcome few hundreds of drawings with phases, subphases, details, customized equipments as lifting, pulling and pushing machines, interfaces with ground, existing foundations, but also quays, barge decks, operational cranes, ship decks, and so on, in an always different engineering vortex.
But what really plays a special and underrated role even among professionals is wind effects during erection. On a building the height changes, but on a stadium or a roof, height is no longer the fundamental parameter as the direction of the exposures takes on importance together with skeleton vs cladding placing, with mixed situations continuously changing sometimes without any feedback to the erection designer. At this point professionals can imagine something like an analysis to be done on a certain number of partial construction situations. Shape variation changes also other fundamental parameters, with unobvious consequences on static, dynamic and safety exposure of the structure and people working on, in, under and nearby, during the complex route to the final structural configuration. In fact, while the need for analysis, calculations and wind tunnel testing for service life is well established, it is far less clear at what level the erection designer have to push his investigations, with companies that have schedules and budgets that are not enforced to include further wind analysis by standards or clients and their third parties. Sometimes third parties, without any background on special wind problems, ask the web for a random list of phenomena to be investigated.
Here are presented real life tales of the author as erection analyst and erection designer of contemporary megastructures, some well-known, other just ran on very specialized circuits, to subsume some proposals to be advanced on the matter, still part of the regulatory debate,

mostly focused on load-to-check issues, rather than on general but incisive prescriptions, that bring eventually to effective design notices and hints.

2. OLYMPIC OAKA STADIUM ATHENS ERECTION

In 2004, without an established Eurocode, Calatrava Roof in Athens for the Olympic stadium, was modeled in FEM with temporary phases. Due to 90m temporary towers and esoteric changing shape, after design wind tunnel test, wind in construction was the principal part of concern of the erection engineers, without any real innovative instrument, except that the reduced return period, giving a reduction factor of the action of wind.

Figure 1. A phase of the construction site some months before the stating cerimony

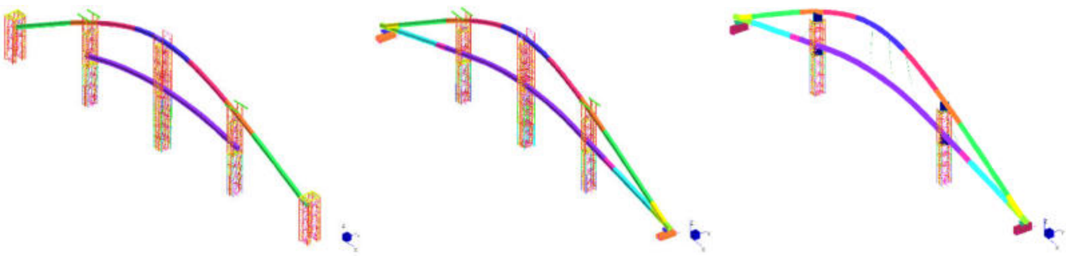
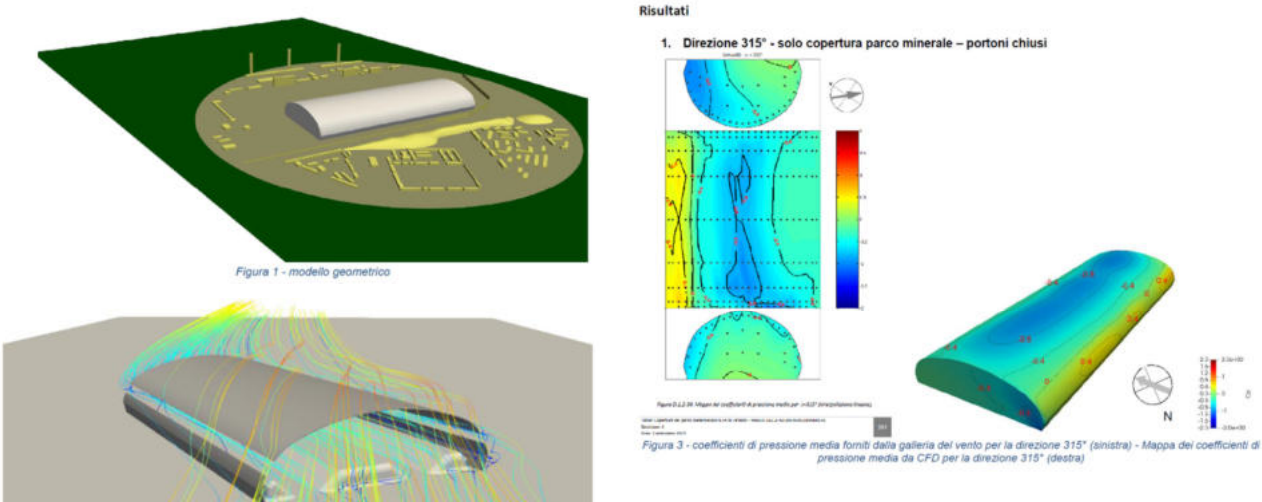


Figure 2. Fem models taking into account the evolution of temporary towers static evolution

3. ILVA TARANTO COAL AND IRON MINERAL PARKS MEGAROOFS ERECTION

In 2018, completely new means of investigation were utilized for the construction of the two mega-roofs of the mineral and coal parks. The two wind tunnel tests (700m version by Prof. Solari UniGe and 400m final version by Prof. Bartoli/Mannini UniFi) gave a very good basis about geometries, wind site analysis, domes behavior, had supplied the benchmark for CFD analysis for temporary phases to wind. CNR-DT-207 standards were an advancement as reliable guide in many points, but no help was supplied in critical decisions about wind in construction. For example it was designed to have a strip on the cladding to permit wind to flow reducing forces on the translation rollers.



Confronto forze risultanti

LIFT Sum (Z)	DRAG Sum (XY)		LIFT Sum (Z)		TOTAL	
	(t)		(t)		(t)	
GALLERIA	3060		10790		11220	
CFD	2780	-9%	11460	6%	11790	5%

Figure 3. Geometry, WTT and CFD benchmark

Figure 4. 3000t module lifting, translation, cladding phases

Caso	SOLLEVAMENTO h=78 m TR=5 anni	TRASLAZIONE M0+M1 liberi con cumuli TR=5 anni	TRASLAZIONE /STAZIONAMENTO M0+M1+M2 liberi TR=5 anni	TRASLAZIONE /STAZIONAMENTO M2 libera con cumuli	STAZIONAMENTO (inghisato) CLADDING COMPLETO TR=5 anni	ESERCIZIO TR=50 anni
TR (anni)	5	5	5	5	5	50
Cpe	-0.26	-0.55	-0.56	-0.63	-0.64	-0.87
Cpi	0.19	0.29	0.18	0.13		
Cf	-0.45	-0.84	-0.74	-0.76	-0.64	-0.87
		Situazione da evitare				

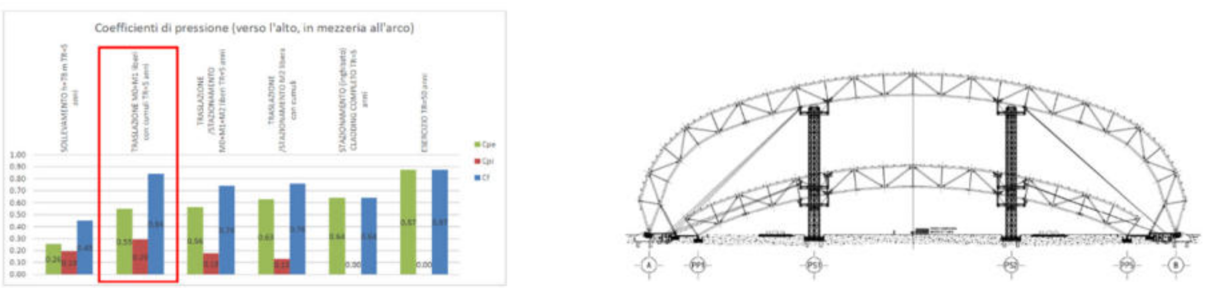


Figure 5. Desktop CFD analysis permitted multiple analysis to mitigate or excluding dangerous situations

4. NANAY CABLE STAYED BRIDGE IN PERU

As the only one WTT for construction phase was useless, for the Nanay bridge in Perù all analysis, vertical galloping, torsional divergence were done on desktop, catching also the flutter and aerodynamics derivatives.

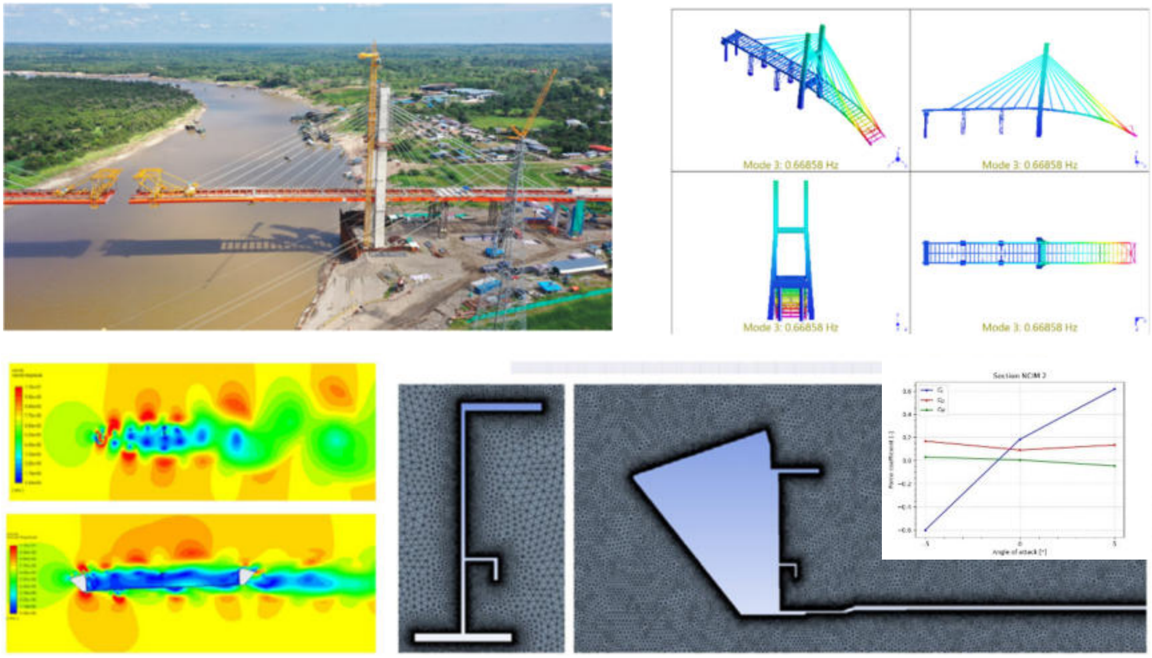


Figure 6. Full aerodynamic instabilities by desktop analysis

5. CONCLUSIONS

In erection design wind is the most sophisticated and impactful issue, but it is inserted in the more general idea that assembly and construction are not to be designed, calculated, and planned with fixed and mobile equipment in all the foreseen phases, but just discussed on field arrangements on the fly before executing. Many other real cases can be supplied to demonstrate that on the contrary the challenges are top engineering intensive with the difficulty exponents of time running, no standards guidance and the heavy eye of who pays the bill.

Acknowledgments: Cimolai S.P.A.

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