> **MAJOR STRUCTURES**

Stadia

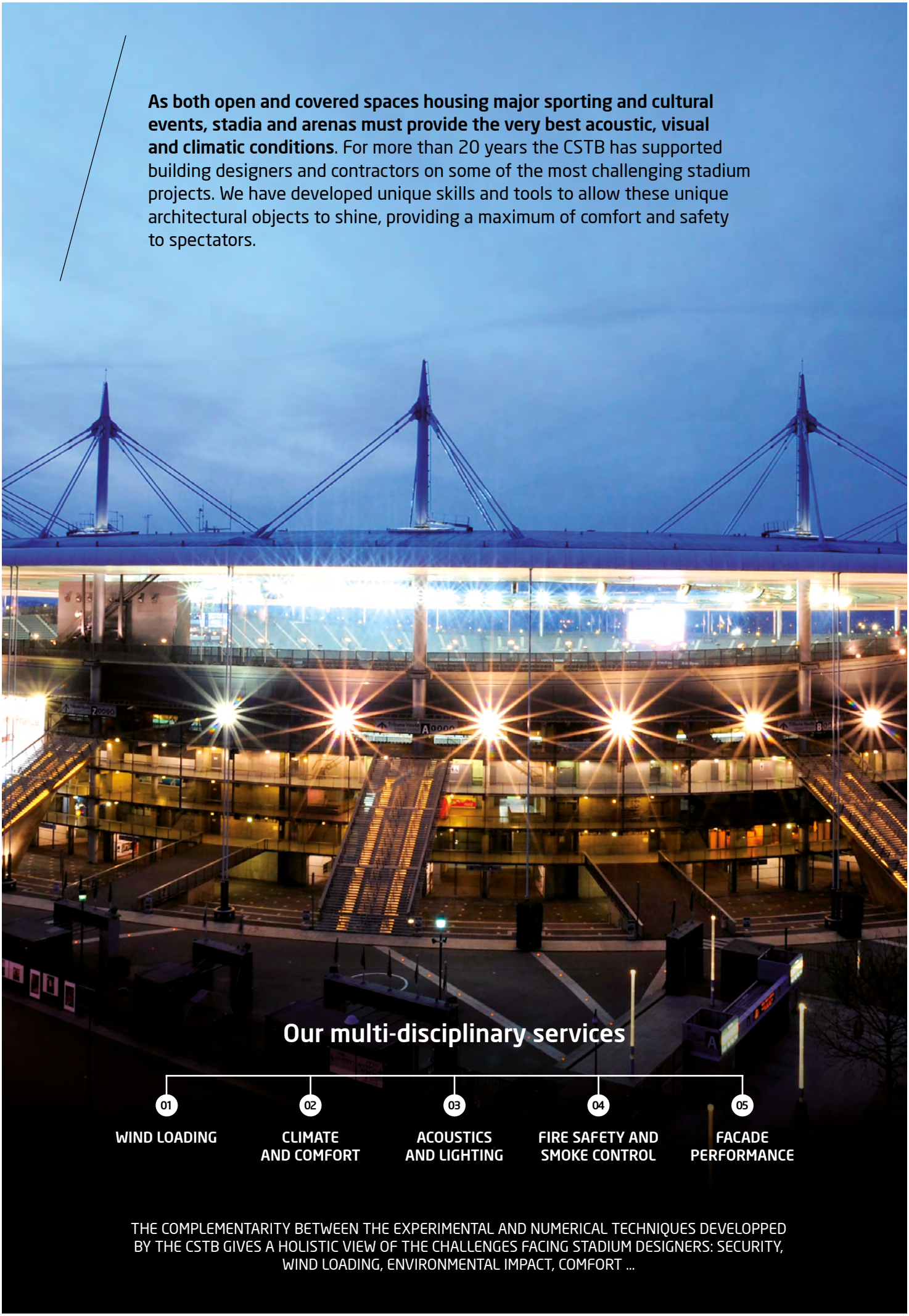
Supporting design and renovation

Multi-disciplinary services.
An integrated physical and numerical approach.
Exceptional experimental facilities.

www.cstb.fr

CSTB
le futur en construction

As both open and covered spaces housing major sporting and cultural events, stadia and arenas must provide the very best acoustic, visual and climatic conditions. For more than 20 years the CSTB has supported building designers and contractors on some of the most challenging stadium projects. We have developed unique skills and tools to allow these unique architectural objects to shine, providing a maximum of comfort and safety to spectators.



Our multi-disciplinary services

01 WIND LOADING

02 CLIMATE AND COMFORT

03 ACOUSTICS AND LIGHTING

04 FIRE SAFETY AND SMOKE CONTROL

05 FACADE PERFORMANCE

THE COMPLEMENTARITY BETWEEN THE EXPERIMENTAL AND NUMERICAL TECHNIQUES DEVELOPPED BY THE CSTB GIVES A HOLISTIC VIEW OF THE CHALLENGES FACING STADIUM DESIGNERS: SECURITY, WIND LOADING, ENVIRONMENTAL IMPACT, COMFORT ...

01 WIND LOADING

The key structural feature of stadium is the large roof covering the stands, which can experience significant uplift forces in strong wind conditions. These loads can be highly variable, fluctuating rapidly upwards and downwards.

PREDICTING WIND LOADING

To capture a series of accurate «snapshots» of these highly variable wind loads the CSTB has developed a unique synchronous pressure measurement system for the wind tunnel. Hundreds, or even thousands of pressure taps are connected to pressure sensors and sampled at high frequency, recording pressure variations across the entire structure.
These physical measurements are then combined with structural vibration data taken from a finite element model of the stadium (information usually provided by the structural engineer). This allows us to calculate a full set of equivalent static and dynamic load cases for the structural design of the stadium, both local (cladding pressure) and global (stability loading and primary structural elements).

1. Allianz Riviera Stadium, Nice
Wind loading for the new Nice stadium was assessed in the atmospheric boundary layer wind tunnel at CSTB Nantes.

2. Lille Stadium
The stadium cladding with its opening roof and translucid polycarbonate tube facades were tested in the atmospheric boundary layer and Jules Verne climatic wind tunnels at CSTB Nantes.

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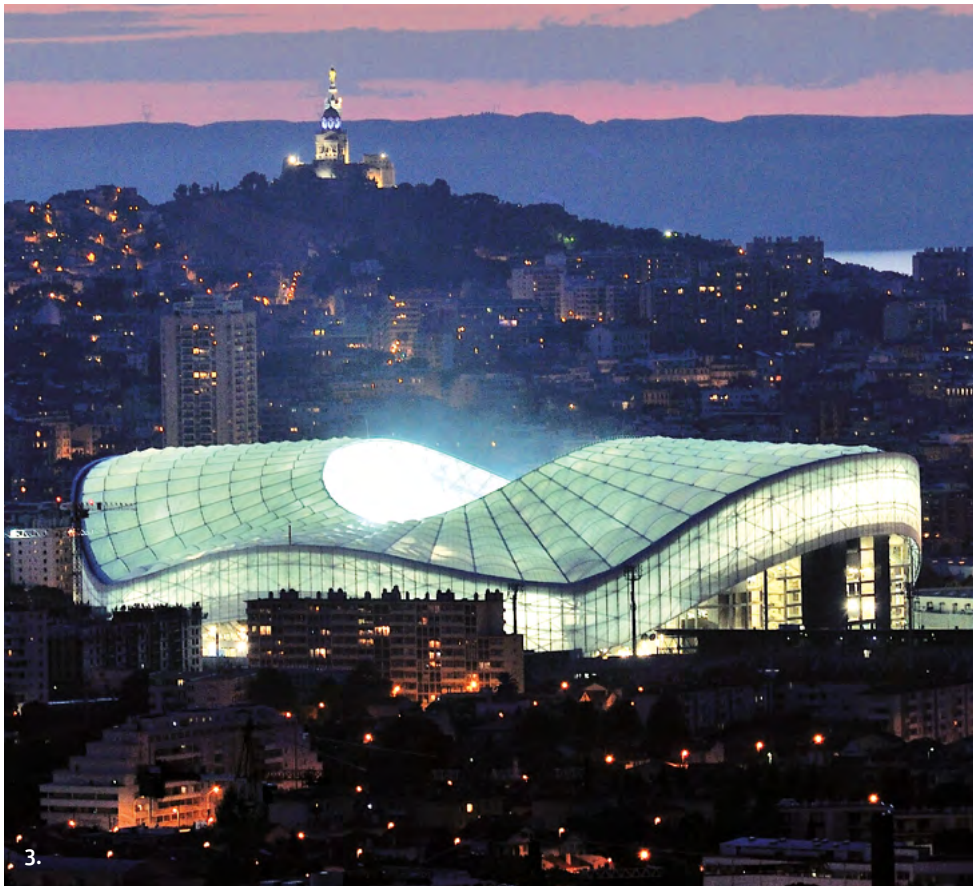
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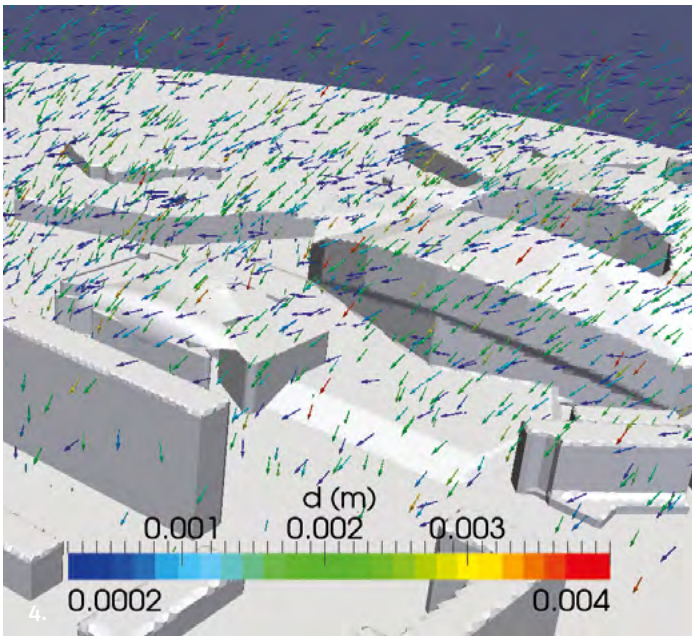
3. Stade Vélodrome, Marseille
The CSTB carried out wind loading studies for each construction stage (15 configurations) as well as tower crane stability studies.

> We've built a trust-based relationship with the CSTB team. The next time I have a new structure of equal complexity to test the issue will be very quickly resolved, because I already know who I want to work with.

Romain Vondière, technical director at GFC Construction (Bouygues)
Stade Vélodrome, Marseille



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02 COMFORT AND ENVIRONMENT

The site, layout and architectural massing of a stadium are key to the internal environment. Comfort in these spaces depends upon multiple factors: wind, temperature, direct exposure to the sun, humidity, precipitation, shading and more.

ASSESSING THE KEYS TO COMFORT

The CSTB has developed a number of complementary techniques, allowing comfort in the stadium and its surroundings to be described in the form of a discomfort criteria accounting for local meteorological data.

Wind tunnel testing

Studying local wind and gust conditions at spectator level.

Computer simulation

Calculating the effect of temperature, solar exposure and rainfall.

The results obtained permit clear dialogue within the design team to optimise the design of any zones which are considered uncomfortable.

4. Stade Vélodrome, Marseille
Numerical modelling of driving rain in order to map out exposed zones.

5. Lyon Stadium
Multiple design iterations were tested in the wind tunnel Numerical simulations were used to predict the acoustic conditions in and around the stadium.

6. Lyon Stadium
ICARE acoustic modelling software, using the acoustic ray tracing method.

7. Lyon Stadium
Acoustic impact map in dB(A) : difference in noise levels between the base state and the match configuration

03 ACOUSTICS AND LIGHTING

Optimising spectator comfort while limiting environmental impacts guarantees the attractiveness of a project to the designers and operators and improves acceptance within the local community.

OPTIMISING SPECTATOR COMFORT

– Checking volume for spectators during events
– Ensuring message intelligibility
– Sightlines and pitch viewability
– Evaluating risk of glare from spotlights

ASSESS AND MITIGATE IMPACTS

– Predict nose levels near to the stadium
– Proposals for architectural solutions to limit noise levels
– Overshadowing and rights to light

Modelling with the CSTB's numerical tools

– PHANIE : Daylight module
– ICARE : Acoustic propagation in complex environments
– MithraSIG : Acoustic mapping
– MICADO : Noise mitigation via protection schemes

Learn more about our software tools on:
logiciels.cstb.fr


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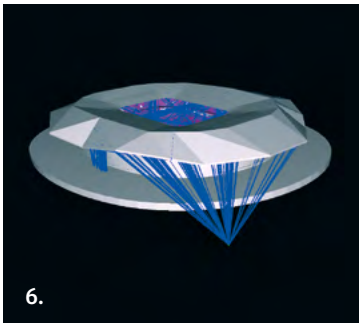
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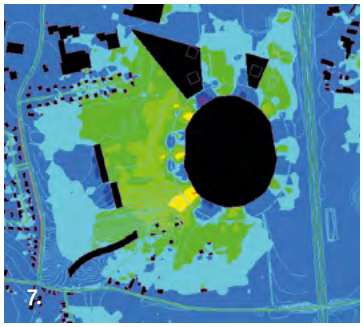
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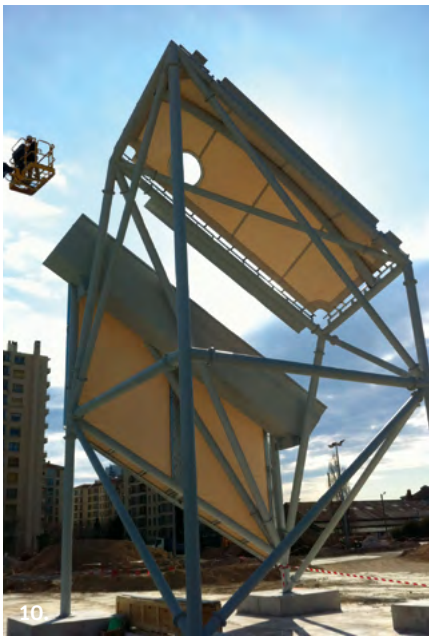

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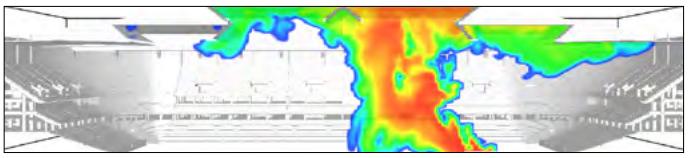
04 FIRE SAFETY AND SMOKE CONTROL

Public safety is the principal objective of the codes of practice and legislation surrounding fire control. Evaluation of the proposed or existing fire safety measures is a necessary step in a full engineering study. For each fire scenario considered we must check that all persons potentially exposed to danger from a fire can either safely exit the structure or reach a designated refuge area.

EVALUATIONG LIFE SAFETY

The CSTB's smoke evacuation studies consist of sizing the smoke removal system, taking into account architectural characteristics and activities planned within the building. The CSTB can also provide recommendations about specific operational measures to be applied.
The CSTB provides numerical simulation, control of smoke collection and evacuation. To evaluate the effectiveness of a smoke removal system, it designs and performs innovative in-situ smoke collection tests («hot» and «clean» smoke) that take account of the key physical processes involved.



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05 FACADE PERFORMANCE

Construction of large-scale facades and roofing requires innovative methods such as high-performance fabrics which may fall outside standard technical approvals, photovoltaic panels double-skin facades and translucent coverings.

In order to test and demonstrate these new methods, multiple issues must be addressed:

- Material characteristics by sample testing; characteristic strength and durability
- Resistance testing and numerical simulation
- Feasibility studies by prototype testing or fabrication drawing studies
- User and operator safety, validated by impact testing for facades or by sizing and impact testing for roofing.

Integrated numerical and physical testing

- The CSTB can provide consulting and advice ahead of testing in order to prepare the necessary supporting documents and reduce risk and delays in approval.
- For technical approval of innovative methods on French soil the CSTB offers the ATEX (Appréciation Technique Expérimentale) service specific to the project.

8. Bordeaux Stadium
The new Bordeaux stadium was studied for wind loading, driving rain and for fire engineering and smoke extraction.

9. Lille Stadium Simulation
Numerical model of a stage fire in the new Lille Stadium

10. Stade Vélodrome, Marseille
Via two ATEX (Appréciation Technique Expérimentale) involving an on-site prototype, the CSTB approved the use of a fabric roofing and façade material and demonstrated its feasibility.

EXCEPTIONAL EXPERIMENTAL FACILITIES

JULES VERNE CLIMATIC WIND TUNNEL

Components are tested at up to full-scale in the very large Jules Verne climatic wind tunnel. Wind, snow, rain, sand and extremes of temperature, humidity and wind can all be produced and tested in combination.

ATMOSPHERIC WIND TUNNELS

Our two atmospheric boundary layer wind tunnels reproduce all aspects of wind storms; the wind speed gradient, turbulence intensity and length scales are accurately replicated at reduced scale, allowing the dynamic response of the structure to be measured and predicted. Tower crane stability studies can also be carried out.

EUROPEAN ACOUSTICS LABORATORY - LABE

Acoustic comfort and performance, regulatory compliance and material characteristics. The CSTB carries out approved tests under European testing certificate Cofrac n°1-0305 at 9 experimental stations across our 2000m² facility.

EXPERIENCE

The CSTB has recent experience of work on a large number of FIFA-accredited stadia including retractable roofs, symmetric and asymmetric designs, innovative materials and complex construction schedules as well as smaller multi-use arenas and concert halls around the world.
The CSTB's teams regularly work on major projects around the world including some the world's most important sports, infrastructure and commercial developments.

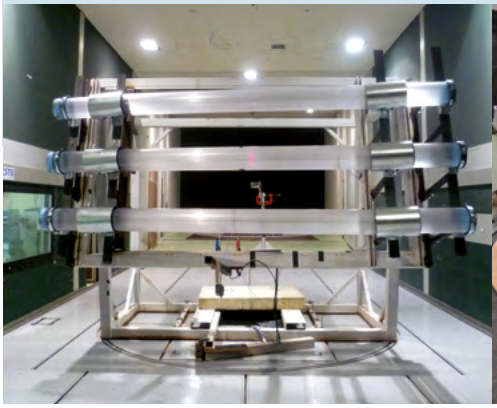
EURO 2016

The CSTB has worked on the majority of the construction and renovation projects for EURO 2016, totalling over 330,000 places : Stade de France, Paris / Stade de Nice / Stade de Bordeaux (MATMUT) / Stade Vélodrome, Marseille / Stade Pierre Mauroy, Lille / Stade de Lyon.

OUR PROJECTS

Ataturk Olympic Stadium, Istanbul, Turkey / Alexandria Stadium, Egypt, Baraki Stadium, Algiers, Stade Jean Bouin, Paris / Arena Nanterre La Défense / Nantes Stadium / Stade Léo Lagrange, Toulon / Montpellier Stadium / MMA, Le Mans / Roland Garros, Paris.

Jules Verne wind tunnel



Atmospheric wind tunnels

European acoustics laboratory - LABE

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